Adaptations of Green Growth and Degrowth in an Oil-Dependent Economy Toward a Better Future

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract:

Throughout the history of Newfoundland and Labrador (NL), the province has been relying on natural resources as the main sources of economic production. Consequently, NL is prone to external shocks from demand and price fluctuations. For example, the collapse of fisheries during the 1990s and the fall in global oil prices during the 2008 financial crisis have had negative impacts on the NL socioeconomic system, increasing unemployment and out-migration rates. A lack of modeling studies in the literature related to NL natural resources dependency, unemployment, and migration is the motivation for this research. This research focuses on studying the impact of oil, as a major natural resource for NL, dependency on other industries within the economy, employment, and migration through implementing green growth and degrowth policies as an alternative to decoupling the natural resources dependency and shifting away from the region's historical sources of economic growth. This research links econometric, input-output (IO), and agent-based modeling techniques as a novel combination of methodologies to study the impact of an oil-dependent economy using oil prices and production reduction rates (scenarios of green growth and degrowth) as exogenous variables. The data used in this empirical analysis is obtained from Statistics Canada. The results help create suggestions for policymakers to steer socio-economic policies toward developing their economy for a better future.

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Dedication

To my family.

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Chapter 1: Problem Definition, Research Objectives, and Contribution

This chapter introduces the research, defines the problem, states the objectives and contributions.

1.1 Introduction and Problem Definition:

The natural resources economy is the economy in which products and activities are related to the extraction and processing of non-renewable natural resources, as well as the consumption of renewable resources being harvested at an unsustainable rate. Examples of non-renewable natural resources in this region are fossil fuels such as oil, natural gas, and coal; metallic ores like chromium, nickel, platinum, gold, silver, lead, zinc, and copper; and the non-metallic ores are graphite, sulfur, and phosphorous. Examples of extracting renewable resources include the overharvesting of fish stocks, grazing pastures, forests, etc. The main problem is that these natural resources are being depleted at an unsustainable rate, where resource over-extraction or over-consumption have had a negative impact on the environment and the greater ecosystem in general. Further, nations that rely on any of their natural resources as the main drivers for their economic activities make their economy vulnerable to external shocks and volatilities in both prices and resource demand.

In the economic development literature, theories like Dutch Disease and Resource Curse [1]–[3] suggest that the negative impacts of the region's natural resource dependency create a drag on the aggregate economy over time. The term Dutch Disease was used to explain the causal relationship between declines of the manufacturing sectors of the Netherlands when the Groningen gas field was discovered. The increased growth of a specific sector's gas production led to the increase in its exports, which led to the nation's currency becoming much stronger. The unintended effect was that exports from the other sectors became increasingly unaffordable for foreign consumers, causing demand for these other production sectors to decline. The term Resource Curse was used to describe how those countries endowed with relatively more natural resources tended to have lower rates of economic growth.

Economies with such natural resources' dependencies were much more susceptible to price shocks and volatilities. The production rates of their industries decreased, and the rates of unemployment and out-migration from these economies increased the inability of unemployed workers from these declining industries to readily transition to unaffected industries within their domestic economy. Ultimately, overall economic productivity fell as these workers' skills depreciated over time. Subsequently, selective migration occurred, in which the younger, highly skilled, well-educated/trained, and even wealthier workers were the first to migrate to other economies with better opportunities. The resulting "brain drain" discouraged future investments and decreased the rate of economic growth, which ultimately resulted in economic decline and urban shrinkage [4]. Since economic opportunity is the key determinant of employment, population dynamics, and urban change, this affected both gross investment and available job opportunities within these economies [4], [5].

Those economies that were highly dependent on non-renewable and over-consumed natural resources initially enjoyed a relatively higher rate of aggregate economic growth. Indeed, the policy makers of these countries often depicted themselves as having more diverse economies that were less dependent on natural resources. However, examining these economies at a smaller scale, like at the provinces or state level, the situation was quite different. We select the Newfoundland and Labrador (NL) province in Canada as case study for an economic analysis of a natural resource intensive economy. In an aggregate level, Canada seems to be more diverse and less dependent on natural resources. However, it is not the case when we examine the economic situation at provincial level. NL suffers from the highest unemployment rate among all Canadian provinces; its economy is heavily dependent on natural resources; prior to the 19th century, cod fishery was main economic activity. From the late 19th and early 20th century, mineral resources' mining emerged to gradually become a leading industry during that time. Since the 1960s, the NL economy fluctuated because of cod stock decline due to overfishing, and fluctuations in the world demand of paper pulp. Lately, NL has been dependent on production and export of oil and gas from its four offshore fields. The NL government strategic policy is to double the oil export by 2030, therefore, it invests in 100 new exploration [6]–[9]. A limited quantity of research exists in the socio-economic literature that addresses the impact that market failures and price shocks exert on the natural resource industries of an economy. The natural resource-intensive economy of the NL region is associated with the highest unemployment rate relative to all the other Canadian provinces, which appears to have led to out-migration and socio-economic instability [7].

The gap in current literature and natural resources' dependency challenges motivate this analysis, which is designed to examine the potential negative impacts of a natural resource dependent economy. A primary focus is on the impacts emanating from the energy sector on the other economic sectors of the region, including employment and population dynamics. Further, the potential benefits of introducing green-growth and de-growth emphases as alternative economic models are also examined. The traditional economic model, which is based on classical and neoclassical economic growth theories is directly examined, to illustrate how current economic growth in the NL region depends on the amount of natural resources capital and labor, where this neoclassical view perceives utility as the value of economic production [10]. This contrasts with the green-growth and degrowth economic perspectives. In green growth, the economic growth and natural resources consumption are decoupled where the value of economic growth is derived from the associated improvement of human wellbeing, social inclusiveness, and environmental quality. This perspective does not rely upon physical capital itself as the main measurement of economic success [11]–[14]. While the de-growth perspective is an economic stationary steady-state (post growth) model that is achieved by trimming the rates of economic production throughput measures, such as natural resource quantities, production levels, and consumption rates [14]–[16]. The common denominator between green growth and degrowth in the context of this research is both trying to reduce the extraction and production of natural resources. For NL case-study, we assume the green growth is setting lower production percentages of oil, while degrowth is setting higher percentages. The aim is to test the impact of 6 policies - the oil production reduction in different rates - on NL economy, employment, and migration.

The economic system is a component of the socio-economic system, which implies that people are affected by changes in economic activities. It is a complex combination of complex subsystems. Since the interaction among sub-elements of any socioeconomic system is dynamic, capturing the emerging phenomena of society, such systems require representation through mathematical modellings that reflect the dynamic nature of such changes. While most statistical models, Bayesian networks, and equation-based models lack dynamic feedback to reflect this characteristic, a system dynamic approach doesn't account for the evolution of system and models using aggregate level variables. Most economic research use optimization as the main methodology to model the economy toward a predetermined state of equilibrium, or statistics to predict the future trends. Those models oversimplified the complex nature of the economy and cannot handle the nonlinearity, heterogeneity and heterogeneous variables and their interaction at individual level. However, agent-based modelling (ABM) is relatively powerful, as this methodology covers all the features that these other modelling techniques lack. Further, this approach is also adaptive and has the ability for geographical representation. Additionally, the ABM approach does not rely on equilibrium and perfect information assumptions, unlike Dynamic Stochastic General Equilibrium (DSGE), and implements micro-level rules that can be grounded based on socio-psychological behavior theories as well as economic theories. While current research studies rely on statistical methods for impact analysis, ABM microlevel individual interactions can provide unprecedented understanding of emergent patterns and behaviors in the empirical data for impact or shock analysis. Also, ABM methodology enables better observation of macroeconomy behaviors as responses to different policy scenarios [17]–[25].

1.2 Research Objectives:

The objective of the following research effort is to study the impact of implementing different economic policy scenarios for oil production reduction percentages as a mean for green growth and degrowth economic models. Modeling and simulation of the impacts of the policies on economic situation - at industrial level and provincial level – employment, and migration. To analyze the impacts of policy scenarios, this research proposed integrating the econometric model, input-output (I-O) model, and ABM model, to simulate different scenarios and examine the resulting implications on employment and migration. Utilizing the historical data analysis using econometric, and interindustry analysis from I-O, the ABM simulates the impact of oil price volatility and oil production reduction percentages from individual level. Then we analyze the aggregate outcomes to create suggestions for policy makers who are steering socio-economic policies toward developing their economy.

1.3 Contribution:

The research contributions of this research project are:

1. Reviewing and identifying socio-economic indicators that can be used for current green growth, and degrowth economies.
2. Modeling the reduction of oil and gas (finite natural resources) production as part of implementing green growth and degrowth policies using different resource pricing models and scenarios.
3. Integrating econometric, input-output, and agent-based modeling methodologies for studying the impact of each economic scenario on employment and migration.
4. Analyzing the socio-economic of region of Newfoundland and Labrador as case-study and addressing the impact of its oil industry on other industries, employment, and migration.

1.4 Thesis Organization:

The thesis is organized as follows:

- Chapter 2: Literature Review, which includes a review on population migration and different economic models of production and their various indicators, as well as a discussion of economic shocks and their impact on these indicators.
- Chapter 3: Research Methodology, which explains my application and extension of three separate methodologies of empirical analysis, including econometric, I-O, and ABM methodologies. It also covers the case study of Newfoundland and Labrador.
- Chapter 4: Empirical Results for Newfoundland and Labrador Province, from the integrating the three methodologies econometric, I-O, and ABM, and implementation of policy scenarios.
- Chapter 5: Conclusion, Recommendations, and Future Works, which summarizes the empirical results and limitations of this research, the implications for current policy making, and potential future developments of this research direction.

Chapter 2: Literature Review:

This chapter provides a literature review for main aspects of the research thesis, mainly research papers that are related to migration and uses ABM as its methodology. Then, economic models such as classical/neoclassical, green growth and degrowth, and their indicators are addressed. Finally, a discussion related to the selection of policies and indicators that are directly related to the thesis is covered in this section.

2.1 ABM and Migration:

The main purpose of modelling migration is to understand and explain the observed migration flows, including identifying the factors that trigger migration and how these factors influence the immigration decision-making process. The insights from this analysis can be used to predict changes in future migration flows [26]. The modelling techniques for migration in the existing literature have been evolving over time. The most common approach is the gravity model derived from the Newtonian Law of Gravity, in which population migration is affected proportionally to the two geographic locations, their relative importance, and the rate of distance decay [27]. The spatial interaction models improve upon the gravity model, in that additional factors are included, such as existing migration patterns [28]. Because of the lack of ability to perform decision making at an individual level inherent in both models, alternative models, such as microsimulations, behavioral models, and agent-based models, are becoming increasingly more common. The behavioral models of migration are dominated by the models expressing an individual's expected utility (utility maximization models) or perceived value (value expectancy model), which ultimately trigger the migration decision [26].

While microsimulation and ABM models are relatively similar, they differ in the process of modeling an individual's actual decision-making process. Microsimulations use transition rates (expressed as probabilities) that vary across heterogenous individuals, while ABMs use decision rules (described as procedures) that vary based on causal mechanisms governing the migration decision [26]. The limitation of microsimulation over ABM is that the microsimulation models have unidirectional interactions which represent the impact of policy to the individuals only, but do not account for impact of individual interactions to the policy or individuals among each other [29]. The interaction between individuals produces nonlinear effects at the aggregate level, where such effects visualize the social networks that result from interactions. Specifically, the network describes the individual's migration related decision information path [26].

Authors in [26] performed systematic review of 270 research projects within the migration literature that had used ABM as a methodology for their analysis. Table 1 shows the evaluation of the theories according to their consideration of the following criteria across the row. The criteria are: a) gap between desired and actual behavior; b) social influence of others on migration decision; c) uncertainty; d) the decision situated during the life course of an individual; e) time for planning the migration; f) empirical evidence; g) if the theory is as simple as possible and as complex as necessary; h) theory is falsifiable in principle which means that if the outcome of the model as the aggregate level does not align with empirical evidence, the assumed decision behavior is unlikely to describe the data gathering process.

Table 1: Evaluation of Decision Theories [13]

Decision theory	Difference desired-actual behaviour	Social influence	Uncer-tainty	Life course	Time for decision	Empiri-cal rele-vance	Simple	Falsi-fiable
Minimalist	white	black	grey	white	white	white	black	black
Micro-economic	white	grey	black	white	white	white	black	grey
Psycho-social	black	black	black	black	white	grey	white	black
Heuristics	white	black	black	black	white	white	black	black
Mixture	black	black	black	white	white	black	white	grey
Empirical	white	black	black	black	white	black	white	white

White: not applicable, grey: somewhat applicable, black: applicable

Six different migration decision making theories appear down the column of Table 1. These are also synthesized from the same 270 projects, and each was analyzed based on the above criteria. Theories are [26]:

- **Minimalist**: This is an approach where no theories are considered before making observations. Instead, these projects focused on how macrolevel behavior observed in society emerges from microlevel interactions observed among individuals. The resulting analysis is based on simple rules with a minimum number of assumptions. While this method is known for its simplicity, the empirical relevance of resulting migration decision rules is questionable.
- **Microeconomic Expected Utility Maximization**: This methodology is based on using standard economic theory to explain the choices that individuals make between discrete alternatives and is based on the assumption that individuals rationally perform expected utility maximization decisions. The interactions are only based on a comparison with the individual neighbors' earnings, which implies that decentralized information acquisition occurs during this process and results in high levels of coordinated activity. This approach presumes that individuals predict their own employment probabilities, anticipated income levels, existing search costs, and resulting migration costs.
- **Psycho-Social and Cognitive Models**: This methodology applies theories gleaned from the social psychology literature. One common approach is derived from the theory of planned behavior, which depicts the individual’s attitudes towards migration as a behavior that is formed based on individuals’ evaluations of different outcomes arising from the action and weighted by their subjective probability of occurrence. Another common approach is

based on Maslow's theory of the hierarchy of individual needs (income, safety, and social needs), where the migration decision is influenced by this hierarchy. Generally, this method is considered complex, as an infinite number of behavioral factors (i.e.: migration) can be included within this approach.

- **Heuristics without Direct Empirical Correspondence**: This methodology is based on heuristics. It defines as ''a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods''. The migration decision is triggered by a simple decision rule that is set to meet predetermined decision thresholds. Such a threshold could be population in community, the quantity of available resources, or if incomes fall below certain levels. The method is simple, but more complex and insightful decision rules could be considered using other approaches.
- **Decision Theory and Direct Observation**: This methodology builds from decision theory (e.g.: economic theories) and is supported by empirical evidence of observational rules (e.g.: survey data). This approach lacks the ability to draw a generalized conclusion from the individualized level of analysis, but appears to work more accurately when applied to specific case studies.
- **Purely Empirical:** This methodology is based purely on empirical evidence from observed trends that are discovered and described without consideration of any pre-existing theories. The migration decision and choices among alternatives are derived from the data, either through statistical and econometric analysis or experts' or stakeholders' interviews. This method lacks guidance on which factors that need to be included, such as defining the appropriate composition of the data set, or the generalization of the observed behaviors. However, this approach can be very accurate for specific case studies with more localized information and knowledge.

The authors in [26] also identify two main challenges that face researchers who work in migration modeling. Firstly, there is great difficulty in choosing the appropriate decision theory from across the many diverse approaches in the existing literature. Indeed, it has been noticed that theories are often chosen based on researchers' personal backgrounds. For example, economists tend to choose utility maximization models, social scientists tend to choose cognitive psychology, and physicists and engineers tend to prefer minimalistic theory. Few research efforts consider applying a mixture of different theories to the same database, which has resulted in more arbitrary behavioral rules. However, models starting with any specific decision theory are useful to ground the decision rules governing the analytical effort, and to interpret the observed aggregate behaviors. Also, selecting a specific methodology allows the resulting models to be built whenever reliable data is not available for analysis.

The second challenge concerns the role of empirical data under analysis, which is used for estimating relevant decision parameters and validating the implications of the proposed model. Hence, meaningful estimation requires determining the most acceptable parameter values used by the model and the potential validation of the model implications by establishing their robustness by replicating them when using different data sets. Further, sensitivity analysis adds to the validation effort when it determines which parameters are very sensitive to changes in the data or the inclusion of additional explanatory influences. The amount of empirical data used in ABM is wide-ranging.

Authors in [30] reviewed 15 research papers that use ABM methodology to understand environmental migration linkage types. There are three types of linkage: one way, partially integrated and fully integrated two-way linkage. The one-way linkage is unidirectional in which the environment influences the agents, the opposite is not true. The partially integrated linkage and fully integrated two-way linkage are similar in which the environment and agents have influenced each other, but latter is closed loop feedback (lasting impacts on environment). The central bank of Canada [31] reviewed 64 research papers published between 2008 and 2021 in area of macroeconomy and noticed that majority of papers are focused on policy and risk analysis as shown in Figure *1*. It realized the importance of ABM and developed Canadian Behavioral Agent-Based Model (CANVAS) for forecasting and policy analysis purposes to complement its current inhouse commonly used models such as dynamic stochastic general equilibrium (DSGE) and Terms of Trade Economic Model (ToTEM); application of the model is tested against the impact of 2020 pandemic lockdown on Canadian economy.

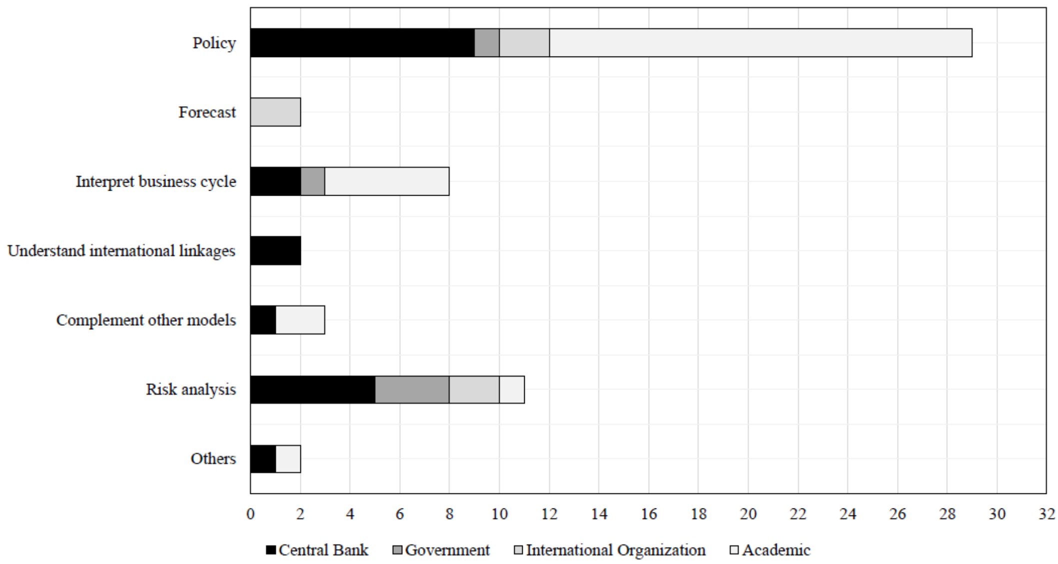


Figure 1: Objectives of ABM [31]

2.2 Economic Models:

An economic model aims to generate testable hypotheses about economic behavior by simplifying observed reality to consider only those relevant aspects of the decision problem. Because economic outcomes often cannot be measured objectively, assessing the design of an economic model must necessarily be subjective. When it comes to determining what is required to explain a particular view of reality, various economists will arrive at different conclusions [32]. The plethora of economic models can be categorized into various, meaningful taxonomies, which are explained below.

Categorizing by resource allocation mechanisms

For example, variation across economic theories is quite evident in their portrayal of a nation's macroeconomic systems. Some are categorized based on a country's traditions. Others are based on its heavily planned-out resource allocations (command and control). Still others are based on a decentralized process of resource allocations (free market). Further, many are based on mixed economic systems that fall somewhere in between free market and command-control systems [33][34]. Table *2* shows the main aspects of each methodology. Regardless of the type of economic system, all deal with three main elements: a) what products are to be produced and at what quantities, b) the optimal process to employ for producing them, and c) to whom will these outputs be distributed [35]. Since it is inevitable for the traditional economy to interact with other types of economies, pure traditional economy became almost obsolete and is not commonly considered by most economic studies.

Table 2: Economic Systems' Categories

	Characteristic	**Advantage**	**Disadvantage**
Traditional	Guided by traditions, customs and beliefs. Almost obsolete, exist in developing countries. *(e.g.: Haiti)*	No friction between members. Everyone contributes.	Rare surplus. Little trade (barter).
Planned (Command)	Centralized by government. *(e.g.: Soviet Union)*	Economic production focuses on satisfying the economic needs of the individuals. More efficient use of resources. Creates sufficient jobs. Provides affordable products and services.	Lack of research and innovation. No competitive market. Slow reaction to changes.
Free Market	Individuals (firms and households) self-interaction. *(e.g.: USA)*	Produces only profitable goods/services. Incentive for entrepreneurship. Competitive market. Research and development investment and innovation.	Higher income inequality. Economic needs over social and human needs.
Mixed (Dual)	Combination of planned and free market. *(e.g.: rest of world)*	Less government interventions. Government intervenes: market failure, safety net programs, taxation (reduce inequalities).	Level of government interventions. Debts of uncompetitive subsidized industries.

Characterizing by type of industry:

A nation’s economy can be also categorized based on its dominant industries. For example, industries can be categorized by the consumption of natural resources [3], [36] and [22], or by the age of each industry [23]. Figure 2 illustrates a proposal for depicting these three types of economies in a manner that reveals the following useful insights:

- **Natural Resources Economy**: Those economic products and activities whose inputs require the extraction and processing of either finite or renewable natural resources, such as energy, fishing, forestry, and mining.
- **New Economy**: Those economic products and activities whose inputs require intensive proportions of human capital and technology, such as pharmaceuticals, aerospace, financial services and education.
- **Rest of Economy**: Those economic products and activities that are related to agriculture, residential services, and residential manufacturing.

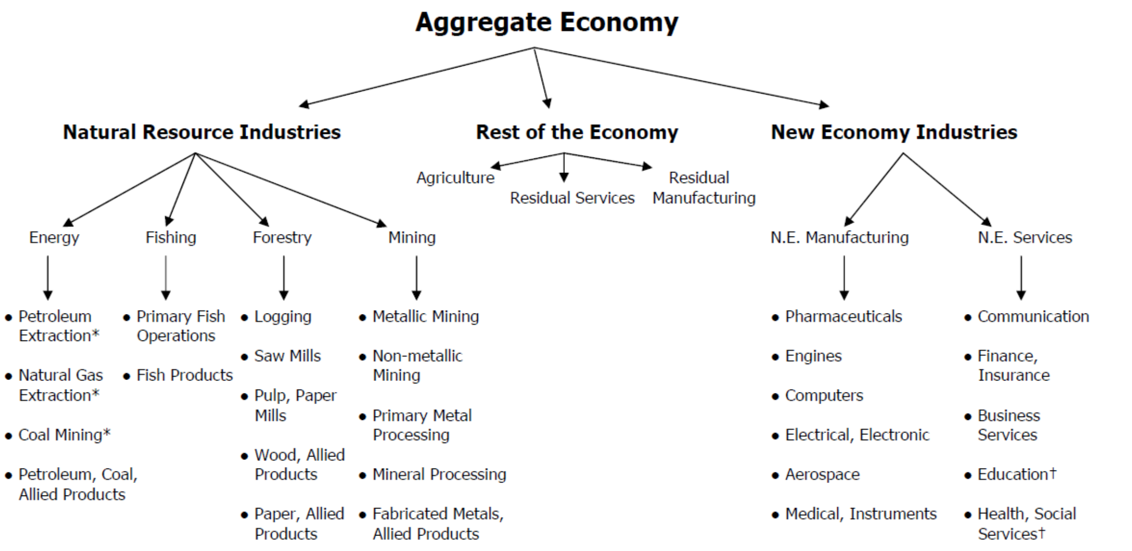


Figure 2: Industries' Categorization [3]

Characterizing by Objective:

The assumptions of economic views or doctrines on macroeconomic variables and their interactions differ in alternative economics schools. Indeed, economic models can be categorized by their intended goals. For example, neoclassical models focus on the efficiency of transforming inputs into outputs that generate the greatest utility for society. Green-growth models also seek efficient economic production, but directly include additional goals for increasing ecological preservation and quality. This generally includes reducing both pollution and greenhouse gas emissions and improving resource sustainability. De-growth models seek to maintain existing economic production without increasing or decreasing overall economic prosperity. By de-emphasizing material production, the negative ecological and sociological impacts of human economic activity can be minimized. The following three sections discuss how each methodology can be analyzed from their own respective dependencies on natural resources to achieve their stated goals.

2.2.1 Classical/Neoclassical Economy:

As economics is a social science that combines normative and positive components in analyzing human economic behaviors, it has evolved over time to develop new arguments and assumptions. The basis of modern economics as a science, now known as the classical school, was first established by Adam Smith and further developed by Walras, Marshall, Pareto, Edgeworth, and Pigou [40], According to the classical growth model, the amount of capital a country accumulates and how it is put to use are crucial factors in determining the economy's relative efficiency at production, which in turn produced its rate of economic growth over time. An economy's total output in this modeling approach is determined by the interaction between the productive inputs of land (natural resources), capital (productive machinery), and labor. Later classical growth models incorporated the concept that technology enhances labor productivity, also influencing overall production [41].

While the Neoclassical paradigm primarily focuses on how the long run economic impacts of shocks on these productive inputs impact short-run behaviors in the economy, other paradigms, such as Keynesian models, focus on how short-run shocks on productive inputs in the economy can have lasting, long-run impacts on economic outcomes [42]. For that reason, after the Great Depression in 1930s, Keynesian views on a nation's economy primarily focused on short-run rules and economic policy to achieve relief from economic recessions. In contrast, the Neoclassical view recognized short-run policy as only temporarily impacting aggregate economic activity, which inevitably moved towards an economic equilibrium determined by available productive resources. According to neoclassical economics, the following basic assumptions are valid [43], [44].

- **Perfect competition market rules apply**: Goods in the economy are homogeneous or the same. Therefore, there is no differentiated product. It is also free to enter and exit the market. In other words, there is no obstacle to the entry or exit of new firms, as in the monopoly or oligopoly market. In addition, there are many buyers and sellers of goods and services, so every newcomer accepts the price as given. In other words, it is a price taker, not a price maker. Finally, buyers and sellers have full and symmetrical information about the product, and asymmetric information is not available.
- **The economy is always at full employment**: If there is unemployment in the economy, it is voluntary, and individuals do not want to work. Economic activities are at a level that will provide full-capacity employment. It could be some temporary deviations from the full-market employment levels, but the invisible hand will make it in equilibrium again.
- **Individuals are rational**: The driving force in economic activities is that individuals are assumed to be self-interested, knowledgeable of all relevant information pertaining to their decision-making process and make such decisions in a manner that can be reflected using a marginal utility framework. Consumers will continue to consume until the

marginal benefit of the goods they consume is equal to the marginal cost. The consumer's and producer's rational expectations will both be reflected in the market demand and supply model as producing a natural resting point—or equilibrium state—that reflects a high degree of coordination, as if directed by an invisible hand. Hence the marginal value of goods or services in society will be reflected in its market price, which will be produced as a result of rational expectations of both producers and consumers.

- **The source of value is utility**: Unlike the classical economists' understanding of the source of value is material and labor expenses, neoclassicals defended the view that "the source of value is utility". Accordingly, the value of a good or service will be determined not by the effort given to it, but by the benefit it provides to the consumer. Further, the value will be revealed by the market price created through the voluntary exchange between consumers and producers.
- **The quantity theory is valid MV = PY:** The Neoclassical paradigm was used to generate the quantity theory of money as a model for any national economy. The value of aggregated market outcomes is the aggregated sum of all outputs (Y) multiplied by their respective prices (P). The value of all monetary transactions is the total money circulating in the economy (M) multiplied by the velocity of money (V), or the number of times each monetary unit is utilized in an exchange. By definition, these two products must equal each other in the long run.

Market failures to achieve efficient productivity, such as full employment and price stability, are described by the Neoclassical perspective as arising from market deviations from an environment of perfect competition. The tendency for the market to move towards long run equilibrium renders monetary or fiscal policies ineffective for achieving the levels of production efficiency under perfect competition, unless they specifically address the artificial barrier to competition that is creating the inefficiency. For example, the Neoclassical perspective perceives economic policies that involve rebalancing the market with changes to the supply of money in the economy, or government budgetary interventions like deficit spending or changes in tax burden on the economy, will be ineffective for re-establishing production efficiency and reducing underemployment and inflation in the long run. Indeed, Neoclassicals believe that observed variations in unemployment and inflation are primarily short-run responses to economic shocks to the economy and merely reflect the progress that the economy is making towards readjusting towards the long-run equilibrium over time. Neoclassical economists see real market failure as a rare phenomenon that occurs in very extreme and are usually artificially created through government interventions [45].

Later Neoclassical models were developed to describe those conditions in the market that generate well-known market failures to achieve efficiency. This includes the production of public goods, the presence of asymmetric information between buyers and sellers, the presence of positive or negative externalities on third parties outside of the market transactions, and the exercise of market power by one or more producers in the market.

The market for public good exhibits the characteristics of non-excludability (non-payers cannot be prevented from consuming the product) and non-rivalrous consumption (one consumer's ability to consume the product does not preclude any other consumer from consume the same product). Examples include national defense or civil law enforcement. If the service is provided by a private producer to serve a defined region, the same level of service quality is enjoyed by everyone. Yet some will decide to not pay for the existing quality of service to effectively enjoy a "free ride" and avoid paying for it. As a result, the private sector fails to produce an efficient quantity of output, as producers cannot receive a sufficient price for producing an efficient level of quantity. In this case, government provision of public goods can theoretically achieve a level of production that is closer to, but not exactly equal to, the efficient level of production of the public good.

The case of asymmetric information describes the fact that the buyer and seller of a good do does not have equal/symmetric information about the true quality of a given product. For example, in a market where both high quality and low-quality products are offered for sale, the consumer may not be able to determine product quality until after the purchase is made. In such a case, the naïve buyers will offer a high-quality price under the assumption of receiving a high quality good, when in fact the product was of low quality. While the consumers may make the mistake in the short run, they learn to avoid that in the long run by never offering high quality prices again. As a result, high quality sellers cannot remain in business, leaving only low-quality products available for sale in the market, despite consumers willing to pay high quality prices for high quality products. In this way, the private market suffers from adverse selection of product quality. In this case, the government could theoretically require product quality certification standards that must be met by producers, who would be subject to random inspections.

Market power refers to the ability of the producer to charge higher prices than in a competitive market, without the fear of competitor producers stealing away their market share. Such situations include a monopoly market, a cartel, or an oligopoly market. Rather than taking the market price as a given, these producers have the capacity to choose their own price that maximizes their profitability. In this case, the government could theoretically create price ceilings that more closely reflects the competitive market price or break up the monopoly firm or cartel arrangements into multiple competing entities that cannot coordinate their marketing approaches.

Of all the market failures, the issue that most closely concerns the green economy or other derivative paradigms is the case of externalities. Externalities define the situation in which the third parties are affected by the production or consumption of a good or services even though they are neither a producer nor a consumer of that good or services [46]. Externalities can be negative or positive according to their effect on the third parties. Research and development (R&D) activities are often cited as creating positive externalities, just as environmental pollution is often cited as producing a negative externality. Negative externalities, especially in the long run, will create over-production of products and an inefficient allocation of productive resources. This can range from the over-extraction of finite natural resources to the over-harvesting of renewable natural resources. For this reason, green economy growth methods focus on achieving sustainable, long-run growth by decreasing negative externalities in production.

All market failures ultimately distort the private market equilibrium from its competitive demand and supply balance, creating an inefficient allocation of productive resources. Thus, in an economy where externalities emerge, production is neither efficient nor long-term and sustainable [47]. Several studies have concentrated on classical and neoclassical economic models in a variety of sectors, including investments, business failure, consumer income, product creation, decision making, and the monetization ratio [48]. Grey systems and genetic algorithms (GA) have been combined in a number of ways to create hybrid economic techniques and models that have had a number of essential outcomes. In the second category, grey-neural networks (NN), grey-rough set theory (RST), and grey-fuzzy techniques are all included, respectively. There are a number of studies that incorporate more than two theories, including GST, CBR, and RST [48].

Economic diversification is the key to mitigate the negative impacts of an economy's dependence upon natural resources. Without diversification, the economy is vulnerable to external shocks, and sudden price fluctuations due to the large foreign exchange inflows and pronounced volatilities in commodity prices. The main determinants to the export diversification are a well-developed infrastructure, high quality political and economic institutions, sustained investment, and freedom to trade internationally [49]. Natural resource dependent countries can benefit from the revenues to utilize already existing physical and human capital to widen their economic portfolios. One study analyzed the economic diversification policies of Azerbaijan, Botswana, Chile, Indonesia, Kazakhstan and Malaysia were analyzed, which are all resource-dependent economies [49]. The study identified five factors that contributed to successful economic diversification efforts:

- "Maintaining a good macroeconomic environment".
- "Designing a realistic diversification strategy that takes into consideration local conditions and geographic factors".
- "Creating well-functioning government institutions to aid the diversification process".
- "Adopting policies to mobilize financial resources and support the general public".
- "Building adequate physical and social infrastructures to support diversification efforts".

2.2.2 Green Growth:

Alternatively, the green growth paradigm, as defined by United Nation Environmental Program (UNEP), focuses on economic growth that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities".

It implies that income and employment growth can be driven by both public and private sectors' investments that reduce greenhouse gases (specifically carbon), improve the efficiency of energy and resource use, and reduce the risk of biodiversity loss and the degradation of ecosystem services. The main idea of Green Growth is to guide the transition toward a green economy that maintains the balance between the traditional economic growth and investment goals, while protecting environmental quality and promoting social inclusiveness [11], [50].

Transitioning towards a green economy can be an element of socioeconomic sustainability, where it is recognized that economic growth involves social dynamics. Sustainability as a term that is traditionally defined as the ability to meet current economic needs without compromising the future welfare of unborn populations. It is an interdisciplinary concept where society, environment, and economy are recognized as inextricably interrelated to each other [51]. This leads to the term the "triple pillar sustainability", as the sustainability structure will not be stable if one or more of its pillars (social, economic, and environmental sustainability pillars) is weakened, which then confirms their interdependencies [52], [53].

The Green Growth paradigm has been receiving increased attention by national governments during the last decade, not only because of the increased problems associated with global warming, but also the weak global economic recovery after the 2008 financial crisis, resulting in poor job creation in terms of both quantity and quality. Decent quality jobs, as defined by the International Labor Organization, are "good jobs that offer adequate wages, safe working conditions, job security, reasonable career prospects and worker rights". International organizations such as UNEP, the World Bank, and the Organization for Economic Co-operation and Development (OECD) suggest that nations pursuing the green growth initiative would generate increased employment in same or even greater scale as the current transitional rate of economic growth. Their analysis assumes that clean energy industry is relatively more labor-intensive, but some are location specific and require localized labor force [54]–[56]. The goods and services that are provided by green industries and sectors are fallen under either one or more of the following categories: energy from renewable sources, energy efficiency, pollution reduction and removal, greenhouse gas reduction, recycling and reuse, natural resources conservation, environmental compliance, education and training, and public awareness. Therefore, the employment that is provided as the result of implementing the green growth is as follows:

- **Direct jobs**: employment created to deliver goods and services from environmentally beneficial and sustainable (green) industries and sectors.
- **Indirect Jobs**: employment created to support the supply-chain in green industries and sectors.
- **Induced Jobs**: employment created as a result of spending power of direct and indirect employment in green industries and sectors.

Figure 3 shows the potential proportions of jobs creation in green growth. There are two main important considerations for green growth to achieve its employment outcome. First, the level of government interventions needed to create green policies. "The use of government revenues from environmental tax reform for lowering labor taxes, mitigating undesirable distributional consequences and funding education and training programs can be crucial in achieving positive overall employment outcomes from green policies" [55]. Second, the time effect of creating and destroying the jobs; the question centered around the long-term job growth and its sustainability rather than short-term.

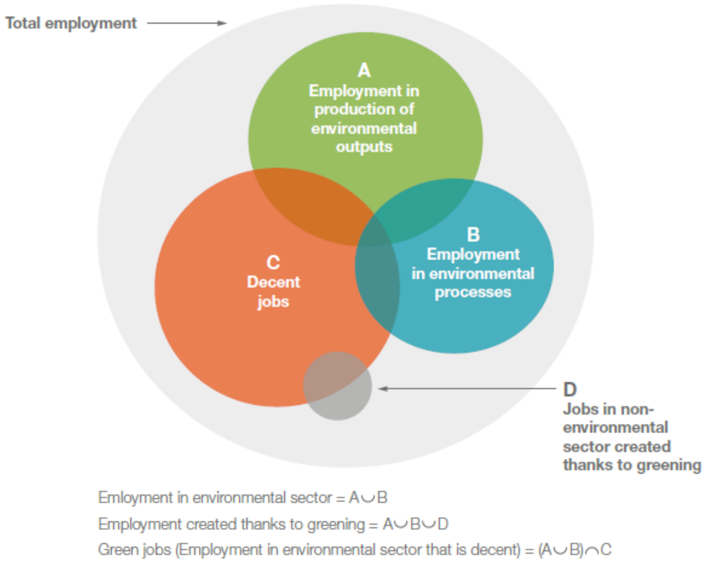


Figure 3: Relationship between total employment, employment in the environmental sector and decent work [55]

For instance, implementing climate change policy might result in jobs being lost in the sectors that are affected by the policy, but a set of new jobs would be created for replacement industries. The inefficiencies arising from this dynamic effect on labor is a short-term effect. However, the medium-term effect is when the impact of such policy diffused through the entire economy, many jobs are lost and created along the value chain of different industries and sectors. Because jobs created are not only direct ones, but also indirect and induced jobs, the medium-term effect is known as the "higher-order economy-wide effects" of climate policy. The long-term effect of the policy is related to the innovation and the development of new technologies which in turn would create further opportunities for investment and growth; the long term-effect is called the dynamic effect of the policy [54].

Introducing market-based green policy will impact the economic sectors as well as labor market, and can occur through the following channels [55]:

- **Change in production modes**: industries use less polluted-intensive inputs and processes which result in change in labor demand.
- **Change in demand pattern**: the prices of clean goods and services are lower because of green policies, which affect the demand of clean versus nonclean goods and services and

induce the shift of their production across industries and sectors. This affects the employment demands across industries and sectors.

- **Change in aggregate income and macroeconomic condition**: the aggregate supply, demand and employment are changed due to the implementation of green policies and their effects on the economy. Government budget through taxation will be changed because of changes in economic activities. Reduction in labor market taxation, or revenue redistribution to mitigate negative distribution impacts, or funding education and training programs, will result in not only be improved from environmental objectives perspective, but also from social and economic perspectives, as improvements in health and wellbeing of citizens occur, and a more efficient economy is attained.
- **Change in trade and competitiveness**: pollution-intensive goods that are produced from regions where green policies are imposed will be more expensive compared to same goods but from other regions with no policies. This makes trade more challenging, especially compared to other regions or internationally.

Green policies impose change in economic activities that result in jobs losing and gaining, but net employment is maintained or even increased. The labor market needs to be flexible enough to allow worker to change their jobs and shift across industries with the least period of unemployment, especially when their skills can be utilized in other industries. Figure 4 shows the effects of green policies implementation on employment across different sectors where BAU is Business as Usual.

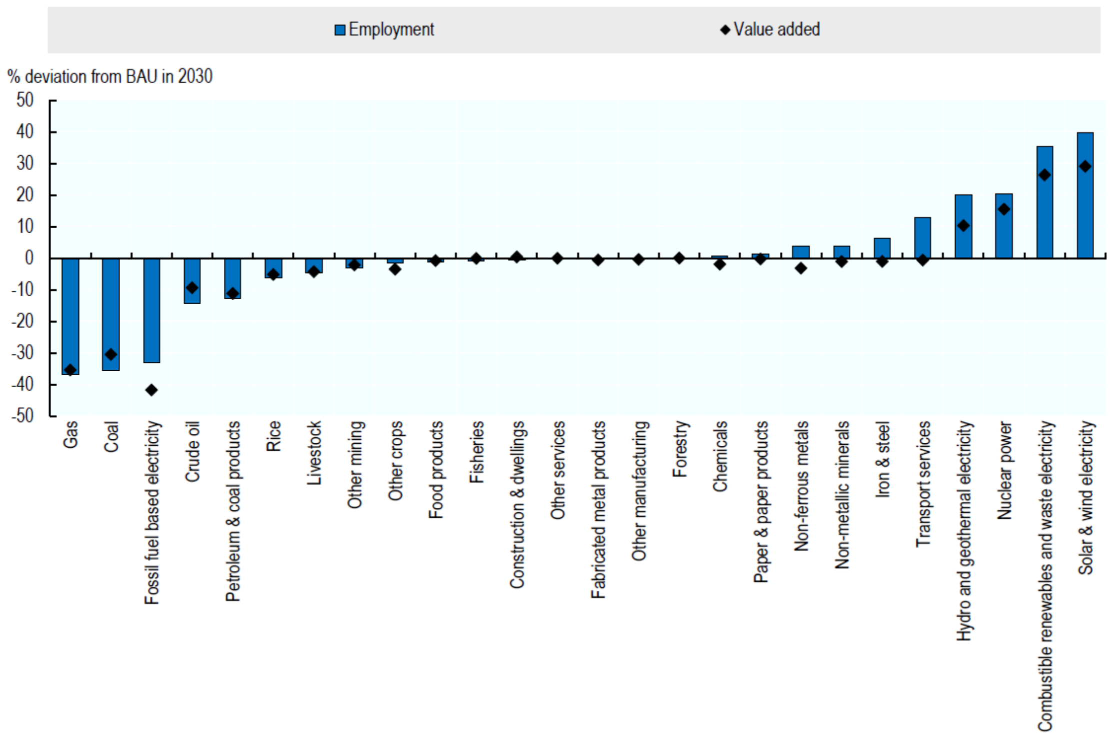


Figure 4: Green Policies impacts on Employment across Sectors [55]

In general, governments have been seeking regulatory changes, policy reforms and provided public expenditures to fund strategies that accelerate green growth. Some of the aims that are targeted include: boosting productivity, increasing investor confidence, starting new markets, contributing to fiscal partnership, and lessening risks of negative shock waves that interfere with growth. Most developing and underdeveloped countries have inadequate resources for dealing with environmental degradation and usually have very weak environmental regulations. The focus of these countries is generation of employment opportunities and stable economic growth. Levels of pollution, resource degradation, and biodiversity loss are increased because of industrialization and limitless economic growth. This illustration clearly indicates that most countries are interested in the philosophy of economic development first and cleaning up the economy later. However, such an approach may not be favorable because a country may take a very long time to expand to a level where the citizens call for a cleaner natural environment. The Environmental Kuznets Curve (EKC) is a curve that shows the inverse correlation between the level of income and level of pollution in an economy, as shown in Figure 5. However, EKC fails to consider other structural factors in its analysis. For instance, government regulations and climate change the vulnerability of the economy [57]. Further, Figure 5 illustrates the relationships between the indicators of environmental degradation and the per capita income of a country. In the stages of early development, the rate of pollution usually increases with the total population. However, after a certain level of per capita income is achieved, the trend reverses so that the rate of pollution decreases with economic growth, resulting in richer countries generally having cleaner environments. This also means that the relationship between per capital income and environmental improvement forms a u-shaped curve.

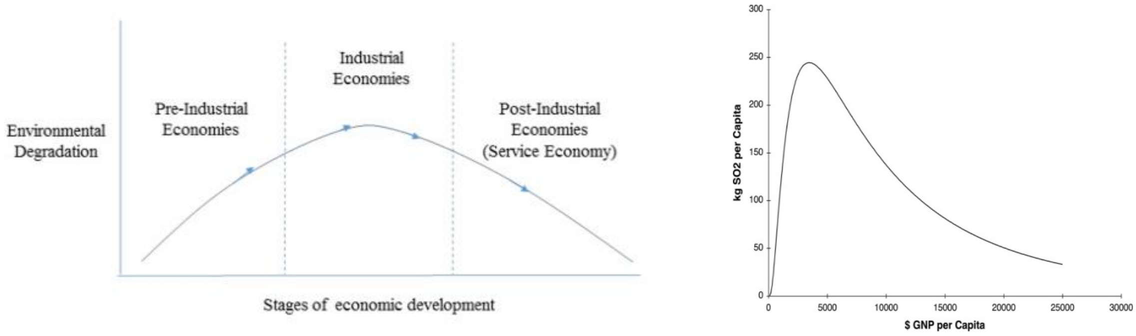


Figure 5: Relationship between per capital income and environmental pollution [54]

The EKC is one of the solid approaches that is used by economists when they are coming up with models regarding pollution and emissions. But in some cases, most model estimates of the EKC are not statistically accurate. This is because statistics show that the level of pollutants in some developed countries has declined, while in other countries the levels have increased. Studies of the relationship between per capita income and level of pollutants endeavor to avoid such pitfalls while generating their models by controlling for the influence arising from other factors that are affecting pollution. A simple mathematical illustration of how to estimate the EKC can be shown in (Eq. 1).

$$y = a + bx + cx^2 + \varepsilon, \quad (1)$$

where y is a metric of environmental damage,
x is per capita output, and
ε is unobservable residual

The coefficients a, b, c, are each estimated to show the non-linear effect of level of income on the quality of the environment. According to EKC hypothesis, $b > 0$ and, $c < 0$ [58]. By adding the control variable z, which reflects the level of some other influence on environmental damage such as level of urbanization, the value of its coefficient, *d*, can be estimated. Including the control variable allows the full influence arising from the per-capita income variable, *x*, to be observed.

Green growth can generate other sources of growth through an increase in productivity, modernization, and opening of new markets of green oriented technologies and products. These aspects of the new green industries can create new job opportunities. Increased efficiency of the use of natural assets is critical for sustainable economic growth, due to its environmental impact and guaranteed increase of productivity in the long run [59]. This cannot be met without advancing current levels of technology, but such growth is not dependent on innovation only. The expansion of non-technological factors is also required, such as upcoming business plans or models of city planning. However, no country can afford all the resources required to put green growth initiatives into fruition. For example, the production of infrastructure is relatively capital reliant. Poorly developed countries lack the capital for creating the optimal level of infrastructure, which is one of the green growth shortcomings. This is complicated by low returns to investment and low economic growth returns in underdeveloped countries.

Developing and underdeveloped countries are the main players when it comes to the attainment of green growth. First, the economic and social impacts of the degradation of the environment are the hardest felt by the people in these countries. They cannot afford the many mitigation processes that developed countries enjoy. This makes developing and underdeveloped economies the most vulnerable to pollution and climate change. Further, they tend to depend on developed countries that exploit their abundant natural resources. Social and economic threats also exist, ranging from inconsistent availability of good food and clean water to suffering from an increase in the incidence of extreme climatic conditions. Indeed, premature deaths caused by pollution, poor food and water quality, and diseases have led to persistent economic underdevelopment.

Second, they are the lowest contributors of Global Green House Gases compared to the developed and major emerging economies. Different countries at different levels of growth have come up with ways of implementing policies and programs for green growth. A great number are also experimenting with comprehensive ways of presenting their national development strategies and policies that align with green growth, for instance, low carbon. There is straightforward focus on attaining early wins to ensure there is confidence behind green growth strategies [59].

The OECD report published in the year 2013 outlines some of the key factors that affect developing countries that are pursuing green growth. For instance:

- They should adopt long term visions for national development which require high levels of political good will and stakeholder participation.
- Come up with legislation that focus on eradication of poverty and social equality.
- Expansion of access to financial support.
- Focus on programs rather than project-based solutions.

Green growth weighs long-run impacts on human wellbeing against the push for achieving prosperity through economic growth. It sets up balanced pathways for the utilization of green technology and policies that can help developing countries adopt better development models [60].

2.2.3 De-Growth:

The term de-growth refers to a scenario in which the emphasis on economic policy is to achieve a steady-state level of economic prosperity that does not grow, or even considers the benefits of decreasing economic prosperity in future generations. In contrast to an unwanted economic recession, a negative growth rate in a productivism-based economy is considered desirable to achieve certain environmental goals. The idea of de-growth is purely theoretical and has not yet been applied in the real world. It is founded on the premise that only by cutting back on global production and consumption can we assure humanity's long-term well-being and the survival of our planet. According to this philosophy, all levels of society must be balanced, and disparities must be recalculated. On the one hand, this perspective signifies a decrease in the quantity of natural resources that wealthy countries are allowed to extract. There should be an acceptable level of access to the technological advancements made in affluent countries by poorer countries, referred to here as developing and underdeveloped countries. There are many benefits to the latest technological advancements in developed countries that can be reaped by those who live in developing countries [61].

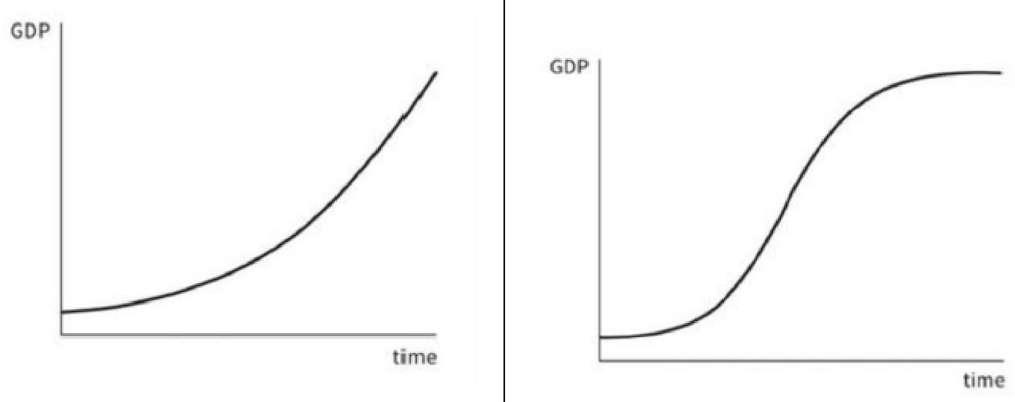
The viability of economic growth is a very serious debate. Capitalist societies are faced with many questions regarding their pursuit of growth, with the idea that uncontrolled growth on a restricted planet may be reaching its limits. There have also been many failed trials of decoupling economic growth. This forms a basis for a contemporary debate over the proper goals of any nation. This issue was initially popularized by the exploitation of workers during a recent economic emergency. Many researchers believe that capitalism is an outdated and environmentally devastating framework for designing development policy [61]. Many activists consider economic growth as the most effective way of tackling pressing issues, such as the quality of life and social inequality. However, their opponents have opened room for developing new measures of progress, like embracing post-growth economics and degrowth.

Degrowth is an ecological term that is used to explain a trimming of economic production, through which is a very important aspect for securing human wellbeing. If there is a coupling of the goals for economic activities with the goals of natural resource use, then the environmental conservation measures that have been put into place will necessarily slow down the economic growth of the economy [62]. Degrowth is the contrast to all forms of productivism that implies that the goal of human society is economic growth and productivity. Therefore, it does not match with the contemporary arrangements of sustainable development. Sustainable development maintains that development ideas should focus on increasing the output of capitalist growth and consumption. Degrowth views this as an oxymoron because any development that is derived from a stressed environment is unsustainable.

Consumerism and productivism led to concerns like the future reduction in available sources of energy, the decline in the environmental quality, and the health of flora and fauna upon which humans rely. It also led to an increased negative side effects on the society like poverty and poor health. As economies continue to grow, there is also an increase in the need for resources. The supply of fixed resources like oil gets depleted over time since it is a non-renewable resource. However renewable sources can also be depleted over time if they are being extracted for extended periods and at unsustainable rates. The rate at which the growing demand for the resources as supplies decline becomes a major concern. Many governments in turn start to look for alternative sources like biofuels and solar energy to meet the demand. However, none of the substitutes can be able to meet the adaptability of oil. According to the proponents of degrowth, the only way to lower the level of demand is to close the demand gap permanently. Once the demand and production of non-renewable sources goes down, then the rate of depletion of the resources goes down [63].

As opposed to sustainable development, degrowth does not look forward to being adopted by the OECD, United Nations, or European commission. The concept of sustainable degrowth primarily focuses as a bid for revolutionary change in social perspectives. It is an attempt to re-politicize the argument about how much social ecological transformation is truly needed. In the early 2000s activists' movements in France organized the slogan "decroisance" which implies degrowth in English. The term was derived from an economist known as Nicholas Roegen who in the 1970s developed a theory of economic processes that stated that, in the long run, economic productivity will decrease to a level that can be supported by available solar flows. Degrowth became known among the activists in Italy and France. Community scholar activists practicing degrowth were also formed and they started biannual conferences in 2008. Leiziping conference that was converged in 2014 mainly focused on the issue of degrowth. The review of the conference was that social and biological sustainability requires a streamlined organization of society, although room for views should be provided. The role of then scholars was to gather knowledge and theorizing degrowth, articulate with and make use of perspectives already embodied by prior social movements especially those involved in environmental justice struggles. Degrowth is therefore a normal idea which involves both practical and rational concepts [64].

According to Neoclassical theory, the prevailing implication is that a nation’s GDP will grow indefinitely over time, resulting in exponential growth. However other economists have argued that growth will eventually reach a maximum limit. The implications of both views are contrasted in Figure 6.



Exponential growth curve	*The S curve*

Figure 6: Growth Curve [54]

The view of Neoclassical economists was that economic growth is desirable because it can increase both economic growth and prosperity (real income per capita). However, this can be considered pessimistic in the long run, due to their insensitiveness towards infinite feasibility. The economists not only failed to appreciate the possibility of limits to growth but also feared them; therefore, this is a major limitation to their theories. A drastic increase in population would endanger both capital and economic growth. This means that the nations would no longer grow, and they will become stationary state economies. According to Adam Smith, such a stationary state of the economy would be inevitable but very unfavorable to society. However, their thoughts were focused on the economic welfare that is determined by industrialization.

As opposed to this view, author in [65] was interested in economic social transformation, and he was optimistic about his predictions about achieving a stationary economy. His concept focused mainly on the limited possibility of renewing industrial resources. Although he was opposed to the concept of a stationary state economy, he appreciated that it could improve people’s lives. He agreed that a huge social transformation would be ideal to have people agree on equal wealth distribution instead of competing for it. This would greatly benefit societies that are marked by unequal wealth distribution. Yet, this view cannot be advanced to western countries that require a complicated wealth distribution formula to make them stationary. According to Mill stationary state does not mean stagnation of the economy, but it is the rather the most ideal way to promote the common lot. Part of the solution for his idea of stationary growth is controlling the world population. Technological advances and effective family planning would favor the stationary state.

The majority of the promoters of degrowth agree that it entails optimizing the rate of consumption and production to improve ecological conditions while at the same time improving the quality of human welfare. Reduction of production and consumption lowers pollution levels due to less use of resources, hence improving the environmental conditions. The reduction of production is measured by GDP indicators and is referred to GDP degrowth. Downscaling of consumption is referred to as consumption degrowth. Sustainable degrowth calls for an equality in reduction and stabilization of a society's throughput, or the transformation of productive resources into consumable products and services. For instance, the materials extracted, and the energy produced are equitably distributed in society. Lastly, radical growth is a situation that implies that changes in the values, ethics and preferences in society, such as labor, profit making, property ownership, and the role of money, are considered as ways of escaping from the capitalist economy. However, all these explanations and arguments show that degrowth aims at lowering the economic size of world economies to manageable limits within their ecological levels. There is an understanding that degrowth is the only objective to achieving a stable economy [66].

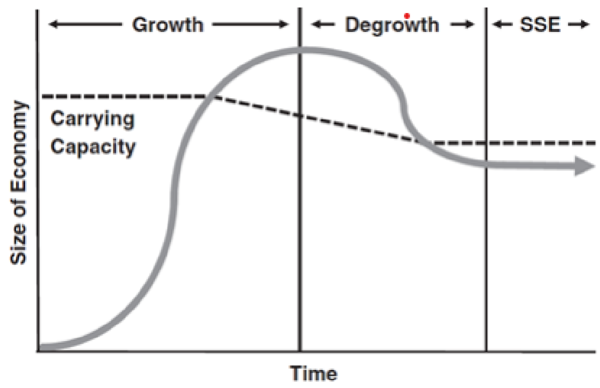


Figure 7: Degrowth[54]

The Figure 7 shows the gradual transition of degrowth to steady economy. It is a complete representation of the step-by-step global transition towards a sustainable (or steady state) economy. The term growth economy refers to the current state of economies in developed countries, where corporate behavior and especially policies by the 19 governments are generally aimed at contributing to growth in terms of GDP. Post-growth economies are the umbrella term for those economies which have abandoned their prior growth paradigm. Degrowth and steady state economies are therefore both post-growth paradigm economies. As already mentioned, visions of steady state economies have their roots in the work of Daly, and more recent research efforts have tried to conceptualize “concrete utopias” the currently prevailing growth paradigm may evolve into [67].

However, it has been argued by the author in [68] that these visions fail to acknowledge the diversity of contemporary capitalism, which would inevitably lead to different forms of steady state economies around the globe. He differentiates between three forms of capitalism and accordingly provides a vision of three different forms of steady state economies which are to be considered. Liberal capitalism, as manifested in the United States or the United Kingdom, have focused on market allocations of productive resources. This perspective sees competitive relationships between businesses as the ideal way to increase productivity and wealth in society. In this case, state interventions are uncommon, taxes and welfare programs are relatively low, and societal redistribution is fair. In such capitalist economies, the driving force behind degrowth transition is often found in societal movements. For instance, the International Transition movement works to enable home-oriented production, micro-enterprises, food cooperatives and local currency systems. Their goal is to promote the ‘liberal steady state economy’, where the local culture remains individualistic and competitive markets that concentrate on maximizing the profits within specified ecological limits.

Human well-being in a capitalist state is often influenced by the form of a social insurance adopted by society, where the state provides income transfer payments. France, Italy, Spain, Japan, as well as the ‘rising powers’ of Brazil, Russia, China and India, are to different extents examples of this form of capitalism. Here, centrally steered degrowth transitions are most likely. Countries with strong intellectual and activist movements that agree with the transitions, such as France, Italy, and Spain, which are also host to social movements such as massive and dynamic worker movements can become leaders in the degrowth transition process [69]. In the ‘statist steady state economy’ which will follow, an interventionist state steers the economy to stay within ecological limits. Markets and private companies still play a pivotal role, but state support in the form of economic subsidies and tax rebates for social enterprises and forms of renewable energy are likely to occur to a large extent. Eliminating inequality might not be the main target here, but minimum and maximum income levels are expected to be higher/lower as in the liberal form, while the system of transferable birth rights to stay within population limits could also be considered by the strong state.

Even though degrowth is considered a macroeconomic concept, there is literature seeking to establish how transition affects different organizations, whether in the transition phase or in the post growth phase. There have been attempts to interpret the concepts of post growth and degrowth economics at the organizational level using different business models. The first stream of literature within the broader degrowth discourse focuses on the organization and is concerned with actual growth in organizations. Though a relatively small niche of scholars has focused on this issue, within the last few years some studies tried to establish how companies can evade the growth paradox and remain profitable. One study conducted by Liesen conceptualized Successful Non-Growing Companies (SNCs) as a possible form of postgrowth companies. By using a document analysis method, the researchers investigated ten SNCs in terms of their motivations, main performance signs and management strategies. Their analysis suggests that organizations should prioritize growth in product qualities over traditional quality methods. Common features in measuring success in SNCs are not only the quality of the product or services sold, but also include type of job and quality of life for people in the workplace [70].

In addition, some studies have found that companies can increase their value-added from employing repair and maintenance services, which can be linked to the required shift from production to service economy that is often called for by degrowth scholars. Other studies find that managers in Small and Medium sized Enterprises (SMEs) can be properly motivated to grow or not grow their firms. Interestingly, this study showed that non-economic concerns seem to play a more important role in motivating managers than personal economic gain or loss. On a similar note, scholars analyzed 14 privately owned companies that made an active decision against growing faster, getting bigger, going public, or becoming part of a large corporation. In practice, these companies do not primarily aim for a maximization of business performance based on classic indicators like sales, market share, or profit. Rather, the shareholders of these companies have other, non-financial priorities in addition to earning a return on their investment. They were also interested in creating a great place to work, providing a great service to their customers, retaining lasting relationships with their suppliers, and making meaningful contributions to the societies that they live and work in.

Degrowth leads to consequences of quick social systems changes. These social practices and beliefs are valuable and useful to any given society. Degrowth transition can likely bring about wellbeing inferences due to quick social changes. While the concept of social beliefs and practices strongly insists that such people are open to change, it’s equally important to accept the fact that these structural factors contribute to society orientation and stability. During transitions, these norms usually lag, leading to social conflicts and disorientation. Hence, such transitions can negatively impact human wellbeing.

The solidity of social structures of a society is likely to determine how people are most likely predicted to behave in the future. The structural dimensions of a society prove to be an important foundation where relationships are built [71]. For instance, modern-day sociological and conventional research indicates that rapid social changes can lead to interruptions of social practices, which in turn can negatively impact human wellbeing, especially in terms of health. Suicide has been recognized as one of the worst results. Scholars also established that during phases of transition that interfere with people’s habits result in disjointed and confusing abnormalities in human actions. Such social irregularities can lead to deterioration of human wellbeing when people feel out of place and unable to be part of the new opportunities produced in society, and they may also end up being mistreated by others. Experiential research shows that a wide range of organizational change influences people's health and death rates. A study across 174 countries examined the level of human wellbeing and performance in terms of healthcare, life satisfaction, and accountability were high during periods of economic stability. However, the same measure was very low during times of GDP growth or decline. This clearly shows that rapid economic growth negatively affects life expectations.

Another challenge to consider is how the current expectations of the modern generations regarding their wellbeing and health standards may compare to suitable degrowth scenarios. Needs theory provides a very important assessment of human wellbeing under degrowth initiatives by differentiating between the influence of needs and luxuries. Needs can be defined as goods and services that are mandatory for basic level of human life, while luxuries exceed this requirement [68]. This theory helps us in establishing a consumption corridor which differentiates between minimum standards and maximum standards. This safeguards that every person is assured of living a good life both in the present and in the future. The dispute is how normal the new ways are in determining people's way of life, especially extreme standards in the present world. The generation is mostly focused on improving living standards and wellbeing, hence increasing the life expectancy.

There seems to be a significant gap in knowledge regarding the role of the transitions in degrowth and post growth economies. Several researchers insist on the importance of focusing on individual organizations during the transition of degrowth, which is best facilitated using a bottom-up economy approach. This implies that both the producers and the consumers are actively present in the transition. In most cases the focus shifts to single organizational forms. This makes their insights less obvious for application to the necessary strategies to be implemented within capitalist economies in our contemporary world. It also lacks sufficient consideration of how different organizations in the current world of diverse societies can adopt the degrowth paradigm into their own strategies. Even though individual organizations acknowledge the important role of implementing degrowth transitions, there is no mechanism in which to explain how organizational strategy should be designed to facilitate strategies at the national level.

Concepts of wellbeing are better placed to discuss the relationship between human welfare and degrowth policies. Factors like health and life expectancy have been the most important human wellbeing measures in the world. Yet, if life expectancy has been shown to fall during times of economic recession, degrowth policies must address this risk [72]. However, the positive relationship between economic growth and life expectancy is very complicated. Life expectancy continues to increase with per-capita GDP and is often (but not always) highest among the developed countries. The role of economic growth can only be shown by research on the long term and how its impacts have been mediated through various ways like adoption of complex technologies in healthcare, innovations, and public education.

2.3 Economic Models' Measurements Indicators:

Indicator is metric used to measurement, assess, or evaluate the state of subject of the study. In economic literature, there are common economic indicators that are widely used and built based on macroeconomic theories. As the economy grows (expanding) and evolves (new industries), indicators for state and change are captured in new indicators. Below highlight main indicators for each type of economies: classical/neoclassical, green growth, and degrowth.

2.3.1 Neoclassical Economy:

According to early classical or neoclassical economic arguments, savings are the basis of growth. It was later discovered that technological development or human capital (learning by doing, skills etc.) are the main engines of growth [73], [74]. The basic dynamics of capital and growth in the Solow-Swan model can be examined with per unit of labor variables examined within the Cobb-Douglas production function in labor augmented format [75]–[77]. The Cobb-Douglas production function is represented in (Eq. 2) where the term ($\mathbf{AL}$) is an indicator of human capital, which reflects the relative productivity labor.

$$\mathbf{y} = \mathbf{f}\,(\mathbf{A},\mathbf{L},\mathbf{K}) = (\mathbf{AL})^{\boldsymbol{\alpha}}\mathbf{K}^{\mathbf{1-\alpha}} \tag{2}$$

where $\mathbf{y}$ is production measured by GDP,
$\boldsymbol{\alpha}$ >0 is the portion of labor-creating output,
$\boldsymbol{t}$ is a time component,
$\mathbf{K}$ is aggregate capital,
$\mathbf{L}$ is aggregate labor, and
$\mathbf{A}$ is technological development

Further, the evolution of the stock of capital over time can be represented as being influenced by the rate of investment (**I**) in (Eq. 3).

$$\mathbf{K}\,(\mathbf{t}+\mathbf{1}) = (\mathbf{1}-\boldsymbol{\delta})\,\mathbf{K}(\mathbf{t}) + \mathbf{I}(\mathbf{t}), \tag{3}$$

where $\boldsymbol{\delta}$ is depreciation,
$\mathbf{I}$ is investment, and
$\boldsymbol{t}$ is a time component

Further, the level of investment is determined by the level of savings (**S**) in the economy as shown in (Eq. 4).

$$\mathbf{S}(\mathbf{t}) = \mathbf{I}(\mathbf{t}) = \mathbf{y}(\mathbf{t}) - \mathbf{C}(\mathbf{t})$$

$$\mathbf{S}(\mathbf{t}) = \mathbf{MPC} * \mathbf{y}(\mathbf{t}) \tag{4}$$

where $\mathbf{C}$ is consumption,
$\mathbf{S}$ is savings,
$\boldsymbol{MPC}$ is the marginal propensity to consume, and
$\boldsymbol{t}$ is a time component

It is clear in Eq. 4 that the level of savings is dependent upon the difference between total income and total consumption, or the marginal propensity to consume (MPC) in (Eq. 5).

$$\mathbf{MPC} = \frac{\boldsymbol{\Delta C}}{\boldsymbol{\Delta I}} \tag{5}$$

After making the necessary derivations in the economy, **capital per unit of labor (k)** and **output per unit of labor (y)** for the steady-state equilibrium are found in (Eq. 6) and (Eq.7).

$$\mathbf{k} = \left(\frac{\mathbf{s}}{\mathbf{n} + \mathbf{g} + \boldsymbol{\delta}}\right)^{\frac{1}{1-\alpha}} \tag{6}$$

and

$$\mathbf{y} = \left(\frac{\mathbf{s}}{\mathbf{n} + \mathbf{g} + \boldsymbol{\delta}}\right)^{\frac{\alpha}{1-\alpha}} \tag{7}$$

- **Gross Domestic Product (GDP):**

Calculation of the goods produced in a country over the price level in a certain period gives the GDP value of that country. The standard measure for GDP is given in Eq. 2.8.

$$\mathbf{y} = \mathbf{C} + \mathbf{I} + \mathbf{G} + \mathbf{X} - \mathbf{N} \tag{8}$$

where $\mathbf{C}$ is aggregate consumption,
$\mathbf{I}$ is aggregate investment,
$\mathbf{G}$ is aggregate government spending,
$\mathbf{X}$ is aggregate exports, and
$\mathbf{N}$ is aggregate imports

In this economy, where environmental factors or indicators related to the green economy are not considered, the composition of growth originates from these inputs that make up aggregate demand. While examining the growth structure of economies, the fluctuations in these variables within the period are taken into account. In other words, at what rate consumption, investment, or net exports $(\mathbf{X} - \mathbf{N})$ contribute to growth can be examined. If an economy is consumption-oriented, the main dynamics of growth are consumption-driven. If the economy is export-oriented, the driving force of growth will be exports [78].

This dichotomy reveals the challenge of creating sustainable economic growth in an economy. Any growth scheme that is fed by high but unhealthy dynamics may bring about a crisis or contraction in the short run. To explain this with an example, let's assume the average growth rate of any country is 4% throughout the last decade. Assume this country grows at a 6% rate when it operates under full capacity. The lower growth rate implies that some productive resources remain idle, as aggregate demand is less than potential, long run supply. The result is unemployment.

Conversely, a growth rate above 6% without any new capital investment or increase in the labor supply, simply brings inflation. Aggregate demand then exceeds the economy's capacity to supply output in the long run. If this economy's growth rate remains above 6% and is created by expansionary monetary or fiscal policy, this growth rate cannot be sustained and is not the result of any real growth dynamism. The economy is simply temporarily on an unhealthy and unsustainable growth path [79].

While the classical growth models have been useful in portraying the basics of economic growth, there is a search for developing successful model to portray a green economy, which focuses on promoting sustainable and healthy long-term economic growth. The Chinese economy, which is the engine of growth in the global economy, has sustained an average annual growth rate of 7% for decades [80]. However, it is important to recognize the long run costs arising from resource extraction that come with this extended growth level. Economy aims to match limited resources with unlimited wants with maximum benefit. Under the assumption that resources are limited, economies that grow by focusing on areas such as environmental pollution and consumption of natural resources will lag behind in the medium and long term. If we consider the countries in the Arabian Peninsula that have grown with oil production, it would not be rational to think that they will grow forever with limited natural resources that will one day run out without investing in alternative resources or technology.

- **Savings**

In a circular economy, incomes of individuals are evaluated in two ways, either consumed or saved. Here, consumption or saving includes both the individual and the public. In other words, government expenditures $(\mathbf{G})$ are divided into two as public consumption and savings are taken as a total. Savings generally refers to the unconsumed income of individuals ($\mathbf{y} = \mathbf{C} + \mathbf{S}$ or $\mathbf{S} = \mathbf{y} - \mathbf{C}$). Here, both consumption and saving are a function of after-tax disposable income which define the consumption function in (Eq. 9). and the savings function in (Eq. 10).

$$\mathbf{C} = \mathbf{C_0} + \mathbf{b}(\mathbf{yd}) \tag{9}$$

where $\mathbf{C}$ is the consumption function,
$\mathbf{C_0}$ is autonomous consumption, and
$\mathbf{yd}$ is after-tax disposable income,

and

$$\mathbf{S} = -\mathbf{C_0} + (\mathbf{1} - \mathbf{b})\, \boldsymbol{yd} \tag{10}$$

Disposable income is income after taxes are paid ($\mathbf{yd} = \mathbf{y} - \mathbf{T},$ where $\mathbf{T}$ is tax rate). The $\mathbf{b}$ in the equation is called the marginal propensity to consume and shows how much of the income individuals consume in a given period of time. Since any unconsumed income will be saved, it can be converted as $(\mathbf{1} - \mathbf{b}) = \mathbf{s}$. Here, $\mathbf{s}$ defines as the marginal propensity to save. Therefore, savings are a function of disposable income ($\mathbf{S} = \mathbf{s}.\mathbf{y}$). The classical view sees saving as a function of interest $\mathbf{S} = \mathbf{S}(\mathbf{r})$ where $\mathbf{r}$ indicates interest rate. This view is partially correct because as interest rates increase, the tendency to save increases or individuals choose savings instead of consumption while maximizing their utility. However, in modern economic literature, savings are accepted as a function of disposable income [81].

The increase in the saving function may have two origins, the first of which is the change in the marginal propensity to save ($\mathbf{s}$) of individuals. However, since this trend is generally accepted as constant in the medium and long term, income must increase for savings to increase ($\mathbf{y} \uparrow \Rightarrow \mathbf{S} \uparrow$). In the Solow model, however, the fundamental dynamic of growth is not savings but technological progress. A change in saving can only create a level effect, allowing a new steady state to be reached. Here, if the long-run propensity to save changes, output per capita will increase [82]. It is one of the most important macroeconomic indicators as the change in saving rates will affect consumption, investment, and aggregate demand.

Since the change in saving rates will show the level of capital accumulation of countries, it also sheds light on the theory of convergence [83]. Because in economies with high growth rates, savings rates and capital accumulation are generally low since they are far from their steady state level of capital accumulation. While developed countries generally produce slower and sustainable growth rates, saving rates are high and they almost reach steady state capital level. In the long run, these economies converge towards each other in growth rates due to convergence of in savings rates.

For all these reasons, the savings rate can be accepted as one of the leading indicators for economic growth and development level. Since they feed the investment with domestic possibilities, they have an indisputable effect on growth engine. Economies with low savings rates are those who tend to have current account deficits and need foreign capital to finance their investments [84]. Since the transition to green economy will transform the savings rates of countries, it can be used in the comparison of neoclassical economy and green economy.

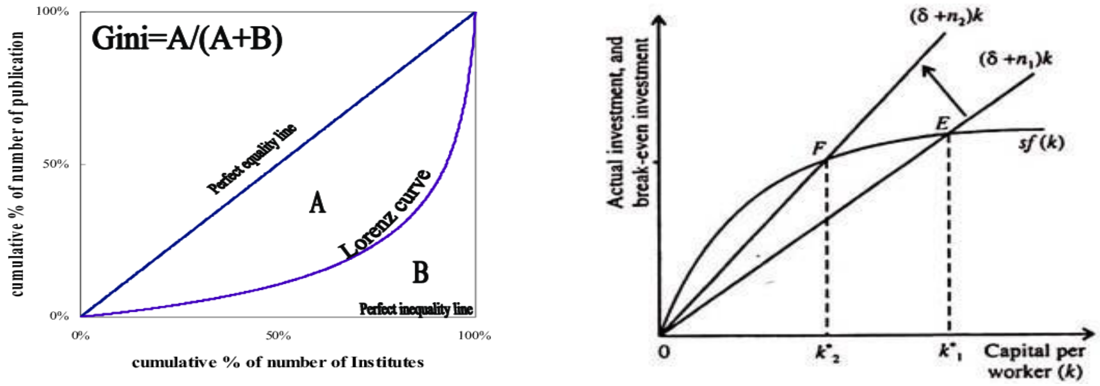
- **Population Dynamics**

The population growth rate shows the change in the population of the countries compared to previous years. Since the number of people living in a country directly affects the per capita income of that country, it also has a strong effect on the growth rate. Population growth can be estimated from the basic equation $\mathbf{L} = \mathbf{L_0}\ \mathbf{e^{nt}}$ in one year. Here $\mathbf{L}$ is labor, $\mathbf{n}$ is population growth rate, and $\mathbf{t}$ is time. When the natural logarithm of the equation is taken and its derivative is taken with respect to time, it will be seen that the population growth rate is constant at $\mathbf{n}$, which is one of the important indicators affecting the Solow growth model [82].

Since per capita income is an inverse function of the population rate, the trend in the population growth rate is positive in terms of showing per capita national income. For example, since the population rate is high in the Chinese economy, which has grown by 7% nominally, per capita income is low as per IMF/World Bank, Macro Indicators, 2021. For this reason, it would be useful to look at the per capita income level, rather than the raw GDP level. However, national income per capita alone is not an indicator of welfare. While it is important for economies to reach high per capita income, it is also important how this income is shared. For example, the per capita annual income in the United States is $40,000. Yet, this measure is merely an average (total income divided by total population) whereas most people in the U.S. earn well below this income level.

Consequently, it would be appropriate to use the Lorenz curve and the Gini coefficient to illustrate and compare income distribution across national economies. The Lorenz curve the curve shows the cumulative distribution of national income across the population, starting from the income received by the poorest individual and ending with the income received richest [85]. The income inequality metric that is derived from this curve is called the Gini coefficient. The greater degree of convexity that is displayed by the Lorenz curve, the more area of separation that it creates relative to the straight, cumulative line of perfect equality. The ratio of this area to the total area under the line of perfect equality creates a value between 0 and 1.0. A value closer to 0, it shows a more equally distributed national income. This is a popular index for examining the relative equity in a nation's income distribution, which sheds light on the degree of social welfare among the population of the economy. The left side of Figure 8 shows the Lorenz curve and the Gini coefficient.

On the other hand, the effect of population growth on the standard growth model can be examined from the graph depicted on the right side of Figure 8. This graph dynamically shows the impact of population growth on capital levels per capita, and on output levels per capita. As can be seen from the chart, an increase in the population growth rate decreases the level of capital and growth. Already in the equations $\mathbf{K} = \left(\frac{s}{n+g+\delta}\right)^{\frac{1}{1-\alpha}}$ and $\mathbf{y} = \left(\frac{s}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha}}$, if the derivative of capital or growth is taken with respect to population growth ($\mathbf{n}$), it will be seen that it is negative ($\frac{dk}{dn}$ or $\frac{dy}{dn}$ both <0). For this reason, looking at the population growth rate in the economy while examining the growth dynamics will give an idea in terms of both capital accumulation and long-term growth indicator [82].



Gini Coefficient and Lorenz Curve — Population Dynamic and Growth

Figure 8: Population Growth [82]

- **Technological Progress**

While technology enables the production of output by using productive resources in the most efficient way, almost all countries undertaking the green economic transformation prefer a convenient transition in terms of the speed and efficiency with which the transformation takes place. Obtaining much timely, high-quality results leads to an increase in the labor productivity path during the transition. At the same time, technology that reduces externalities that arise in the use of capital or resources and minimizes asymmetric information is one of the effective methods in solving market failures [86].

In the Solow model, while technology sometimes comes into play as a constant influence expressed within an efficient workforce as in (Eq. 11), it can sometimes be found as a constant influence at the beginning of the production function and modifying the productivity of all productive resources as in (Eq. 12).

$$\mathbf{y} = \mathbf{f}\,(\mathbf{K}, \mathbf{AL}) = \mathbf{K}^{\alpha}\,(\mathbf{AL})^{1-\alpha} \tag{11}$$

Versus

$$\mathbf{y} = \mathbf{f}\,(\mathbf{K}, \mathbf{L}) = \mathbf{K}^{\boldsymbol{\alpha}}\,\mathbf{A}\,(\mathbf{L})^{\mathbf{1}-\boldsymbol{\alpha}} \tag{12}$$

The Cobb-Douglas production function requires that ($\boldsymbol{\alpha}$) take on a positive value equal to or less than one. This implies that the coefficient ($\boldsymbol{\alpha}$) in these equations reflects from the share of production attributable to either capital or labor in the production process. For example, if $\alpha = 0.3$, the capital is responsible for 30% of output and labor is responsible for 70%. and the value of ($\boldsymbol{\alpha}$) reveals which resource is used more intensively, indicating whether this country is relatively more labor-intensive or capital-intensive in its production processes. Further, in a competitive labor and capital market, labor income is determined by its relative productivity share (α). The coefficient ($\mathbf{A}$) in these equations is a value that shows the influence arising from the level of technological development. Indicators such as the level of research and development expenditures, machinery and equipment investments, and robotics and automation productions can all be considered as leading indicators of the level of technological development.

- **Depreciation**

Depreciation refers to the rate at which capital is consumed or eroded during the production process. For example, if the service life of a purchased machine is 20 years, the straight-line annual depreciation rate is calculated as 5%. When calculating economic growth and the net value of the capital, the depreciation rate of capital is subtracted from the stock of capital, and the remaining value is taken as the actual value of capital. Therefore, investments in capital are subject to depreciation [87].

We have previously mentioned how variables such as savings, population growth, and depreciation can all affect capital per capita and output when using the standard Solow growth model. An increase in the depreciation rate causes both a lower rate of growth and a lower capital to labor ratio at the steady state equilibrium value. Therefore, depreciation rates should be considered when examining growth data. Although this situation is known especially in neoclassical economics, the lack of considering depreciation-like affects in the extraction of natural resources illustrates the importance of properly modeling the depreciation of natural resources when examining the transition to a green economy.

This arises because finite natural resources cannot be replaced once extracted and consumed, and renewable resources can become extinct when harvested at an unsustainable rate. Considering the valuable resources contained in the land, forests, and seas governed by national economies, treating their respective rates of depreciation in the same way as the depreciation of physical capital can reveal the value in green economy transformation. Increasing the depreciation rate for reasons such as pollution and resource overuse is essential in optimizing the transition to green or de-growth economies.

2.3.2 Green-Growth Economy:

The green economy, unlike the neoclassical economy, aims to use natural resources as input in a more measured way to achieve sustainable growth rather than a steady state of output levels. This approach builds on existing sustainable development initiatives in many countries and aims to identify cleaner sources of growth, including seizing the opportunities to develop new green industries, jobs and technologies. It also seeks to optimally manage the structural changes associated with the transition to a greener economy [88]. Resources from the natural world and environmental services are vital to human survival. Thus, economic growth should be obtained while ensuring that natural resources continue to deliver these benefits [89]. As a result, natural resources should stimulate ventures and modernization that will later enhance continuing development and provide new sources of income while maintaining a sustainable rate of use. A more pragmatic and adaptable approach is offered, one that considers the social implications of greening economies' growth dynamics while still making tangible, demonstrable progress in both the economy and the environment. To enhance the long-term viability of green development plans, natural resources must be able to fulfill their full economic potential. It is all part of the ability to provide life-sustaining services like clean air and water and the resiliency of biodiversity needed to sustain food production and human health. Green growth initiatives consider that natural resources are not a limitless substitute [89].

The Green Economy initiative (GEI) suggests that green growth is the key driver for economic growth. According to the report, the sources of green growth include stability, innovation, new markets, productivity, confidence, scarcity, and imbalances. Table 3 below shows the various indicator groups of green growth [89], [90]. These indicator groups are divided into five different categories, containing twenty-six total indicators.

Table 3: Green-Growth Indicator [88]

	Indicator Groups	**Proposed Indicators**
1	Environmental resources, economic activity	
1.1	Carbon and energy productivity	• CO2 productivity ▪ Production based CO2 productivity ▪ Demand based CO2 productivity • Energy productivity ▪ Energy productivity ▪ Energy intensity per sector ▪ Share of renewable energy resources
1.2	Resource productivity	• Material productivity ▪ Demand based material productivity ▪ Production based material productivity • Waste generation intensity and recovery ratios • Nutrient flows and balance

		• Water productivity
1.3	Multi factor productivity	• Environmentally adjusted multifactor productivity
2	Natural assets	
2.1	Natural resource stock	• Index of natural resources
2.2	Renewable stock	• Freshwater resources • Forest resources • Fish resources
2.3	Non-renewable stock	• Mineral resources
2.4	Biodiversity and ecosystems	• Land resources • Soil resources • Wildlife resources
3	Environmental dimension of life quality	
3.1	Environmental health and risk	• Environmental induced health problems and related costs • Exposure to natural or industrial risks and related economic losses
3.2	Environmental services and amenities	• Access to sewage treatment and drinking water
4	Policy responses and economic potentials	
4.1	Technology and innovation	• Research and development expenditure of importance to green growth • Patent of importance to green growth • Environmental related innovation in all sectors
4.2	Environmental goods and services	• Production of environmental goods and services
4.3	International financial flows	• International financial flows of importance to green growth
4.4	Prices and transfers	• Environmental related taxation and subsidiaries • Energy pricing • Water pricing and cost recovery
4.5	Regulation and management approaches	
4.6	Training and skill development	
*	Characteristics of growth and socio-economic context	
	Economic Growth, productivity, and competitiveness	Economic growth and structure: ▪ GDP growth and structure ▪ Net disposable income
		Productivity and trade: ▪ Labor productivity ▪ Multifactor productivity ▪ Trade weighted unit labor costs

		▪ Relative importance of trade: (exports + imports) /GDP
		Inflation and commodity prices: ▪ Consumer price index ▪ Prices of the food; crude oil; minerals, ores, and metals
	Labor market, education, and income	Labor market: ▪ Labor force participation ▪ Unemployment rate Socio-demographic patterns: ▪ Population growth, structure, and density ▪ Life expectancy ▪ Income inequality: GINI coefficient ▪ Education attainment: level of and access to education

▪ **Measurements that track the economy's environmental and resource efficiency**

A central element of green growth is the environmental and resource efficiency of both production and consumption, as well as its evolution over time and space, and across sectors. Understanding this evolution and the factors that drive these changes, is an essential ingredient in developing green growth policies. Progress can be monitored by relating the use of environmental services in production (use of natural resources and materials, including energy, generation of pollutants and other residuals) to the output generated and by tracking decoupling in trends of production and environmental services. Decoupling at the national level can partly be explained by displacement effects (such as the substitution of goods or services produced domestically or requiring high levels of environmental services) with imports (that don't necessarily imply decoupling at the global level). Such shortcomings in production-based measures can be addressed by focusing on the evolution of efficiencies, or otherwise, in relation to consumption [90].

These following indicators, according to the OECD (2018), incorporate efficiency in the production and use of energy, other natural resources, and environmental services produced from natural capital. Some indicators included in this set are relevant to the shift to a low-carbon economy that is also resource-efficient.

- Carbon and energy productivity that exhibit interactions with the climate system and the global carbon cycle, the environmental and economic efficiency with which these energy resources are used in production and consumption, and that respond to policies that promote low carbon technologies and cleaner energy.
- Resource productivity that characterizes the environmental and economic efficiency with which natural resources and materials are used in both production and consumption. This informs the results of policies and measures that promote resource productivity and sustainable materials management across all industry sectors. Important resources and materials include mineral resources (metallic minerals, industrial minerals, construction

minerals); biotic resources (food, feed, wood); water; and nutrients that reflect among other interactions with nutrient cycles and food production systems.

- Adjusted for environmental services and natural resource consumption, multifactor productivity (MFP), new markets and jobs can be created by increasing productivity by making better use of ecological factors and natural reserves.

For the most part, environmental and resource productivity indicators focus on the ecological flows generated or used by domestic production. Environmental fluxes used or created from consumption or ultimate demand are also considered [89]. For demand-based statistics, import environmental fluxes are subtracted from exporters' emissions. These metrics reveal the ecological impacts of consumer spending and government investments. Trade-in Value-Added, a new OECD initiative to collect data on international trade flows, offers an excellent chance to examine demand-based productivity indicators in greater depth [89].

- **Descriptive Indicators of Natural Assets**

Natural resources are a major foundation of economic activity and human welfare. Their stocks are part of any economy's natural capital. They provide raw materials, energy carriers, water, air, land, and soil, and they support the provision of environmental and social services that are necessary to develop man-made human and social capital. The extraction and consumption rates of these resources affect the quality of life and well-being of both current and future generations. This includes oil and gas extraction, mining, fishing, and forestry products. Natural resources differ in their physical characteristics, relative abundance, and value to different countries or regions. Their efficient management and sustainable use are key to economic growth and environmental quality [90]. The aim is to optimize the net benefits from resource use within the context of economic development, by:

- Ensuring adequate supplies of renewable and non-renewable resources to support economic activities and economic growth.
- Managing the environmental impacts associated with the extraction and processing of natural resources, to minimize adverse effects on environmental quality and human health.
- Preventing natural resource degradation and depletion.
- Maintaining non-commercial environmental services.

Progress can be monitored by tracking stocks of environmental assets, along with flows of environmental services, and by using indicators that reflect the extent to which the asset base is being maintained in terms of quantity, quality, or value [90].

Using the descriptive metrics, we can determine whether the natural resource base is being optimally preserved and maintained at levels that are compatible with long-term viability. They should, in theory, be able to point out threats to imminent development posed by diminishing or depleted natural resources. Progress can be measured in terms of natural resource and environmental asset inventories and ecological service flows according [89]. Among this group's key performance metrics are:

- Shares of replenishable natural assets and materials such as freshwater, forests, and fisheries are available and are of high quality.
- Non-replenishable resources, particularly mineral deposits such as fossils fuels are readily available and easily accessible.
- Biodiversity and ecosystems, which includes natural habitats, species, and the production of soil and land resources, such as nutrient and water cycling.

2.3.3 De-Growth Economy

As we have already mentioned that GDP alone cannot be an adequate measure of human well-being. The cost of the growth and the unfair income distribution it often creates have become increasingly important relative to the level of economic growth. The growth created by unsustainable rates of natural resource consumption in the world will eventually cause irreversible damage. As I stated earlier, the main goal for achieving human welfare is learning how to maximize the satisfaction of unlimited human desires with the limited stock of finite natural resources and achieving a sustainable rate of renewable resource consumption. The insistence on boosting GDP without consideration of the long run impact on satisfying consumption demand of future generations merely entails the systematic commodification of subsequent life domains, which in turn proves harmful to both the environment and human relations. In fact, only at early stages of economic growth does focusing on GDP create a strong correlation with creating positive trends in living conditions, this push for maximizing short-run production still does not guarantee the fair distribution of wealth and has little effect on our overall well-being [91].

The main goal of reducing environmental degradation is to create a smooth economic growth path followed by a steady state de-growth era. Currently, global production and consumption levels are overshooting our planet’s bio capacity by nearly 60% each year. Scientists tell us that we are blowing past planetary boundaries at breakneck speed and witnessing the greatest mass extinction of species in more than 66m years [92].

Some GDP growth may still be necessary in poorer countries, but is less essential for the world as a whole. The only option is intentional de-growth and a rapid shift to what legendary ecological economist Herman Daly calls a “steady-state” that maintains current economic activity at ecological equilibrium. Indeed, the surer route to poverty is to continue on our present trajectory, for, as economist Joseph Stiglitz points out, in a world of ecological degradation, GDP growth is diminishing living standards rather than improving them. De-growth will require eliminating unnecessary production and work. But this presents us with a beautiful opportunity to shorten the working week and give some thought to that other big idea that has captured the public’s imagination over the past couple of years: a universal basic income. How to fund it? There are many options, including progressive taxes on commercial land use, financial transactions, foreign currency transactions and capital gains [92].

It is difficult to determine which indicators will be more significant and decisive for de-growth compared to the neoclassical and green economy. Because de-growth has a structure that challenges both and has more qualitative indicators rather than the quantitative ones. Therefore, human happiness and well-being are at its center [93]. Not only quantitative things such as growth indicators or trade figures should be considered, but also qualitative things that prioritize human life and quality. The known indicators of wellbeing, IHD (Index of Human Development), Herman Daly's Genuine Progress Indicator (GPI), Robert Putnam's indicator of social health (ISS), the calculation of green GDP or P.I.D. ("Produit Intérieur Doux"; the "Soft Domestic Product" of the Québécois), integrate corrections concerning "defensive" expenditures, linked to the deterioration of quality of life (water and air pollution, harmful acoustic effects, alternating migration, road accidents, urban crime, loss of wetlands and non-renewable resources, or with accounting for unpaid domestic work). If one begins with the graphs of the evolution of GDP and ISS (Indicator of Social Health of Robert Punam) or of GPI (Genuine Progress Indicator of Herman Daly), one sees that beginning in the 1970's in the United States, these tendencies diverge. Whereas the GDP continues on its own growth trend, each of the other indices start an an increasingly marked decline. Well-being decreases while "well-having" grows. "The so-called economics of Wellbeing are actually, as Patrick Viveret wrote, an economy of "Much Having". "The day when we count our destruction within our famous GDP", notes Bernard Maris, "we are likely to find ourselves quite poor" [94].

It is possible to measure the rate of de-growth by looking at four indicators. At the national level, the signs lead to a stable economy.

- **Gross National Happiness (GNH):**

GDP, as we mentioned earlier in the foundations of neoclassical or capitalist economy, is often used as the country's economy and welfare measure, despite estimating only the value of all products and services produced across all markets. This implies that basic development measures such as income distribution, justice, democracy, and human rights are not considered in standard economic models that rely solely on GDP as the stated goal for consuming productive resources. For this reason, de-growth differs from other models in that it makes the world a more livable place by consuming fewer natural resources and prioritizes human happiness/satisfaction.

The phrase 'gross national happiness' was first coined by the 4th King of Bhutan, King Jigme Singye Wangchuck, in 1972 when he declared, "Gross National Happiness is more important than Gross Domestic Product" [95]. The concept implies that sustainable development should take a holistic approach towards notions of progress and give equal importance to non-economic aspects of wellbeing (Sustainable Development Index, UN). Psychological Wellbeing, Health, Education, Cultural Diversity and Resilience are some of the examples of the measurement methodology in the happiness index. To model and find accurate data for some of the qualitative measurements like cultural diversity in not easy or even feasible in empirical search. However, some proxy metrics can substitute GDP with GNH as a challenge of de-growth.

Of course, there are some downsides to ignoring GDP and putting happiness and people's well-being at the heart of economic policies. Because one of the most basic macroeconomic indicators such as unemployment is directly related to the happiness of people. And there is a high correlation between unemployment and GDP (Okun's Law) [96]. Further, economic degrowth can be volatile and lead to unemployment, increased state expenditures for unemployment benefits, and potentially a fiscal crisis of the state [97]. However, nobody in the de-growth literature is preaching degrowth as a permanent goal. Author in [98] posits that the debate between de-growth and proponents of a SSE (going back to Georgescu-Roegen's excessive strictures against Herman Daly) is false: degrowth is the path of transition to a lower steady-state. But should the resulting steady-state be lower than today, or can we achieve zero growth at current levels of resource consumption? Author in [97] calls for prosperity 'without' growth. However, his own "arithmetic of growth" shows that, save for a technological miracle, degrowth is unavoidable. From the literature on happiness economics, we know that: i) long-run happiness does not increase with national income, ii) in international comparisons of those countries that have satisfied basic needs, the level of happiness does not vary much with national income. The reason for that first the happiness is adaptive and positional. As everyone gets richer, no one gets happier. Second, because after satisfying basic needs happiness is derived from qualities of life that do not necessarily correlate with material wealth. The policy implications are stark: a more equal distribution of income and investment in public services that make a difference in the quality of life, can have greater welfare effects than generalized growth. In the short-term however, a crisis or a sudden loss of income do reduce happiness levels. If money does not buy happiness, then why do people still try to get richer? [99]. As a result, the happiness index is in the core of the degrowth theory and has superiority on GDP.

- **The Index of Sustainable Economic Welfare and Genuine Progress Indicator:**

According to [100], a second way to quantify de-growth could be to utilize the Index of Sustainable Economic Welfare (ISEW) or the accompanying Genuine Progress Indicator (GPI). Income and capital are defined according to Irving Fisher's theory, which serves as the basis for the ISEW and GPI financial indicators. Three fundamental changes are made to the base of personal consumption spending. On the basis that a dollar of more income has a smaller impact on the rich than it does on the poor, personal consumption spending is weighted accordingly. Activities that do not have market value, such as home and charitable work, in addition to the works offered by customer durables and communal facilities, are also taken into consideration. As a third factor, the costs of pollution and additional unwanted impacts of commercial expansion, for example loss of natural wealth, are considered [100].

There are many reasons why ISEW or GPI is superior to GDP as an indicator of economic well-being, including the fact that it splits expenses and reimbursements, concerns for inequality, incorporates non-profitable market activities into GDP, and treats lessening of natural wealth as an expense rather than a profit [100]. Many industrialized countries have created ISEW-like indices. According to these statistics, the GDP has climbed continuously over the past few decades, but the ISEW has stopped growing in the late 90s and, in many cases, has decreased thereafter. The findings of ISEW research have led to forming a divergent perspective relative to the proposition that economic expansion continuously has advantages that outweigh its costs [100].

GDP's current role poses several problems; one major issue is that it interprets every expense as positive and does not distinguish welfare-enhancing activity from welfare-reducing activity. For example, an oil spill increases GDP because of the associated cost of cleanup and remediation, but it obviously detracts from overall societal wellbeing. Examples of other activities that increase GDP include recovery efforts from hurricanes (and all other natural disasters), cancer (and other illnesses), crime, car accidents, and divorce. GPI is not a measure of overall human wellbeing since it emphasizes economic welfare and leaves out other important aspects of wellbeing. It is, however, a far better indicator of economic welfare and was not designed to measure non-material social welfare at all. Societal wellbeing or economic welfare ultimately depends on stocks of natural, human, built, and social capital, and because the GPI makes additions and deductions to GDP to reflect net contributions to these stocks it is a far superior measure of economic welfare than GDP [101].

One of the basic ways to compute the Genuine Progress Indicator (GPI) is as follows [102]: The GPI's current architecture has been formally expressed in an equation that contains seven major aggregations of 26 underlying indicators that can be traced back to each of these core concepts (welfare and sustainability): $\mathbf{GPI} = \mathbf{Cadj} + \mathbf{G} + \mathbf{W} - \mathbf{D} - \mathbf{S} - \mathbf{E} - \mathbf{N}$. In this expression, Cadj is personal consumption adjusted to account for income distribution, G is growth in capital and net change in international position, W is non-monetary contributions to welfare (e.g. household labor, volunteer work), D defensive private expenditures, S depletion of social capital (e.g. cost of crime, family breakdown, lost leisure time), E costs of environmental degradation, and N depletion of natural capital [102]. Here as it can be seen from the equation, while computing GPI it is taken into account not only output produced but also its cost to environment and its psychological reflection on households. Hence, creating a more comprehensive index will make measurements more sensible and provide a different perspective on growth theory.

- **Biophysical and Social Indicators:**

First, this source implies perceiving ecosystems as having value in themselves, and not only as providers of useful environmental resources or services for human consumption. Second, it stresses the impact of competition between ecosystems and the industrial production and consumption systems. An absolute decoupling between industrial expansion and ecological destruction has not been observed yet and it is very unlikely to take place. Degrowth is therefore a possible path to preserve ecosystems by the reduction of human pressures over ecosystems and nature and is a challenge to the idea that decoupling of ecological impacts from economic growth is possible [103]. Economists may use monetary metrics instead of using biophysical and social variables to track development.

Biophysical indicators can be generated using a method called Material Flow Accounting (MFA). When pursuing the complete and quantifiable contributions into state financial prudence, variations in the stock of productive resources inside commercial arrangements, and substantial productions to additional thrifts or the setting, MFA is a typical methodology. Ecology factors such as minerals, fossil fuels, bioenergy, air, and water, are the five primary kinds of material inputs to the economy that MFA conducts research on [100]. Better physical data also helps improving material flow analyses that could be undertaken at a more granular level, and then be extended to demand-based measures, akin to the methodology used to assess the CO_2 contents of domestic final demand. Such work would fit with the measurement agenda on material flows and resource productivity spelled out by OECD Ministers in 2004 and 2008 [88], [90].

The most challenging part of using data on quantifiable streams to gauge growth in a steady-state economy is determining what flows can be sustained. There have been calls for industrial economies to reduce their material use by a factor of four or ten, but these quantification goals are arbitrary. An ethical footprint is arguably the finest attempt thus far to compare supply streams with the ability of the environment to handle these streams in an aggregate indicator [100]. In order to create and absorb the ecological factors it consumes and disposes of, a country must have a certain area of biologically productive territory to calculate its footprint. No consideration is given to the stream of un-replenishable sources such as mineral deposits, but the CO_2 emissions produced by coal, oil, and gas are considered. CO_2 releases are converted to the amount of forest land needed to requisition the CO_2 in order to attain a balance of commercial action in regard to the ecology's capacity for sustaining that level of activity [100].

- **A Composite Indicator:**

Composite indicators combine social and ecological factors to enhance the well-being of society. It tends to negatively modify the value for working hours in the formal economy in exchange for more positively modifying the extent of home-production and leisure. The result is quantifying less income but reflecting more freedom. Wherever possible, growing our own organic food, water our gardens from water tanks, and turn our neighborhoods into landscapes filled with edible plants, as the Cubans have done in Havana. More broadly, it turns our homes and communities into places of sustainable production, not unsustainable consumption. This involves increasing self-sufficiency and reskilling ourselves and our communities to regain practical knowledge that is on the cusp of being lost. In a fourth method, social and biophysical pointers could be combined to provide a composite measurement. First, a composite indicator condenses a large amount of information into a single metric. It is easier for policymakers and the general public to understand a single indicator than a slew of individual metrics. As a second benefit, such an index permits states to be ranked in contrast to each other. This, too, can pique the general public's curiosity and raise consideration to the subject being measured by taxonomy. For countries nearing a steady-state economy, a taxonomy demonstrating how close they are to achieving the stated goals could be a useful tool to promote greater performance from those nations that are further away from a steady-state economy [100].

A composite indication, on the other hand, raises some major concerns. First, a large amount of information is lost when several indications are combined into a single number. Overly simple policy inferences can be drawn from a single indicator when there are conflicting influences across different elements being aggregated. Composite indicators can obscure value judgments under these circumstances. Corrective measures exist that can be performed, but they cannot fully account for such conflicts when aggregating the data into a single metric. For example, the data from the component indicators can be normalized, and the different element measures can be given specific weights. This creates a weighted metric that serves as a composite indicator. A wide variety of methods exist for calculating weights, but they all represent value judgments [100]. Thus, the relative weight allocations can significantly influence the value of the aggregated measure and complicate its interpretation for optimizing economic and environmental policy.

Human Development Index (HDI) is a widely utilized composite indicator. An alternative to GDP, the HDI shows that development is more than just a rise in GDP [100]. To commemorate the Human Development Report's 20th anniversary, a new HDI was developed by averaging many different measures, including average life expectancy, average educational attainment, and average household income [104]. Ecological factors are excluded because this is solely a socioeconomic indicator rather than an ecological indicator. Because of this, the HDI is more valuable compared to additional composite measures that combine both environmental and social concerns.

Also revealed comparative advantage (RCA) as an indicator of international competitiveness, which can also be an indicator for assessing the specialization in green environmental goods. Genuine Savings Rate, CO_2 Generation and Share of Renewables will be composited and standardized to find the RCA of a given country [105].

2.4 Discussion:

What criteria should be sought in the comparison and effectiveness of these three models? After the unsustainable use of natural resources by classical or neoclassical economy, this led the world to the search for economic systems that promoted sustainable growth. However, at this point, the transition to green-growth economy and limited growth may not balance the world ecosystem which led to the idea of degrowth. Some problems will arise about the selecting indicators, especially since most classical and neoclassical economies use quantitative indicators, while some of the green-growth and de-growth economies indicators are qualitative. This raises the problem of defining the data or determining which criteria will be used to select the appropriate data. However, despite all these obstacles, indicators that have been consensus in the literature and empirical studies have been discussed and calculation methods have been mentioned in previous sections.

From identification of economic models' indicators, we analyze each indicator and check its applicability across all three models. In the table below, we list main indicators that are used by three economic models (classical/neoclassical, green-growth, and de-growth), we then identify those that are used, or possibly can be used, across the three different models.

Table 4: Economic Indicators

Indicators	**Neo-Classical**	**Green-Growth**	**De-Growth**
Gross Domestic Product (GDP)	■	■	■
Supply and Demand	■		
Production Determinants	■		
Valuing and Pricing	■		
Indulgence in the use of products and services	■		
Sustainable Economic Welfare (ISEW)		■	■
Accessibility, availability, & value of non/replenishable resources		■	■
Genuine Progress Indicator (GPI)		■	■
Material Flow Accounting (MFA)		■	■
Environmental and Resource Efficiency		■	■
Composite Measurement		■	■
Human Development Index (HDI)		■	■
Descriptive Metrics of Natural Assets		■	
Gross Happiness Index			■

2.5. Summary:

In this chapter, a literature review required for setting up the research methodology (linking econometric, input-output, and agent-based models) has been presented. In the next chapter, we will address the thesis methodological framework of linking econometric, input-output and agent-based modelling, and the data used for modelling and simulation, model calibration and validation.

Chapter 3: Methodology:

This chapter provides an overview of current methodologies used in relevant research areas, and the selection process. Then, we introduce our methodology of linking econometric model with input-output with extension of green growth and degrowth policies scenarios analysis. Then linking the model to the agent-based modelling to study the impact of change on exogenous variables such as oil prices and production level on employment and migration. Theories, assumptions, data, and model environment are covered in this section.

3.1 Overview:

A model is defined as a "purposeful representation of some real system" [106]; it helps to understand how a complex systems or systems of systems work, behave, or if patterns' emerge as a result of multiple elements interacting with each other. Beside complexity, modeling is used to analyze a system that may develop too slowly within the timeframe of the research or experiment. The process of using the model to study the system is called a simulation. There are different modeling tools that can be used to represent the system and may depend on the type of the system itself. Below is a summary of some important modeling approaches.

3.1.1 Statistical approaches:

A statistical model is a simple mathematically formulated model that is used to analyze the data under sets of assumptions and to test theories that can be generalized to draw meaningful conclusions. In this way, implications can be drawn from a sample set and applied to the population. Statistical approaches such as time series analysis, regression, factor analysis, work with homogeneous data, where variables do not interact with each other, and hence, no dynamic feedback is involved [107].

3.1.2 Bayesian Network:

This is one type of statistical model that incorporates variables and their conditional probabilities into directed acyclic graph. The network captures the links and relationships between data variables, but it does not usually consider real-time feedback and any interactions among them within the network [107].

3.1.3 System Dynamics (SD):

This approach involves formulating a set of interrelated equations that are used to analyze the behavior of the complex system over time (such as Ordinary Differential Equations) or time and space (such as Partial Differential Equations) [108]. SD tools interconnect the system's variables to represent the real-world, allowing feedback within the system. However, the variables and system structures in a SD model do not usually evolve, and hence equations and feedbacks explain the entire system-wide interaction for given structure and data. In addition, it is considered a top-down approach, as complex systems are presented and analyzed in macro-level rather than at individuals' level in, say, economics[109], [110].

3.1.4 Evolutionary Models:

Evolutionary models are a computational algorithm designed to solve difficult computational problems inspired from Darwinian evolutionary theory. Many techniques have been driven from the concept of "inspired from nature" where learning and adaptation are the core of aspect, including in such techniques as simulated annealing, artificial neural networks, ant colony optimization and particle swarm optimization, and others [111], [112].

3.1.5 Cellular Automata (CA):

CA is "discrete spatio-temporal dynamic systems based on local rules" [113]; it is considered to be a subset of ABM (explained next), as both approaches are bottom-up, such that the aggregate patterns are discerned by examining the behavior of individual agents. However, agent locations in a CA model are fixed, and the probability of transition among agents (agents' behavior) depends on a neighboring agents' conditions, which are known. Using terse conditions and minimal rules, complex behaviors and emerged patterns can be observed and described, but they cannot be necessarily explained [107]. Keith C. Clarke [114] summarized the classification of CA transition rules done by [115] as shown in Table 5.

Table 5: CA Transition Rules [104]

Type 1	Basic	Transitions based on neighboring agents.
Type 2	Probabilistic	Transitions based on some probability distribution.
Type 3	Pattern Development	Shape or existence of the network.
Type 4	Computational Intelligent (CI)	Uses CI methods (such as case-based reasoning, neural networks, data mining and kernel-based) to determine the rules from previous agents' behaviors.
Type 5	Advance CI	Same as previous type but uses advanced CI methods (such as fuzzy logic and uncertainty reasoning).
Type 6	Remaining	Includes rules that are not compatibles with type 1-5.

3.1.6 Agent-Based Modeling (ABM):

ABM is the most flexible computational model that can incorporate statistical, SD, game theory, evolutionary theory, and stochastic modeling approaches. It simulates the interactions of individual agents among each other, emulates system behavior as a whole, and can explain the observed behavior as well as predict patterns of behavior (such as the changes of behaviors over space and time) [114]. The decision-making functions consist of rule based and analytical functions, where both can be used to represent dynamic behaviors of heterogeneous agents. Discrete event simulation is the foundation of ABM in which the state of the agents changes in a countable number in discrete time step rather than continuous [111], [116]–[120].

3.2 Model Selection:

The transition from natural resources dependent economy is a nonlinear path, and the socio-economic system sufficiently complex to continually evolves and adapts [121]. Agent-based modelling is the most suitable tool to capture the interactions among heterogeneous individuals in this study. Especially, this research aims to analyze the effects of different economic scenarios (including transition to green growth and degrowth) on employment and migration.

Generally, ABM is widely used in many fields including biology, ecology, economy, social science, and ecological economy. It aims to capture the emergence of natural system behavior resulting from the interactions among heterogeneous agents [107]. Agent-based modeling features are [122]:

- **Autonomous**: individual-level decision-making ability (act independently without the influence of centralized control) based on integrations with other agents.
- **Heterogeneity**: ability to have different attributes of individuals.
- **Active**: individuals are goal-oriented, proactive/reactive, receptive, bounded rationality, interactive and mobile.
- **Adaptive behavior**: the ability of individuals to learn from previous experience (memory) and interactions with others (communication), to change its state/behavior, imitate, and evolve.
- **Geographical Representation**.
- **Social Network Structure** (emergent from interaction at micro-level).

The economy is a complex system in which many heterogeneous variables are interacting, and new patterns are emergent. Since, the input-output model is static, it is considered as a framework to record data of a specific economy rather than an economic model [123]. The authors in [124] examined the impacts of the oil price shocks on the Malaysian economy. The methodological framework used is econometric, specifically ordinary least squares (OLS) method as a time series analysis tool to estimate the coefficients of the crude oil export and value added with respect to the oil prices. The estimated coefficients are used in an input-output model to estimate the price shocks on tax revenue, value added, labor income and employment. The outcome of the analysis is that the fall in oil price has negative impact in tax revenues, GDP and employment because Malaysia is an oil exporter. However, the impacts of oil price shocks are not fully captured as impact on export is considered but impact on lower public expenditure as the result of revenue decline is not addressed. The study for the impacts of 2014 oil price shocks in Newfoundland and Labrador is carried by [125]. A dynamic computable general equilibrium (CGE) model is used to estimate the drop in oil prices as a reduction in royalties which are the payment made by firms to the government for the right of using the land in oil extraction and production. This model is a descendant from the input-output model, but places more emphasis on the role of price. Royalty is an exogenous variable in the model, and it affects production, GDP, investment, and consumption. Different scenarios are modelled based on size of shock, timing of recovery, and future growth in prices. The outcomes of the study show that the negative oil price shocks have negative long-lasting impacts (persist until 2040) on the NL economy as the province relies heavily on the oil and gas sector and subsequently the government on the oil and gas royalties.

Today's governments and financial institutions count on econometric and (DSGE) the as main economic models [17]. These models have inherent limitations as explained in the following points:

- **Econometric**: a statistical model that fits the past data to forecast a few months or quarters ahead. The model presumes no change in current economic activities and thus fails to work in cases of great dynamic changes. It also cannot capture the linkages and interactions of different industries and economic sectors [17][126].

- **Dynamic Stochastic General Equilibrium (DSGE)**: a macroeconomic model that consists of systems of non-linear differential equations built based on general equilibrium theory and microeconomic principles. From its name, the model controls for the dynamic nature of the economy (changing over time), stochasticity of the shocks and their impacts to the entire economy as general, and general equilibrium theory. The main limitation of this model is that was it built with the assumption of [17], [127], [128]:

a. The existence of perfect information and understanding the underlying structure of the macroeconomy.
b. Homogeneity across industries, firms, or individuals.
c. The economy moves toward a predetermined state of equilibrium.
d. A simplified version of the structure of the real-world economy as the model cannot handle high nonlinearity and complexity.

3.3 Research Methodology:

Transitioning from depleted resources' intensive and dependent economies to green-growth or de-growth economies as alternatives required designing a set of policies that would ensure a viable transition is possible. The depleted energy resources such as oil and gas are the main engines for those economies to function. In this research, oil and gas are the core focus, and subsequent policies are designed to study the impacts of supply-side production processes to achieve output reductions in the oil and gas production sectors. One of the common denominators between green growth and degrowth is limiting the usage of depleted natural resources. Therefore, for the purpose of this research, oil production thresholds (as policy alternatives) are simulated, to examine the performance of other industries, labor force dynamics (employment), and population dynamics (migration); price volatilities used as exogenous variables in the model. For modeling and simulation purposes we only select quantitative indicators which reflect population dynamics, namely population change and migration.

Scenarios

Table 6: Economic Models/Scenarios

NR Price (Oil and Gas)	**Policy-0** (Baseline) 0%	**Policy-01** Green Growth (-2%)	**Policy-02** Green Growth (-4%)	**Policy-03** Green Growth (-6%)	**Policy-04** Degrowth (-12%)	**Policy-05** Degrowth (-18%)	**Policy-06** Degrowth (-24%)
65.83$	Scenario 1	Scenario 4	Scenario 7	Scenario 10	Scenario 13	Scenario 16	Scenario 19
147.27$	Scenario 2	Scenario 5	Scenario 8	Scenario 11	Scenario 14	Scenario 17	Scenario 20
40.32$	Scenario 3	Scenario 6	Scenario 9	Scenario 12	Scenario 15	Scenario 18	Scenario 21

In this research, the econometric, input-output, and agent-based models are linked as shown in flowchart in Figure 9. An Input-Output model was extended with econometric regressions with the purpose of measuring the impact that changes in both oil prices and production have on employment and value added (henceforth, IOX model). The model is adopted from [124] due to similar nature of both economies, Malaysia and Newfoundland as these economies are less diverse and more reliant on oil as main driver for the economic activities. However, the model IOX is extended to include oil productions reduction scenarios (as result of green and degrowth policies) and then further extended with an agent-based model (ABM) to measure the dynamic changes—that is, the changes over time—in employment and migration as the result of the changes in oil prices and changes in the production of oil. An ABM is a computational model that simulates the behavior of individual agents—in this case the economically active population (EAP) —and the interactions among them, with the purpose of understanding employment and migration trends that arise due to the shocks in both exogenous variables, oil prices and production rates. The emerging trends of migration and employment that arise from the IOX-ABM simulations are compared with a baseline scenario of trends of employment and migration that goes up to the year 2030, which were estimated with econometric regressions based on the historical data of the EAP, the labor market population, and migration in the case study province of Newfoundland & Labrador, Canada.

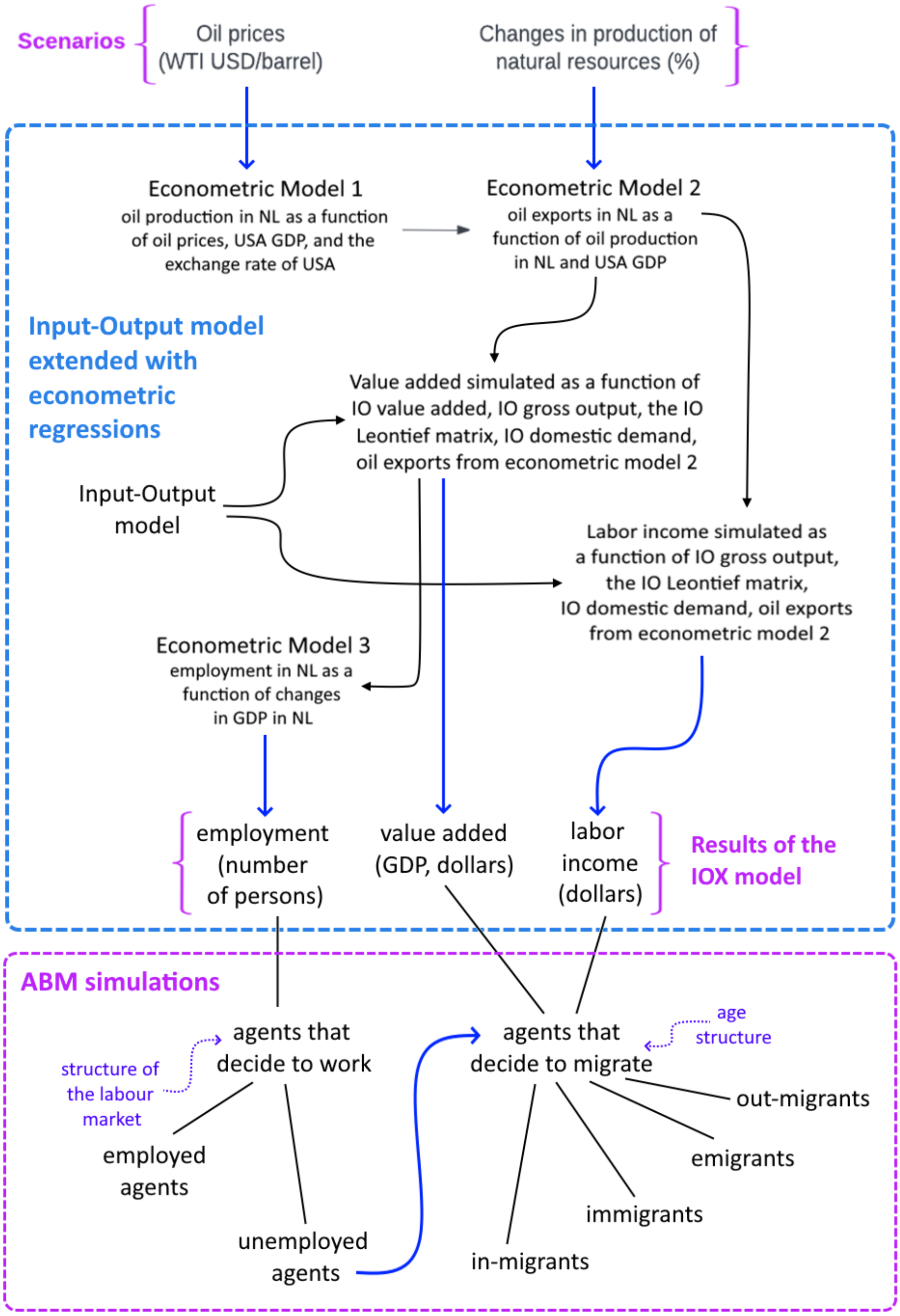


Figure 9: Flowchart of the IOX model extended with ABM models (IOX -ABM model)

3.3.1 Case Study: Newfoundland and Labrador:

Newfoundland and Labrador (NL) is one of ten Canadian provinces and is situated in the most northeast of the country, with area of 405,212 km^2. The economy of NL is heavily dependent on natural resources. Prior to 19th century, cod fishery was main economic activity, but from late 19th and early 20th century, mineral resources' mining emerged to gradually become a leading industry during that time. Since the 1960s, the NL economy fluctuated because of cod stock decline due to overfishing, and fluctuations in the world demand of paper pulp [129], [130].

The Canadian economic system is a mixture of planned and free market economies, where private sector provides most of products and services, while the government manages social security net services, national security, and defense, and it works with private sector to set economic policies and regulations [131]. Generally, the effect of natural resources' extraction and processing activities is not an important topic for a large number of Canadians, especially those who live in southern Ontario, southwestern Quebec, and British Columbia as the main economic activities of these regions are related to new economy. It is also believed that new natural resources exploration might positively impact the Canadian aggregate economy [18]. Post 1970, the Canadian economy became less dependent on natural resources as their contribution to the aggregate size of the economy fell quickly. The share of total employment, income, and investment rate (fixed capital) kept declining over time. In contrast to being a natural resource economy in the past, the new economy has a fourfold higher total employment, a threefold increase in income, and more than threefold increase the fixed capital. Fishing, forestry, and mining contributions to the aggregate economy are lower compared to energy industry, as the latter was affected by a continuous increase in demand [3]. Although Canadian economy overall is less dependent on natural resources, regional economies might not be, like in the case of Newfoundland and Labrador.

The following points highlight the main current economic activities of NL and its associated employment aspect of socio-economic system.

Oil and Gas:

The oil and gas industry contributed to 30% of total NL region's GDP [125], but account for only 2.3% of its employment. There are four main offshore sites (Hibernia, Terra Nova, White Rose, and Hebron) that collectively produce 80.6 million barrels (mmbbls) average annual production and the NL government envisions 100 new explorations that might result in an increase of workforce demand. The Hebron site expects to increase its production while the rest of the sites are decreasing [129], [130].

Mining:

Prior to oil and gas exploration and extraction, mining used to be the main economic activity of Newfoundland and Labrador. The extracted minerals include gold, silver, lead, copper, and zinc. However, the most important minerals are iron ore and nickel, and their prices fluctuate greatly, reflecting the volatility of the world market, largely due to the economic growth of China, as the prices of both minerals have generally increased since 2017. The total workforce in mining industry is 5,300 employees, and the industry is highly dependent on weather conditions to operate [129], [130].

Fishery and Aquaculture:

Fishery is the main source of income for the rural areas of NL, and they are spread across 400 communities. This constitutes a total of 16,619 individuals working in the industry, of whom 6,780 are employed in processing plants, 9,400 are registered fish harvesters, and 424 work in aquaculture industry. Shellfish harvesting contributes to 82% of commercial value of fisheries, while groundfish contribute 16% and pelagics 2%. This industry is expected to flourish due to the increase in global demand for fish and sea food products, as well as its subsequent investment from government into aquaculture and food processing initiatives [129], [130],[8], [132].

Forestry and Agriculture:

Agriculture in NL is challenging due to poor soil and short growing seasons, for it is limited to the areas south of St. John's and Codroy Valley. Around 85% of commercial value is from livestock and its various products, while the rest of the value stems from others such as hay, floriculture, and field vegetables. The forestry industry was at its peak between 1930s and 1960s. Black spruce and balsam fir trees are used for softwoods production that are ideal for pulp and paper. The main product is newsprint, whose demand has decreased recently due to the growth in digital media. Lumber production is another leading source of income for the province, which is used mainly for the structure of housing, paneling and flooring. Its residuals are used in energy applications and animal beddings. The demand of NL lumber increases due to recovery of housing business in US, and shortage of supply in other regions due to wildfires. The total employment in the forestry and agriculture industry is 3000 individuals [129], [130], [6].

Construction:

The NL construction activity is highly associated with natural resources investment projects. Most construction works are related to nonresidential projects, either natural resource production and processing such as Hebron oil development, the Muskrat Falls hydroelectric development, and the Long Harbour nickel processing facility, or to public infrastructures, like roads, healthcare facilities, schools, and municipal infrastructure. The total employment in this industry averages to be 20,700 individuals [130].

Manufacturing:

The manufacturing industry in NL is related to the natural resources' industries; the provincial outputs are refined petroleum, food processing, fabricated metal manufacturing, nickel processing and newsprint. The manufacturing industry employed around 9100 individuals where majority of them are working in petroleum refined production, and United States is the main export market for the NL. Technology based market is limited, 35 employees are working in marine technology company named Kraken Robotics Inc, and only 8 individuals are in Marine Industrial lighting systems Ltd. that imports and installs naval LED [129], [130].

Service:

The service sector in NL contributes to approximately 35% of the province's GDP. It includes banking, finance, insurance, real estate, government services, education and health care services, retail and wholesale trade, and tourism related activities. In real estate, the sale-to-new listings ratio is 35.9% in 2017 statistic, which is considered a buyers' market. This term means that housing supply exceeded the demand, resulting in either the house being sold for lower than expected prices, or remaining in the market for a longer than expected period of time. As for tourism, NL benefits from two types of tourists that are province's residents and non-residents with the highest season being between May to October. It is estimated that the service sector in general employed 177.4 thousand individuals which is 79.2% of total employment of the province [129], [130].

Interprovincial Employment:

Interprovincial employment is a normal practice for NL, as the latest statistic shows that around 5000 people come from other Canadian provinces and territories, while 20,800 people leave NL to be employed elsewhere every year. Such figures change and depend on the economic conditions of NL and other nearby provinces. For example, interprovincial employment peaked in 2008 and gradually declined after the 2008 economic recession. Men accounted for 78% of workers who travel to different provinces for work, and around 59% of all migrated workers employed in western provinces, mostly in Alberta, as their skills will be utilized in natural resources sector [130] [133].

NL Interprovincial and International Migration:

Figure 10 illustrates the high-level causal loop of out-migration in NL. The change in labor demand is affected by rate of change in population growth and the change in external demand (exports). The lower levels of demand led to a decrease in production of goods and services, which in turn has a negative impact on wages as compared to other industries or regions. To reduce the cost, a number of employees might need to be laid off, leading people to migrate to better job opportunities. The relationship is reinforcing, which means that if the population declines, the demand will decline as a response. As production declines, more people are affected by economic loss, and more will migrate.

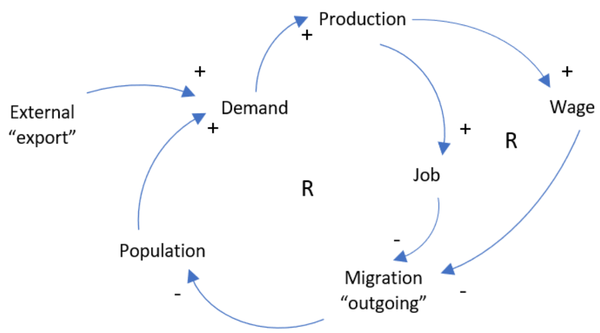


Figure 10: High level relationship diagram for migration and demand

NL Economic Shocks:

NL experienced many economic shocks throughout time and such shocks like cod fish crisis and collapse in fisheries, and oil price shocks. To mitigate the negative impacts of external shocks, economic diversification was observed. However, many challenges affect the growth in different sectors, such as weather conditions that limit agriculture and tourism. While the service sector contributes to 35% of NL GDP, it is reliant on the spending power of employees who work in natural resources industries. Currently, NL suffers from the highest unemployment rate compared to all other Canadian provinces and, as consequence of that, out-migration rate increases, and net population growth rate decreases steady by approximately 0.6% annually. Even though the percentage seems to be small, in the longer run it will result in economic decline and urban shrinkage. It will discourage investments, limit job offerings, and limit economic opportunities. Individuals might lose the opportunity to be employed if they cannot find jobs sooner, as the unused skills are depreciated over time. In the short run, selective migration occurs where younger, highly skilled, well-educated/trained, wealthier individuals tend to be the ones who migrate at the beginning. Then, family members, friends, colleagues, and neighbors are influenced by the others to migrate, due to the lack of opportunities in their home region. There are few studies in the literature that address the impacts of oil price shocks and cod fishery collapse, but no known literature exists about natural resource dependency, or unemployment and out-migration.

3.3.2 Data:

Yearly data from 1997 to 2021 was used to estimate the econometric models in the study:

- The oil production of the province of was obtained from the Canada-Newfoundland offshore petroleum board.
- The data of international oil prices was obtained from the Energy Information Administration agency (EIA).
- The GDP of USA was obtained from the database of the World Bank.
- The information of exchange rates was obtained from the Organization for Economic Co-operation and Development (OECD).

- The quantity of oil exports of Newfoundland and Labrador was obtained from Statistics Canada, the national statistical office of Canada.
- The employment in the province of Newfoundland and Labrador in Canada was obtained from Statistics Canada, the national statistical office of Canada.
- The GDP of the province of Newfoundland and Labrador in Canada was obtained from Statistics Canada, the national statistical office of Canada.
- The estimations of the Input-Output model are based on the Supply and Use tables of the province of Newfoundland and Labrador for the year 2018, obtained from the Industry Accounts Division of Statistics Canada.

3.3.3 Econometric Model:

The first econometric model estimates the quantity of oil production (in barrels) as a function of international oil prices (WTI spot prices USD/barrel), the GDP of USA (constant USD of 2015), and the exchange rate of USD against Canadian dollars (CAD):

$$\ln PROD_t = \alpha_1 + \alpha_2 \ln PRICE_t + \alpha_3 \ln GDPUSA_t + \alpha_4 \ln XRATEUSD_t + \varepsilon_t \qquad (13)$$

The parameter of interest that will be used to extend the Input-Output model is α_2, the elasticity of oil production with respect to oil prices. The parameter α_2 measures how oil production changes with respect to oil prices. A positive relationship where $\alpha_2 > 0$ is expected, since increases in international oil prices should stimulate a higher production of crude oil and equivalents in Newfoundland & Labrador (NL). In NL, the main trading partners of the oil exports of this province of Canada is the USA (that is, were exports of oil go to), according to the information of Statistics Canada [134].

Figure 11 and Figure 12 show that around 65% of the production of crude oil and equivalent of NL were destined to the USA alone, and hence it could be expected that changes in the U.S. demand can affect the production of crude oil in NL, apart from oil prices. To capture this effect, the GDP of USA was included in the regression of oil production of NL, in addition to the exchange rate of US dollars and Canadian dollars, which is used as a proxy for changes in terms of trade. These variables are used as control covariates and are included to avoid an omitted variable bias during the estimation of the elasticity of oil production with respect to the price of oil (α_2).

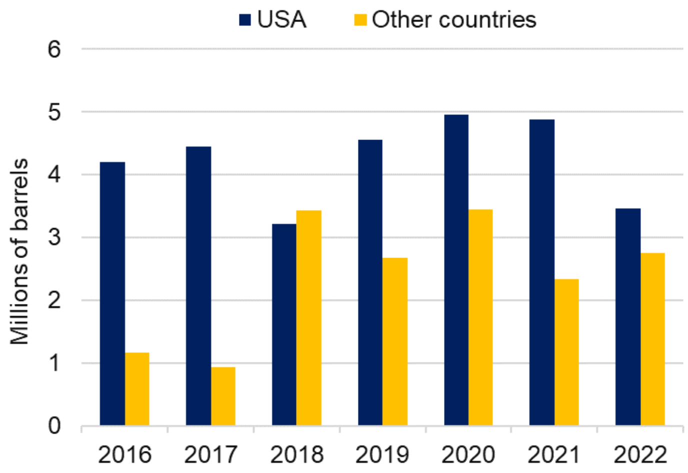


Figure 11: Supply and disposition of crude oil and equivalent in the province of Newfoundland and Labrador (millions of barrels)

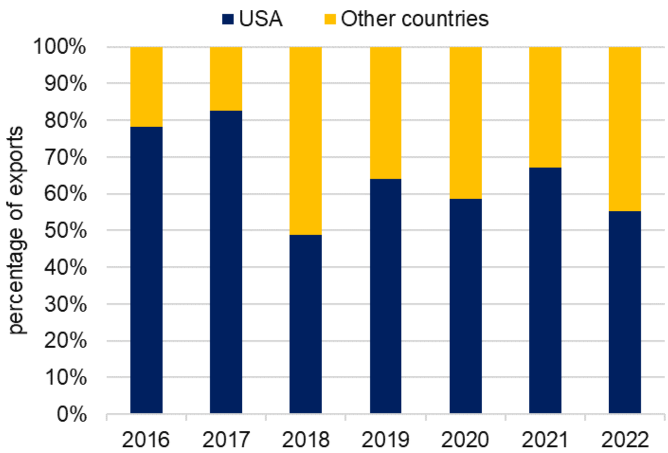


Figure 12: Supply and disposition of crude oil and equivalent in the province of Newfoundland and Labrador (percentage)

The second econometric model estimates the quantity of oil exports as a function of oil production (in barrels), and the GDP of USA (constant USD of 2015).

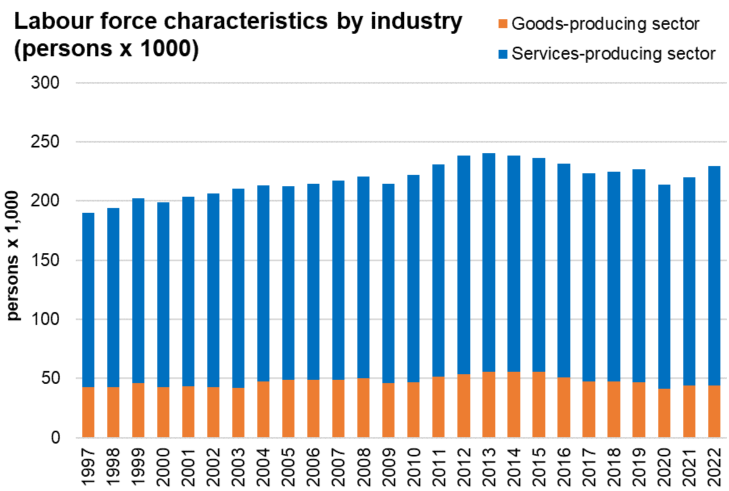
$$\ln EXPORTS_t = \beta_1 + \beta_2 \ln PROD_t + \beta_3 \ln GDPUSA_t + \varepsilon_t \tag{14}$$

The estimate of interest in this equation that will be used in the extended Input-Output model is β_2, reflecting the elasticity of exports to oil production. The parameter β_2 measures how oil exports change with respect to oil production, and a positive relation $\beta_2 > 0$ is expected since exports cannot increase without an increase in oil production. As in the previous equation, the GDP of the USA was included in the regressions because the US is the main trading partner of Newfoundland & Labrador (NL). Other trading partners of the oil exports of NL are the Netherlands, China, Germany, and Japan. The GDP of these other countries were included as control covariates but were not statistically significant or did not have the expected (positive) sign, and hence were removed from the equation to avoid a redundant variable bias in the estimation of β_2.

The third econometric model estimates employment (in number of persons) as a function of the GDP of Newfoundland and Labrador (chained USD dollars of 2012). Chained USD dollars mean that dollar amounts are adjusted to remove the adverse effect of inflation in the measurement of real production over time.

$$\ln EMPLOYMENT_t = \theta_1 + \theta_2 \ln GDPNL_t + \varepsilon_t \tag{15}$$

The parameter of interest in this last equation is θ_2, the elasticity of employment to changes in the economic environment of Newfoundland and Labrador. A positive sign ($\theta_2 > 0$) is expected since a better economic situation in NL should increase the number of persons employed, due a higher demand for employees. Employment was measured with the information of labor force characteristics by industry, from Statistics Canada [135]. Figure 13 below shows that employment in NL has been mainly concentrated in the service sector, as nearly 80% of the labor force of NL works in this sector. Figure 14 shows the GDP in the province of Newfoundland and Labrador, expressed as chained 2012 dollars x 1,000,000. These variables, expressed in logarithms, were used to estimate the parameter θ_2 in the third econometric model. The figure shows an increase in GDP from 1997 to 2007. Since GDP is expressed in chained dollars, this increase indicates a *real* increase in production (so a real increase in economic activity), not an increase in prices, as the use of chained dollars isolates the effects of inflation and reflects the changes in consumer behavior. Since the year 2007, the GDP of NL does not show an increasing or decreasing trend, hence suggesting a stagnation of the economic activity.



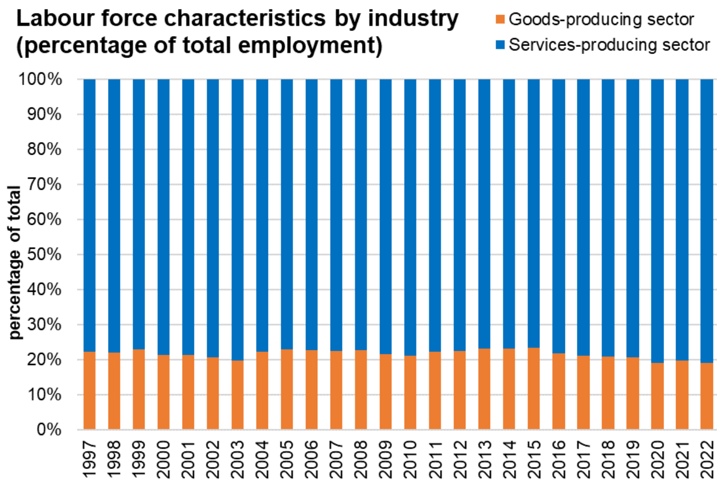


Figure 13: Labor force characteristics by industry in the province of Newfoundland and Labrador

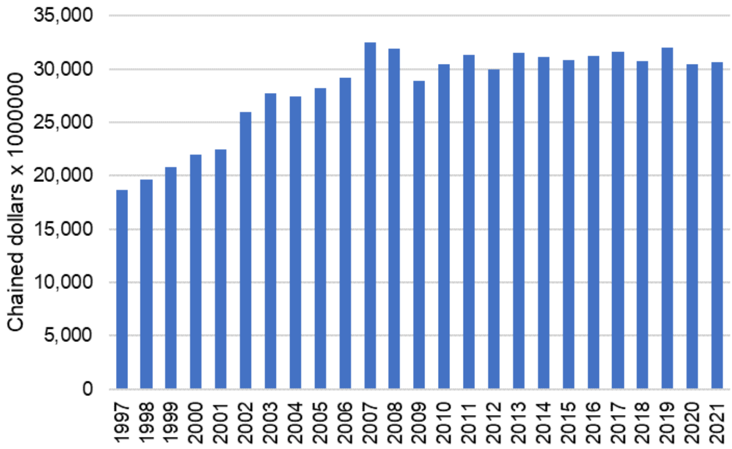


Figure 14: GDP in the province of Newfoundland and Labrador (chained 2012 dollars x 1,000,000)

The three econometric models were estimated with the variables expressed as logarithms, allowing the estimated coefficients to be interpreted as elasticities. Unit root tests, the Engle-Granger cointegration test, tests of heteroscedasticity, and serial correlation tests were all applied to evaluate the quality of the econometric regressions.

3.3.4 Input-Output Model:

The input-output model, also to referred as inter-industry analysis, is a macroeconomic analytical framework that has been created for the purpose of analyzing the interdependencies of industries in an economy. It is categorized as equation-based modelling because the model consists of a set of interdependent linear equations. Each equation describes the distribution of the industry's production throughout the economy. Since its development in 1930s, there has been multiple enhancements and extensions to the original model in which time and space have been incorporated to account for data availability limitation or connect with other economic analysis tools [136][123]. Different size of economy ranges from local, regional, national, or even international can be analyzed; however, it should be large enough for the individuals' imports to be insignificant [137].

The model captures the production flow activities, or supply chain (measured in monetary units within a specific time period), between a group of industries that produce goods (outputs) and consume goods from other industries (inputs) during the process of producing their own final output. Depending on the size of the economy, the number of industries varies from a handful to a few thousand. Figure 15 shows the input-output model's table in which the inflows are recorded in columns (industry input vector; index j), the outflows in rows (industry output vector; index i), interindustry' flows in matrix (intermediate demand matrix z_{ij}), final demand columns of household, government, and exports (labeled as y) that recorded the sales of each industry to the final markets, and value added rows of employee wages, interests, profits, taxes, and imports that are non-industrial inputs to the production [136][123][137]. The household sector inputs to the production industries the capital and labor, and gains interests and wages. Similarly, the government sector input is in term of the products' purchases and its output is services' delivery (thus receives taxes) from industries [136][123].

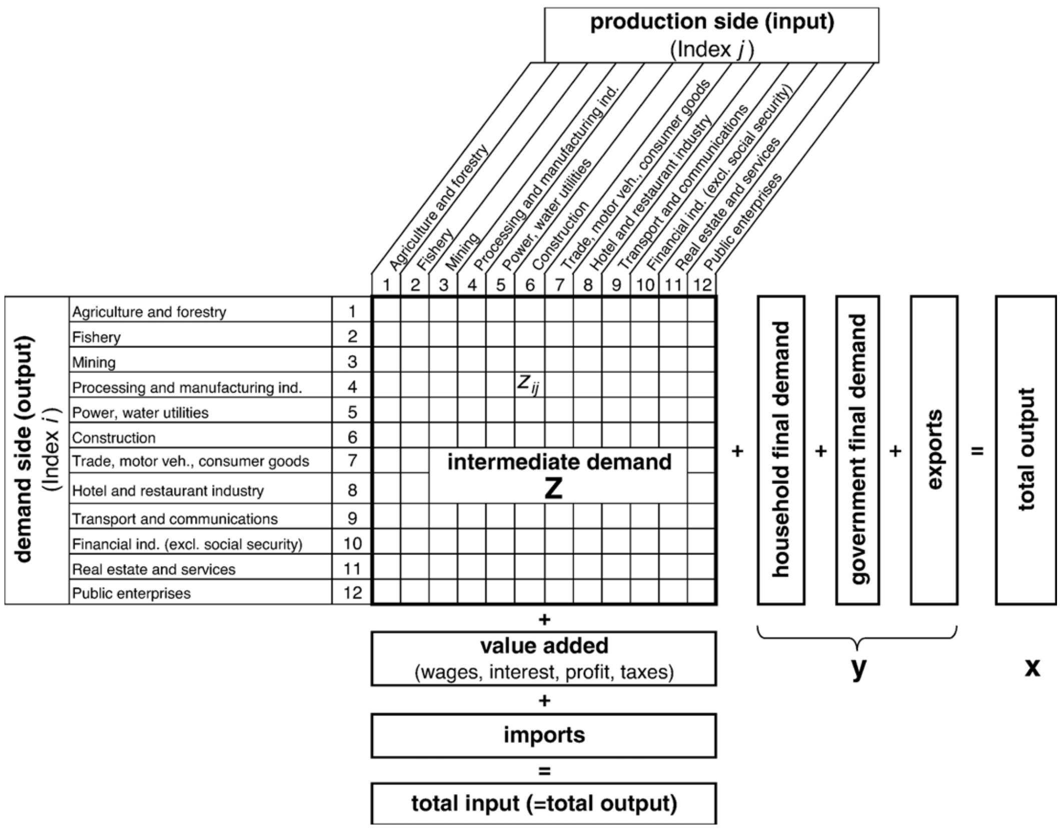


Figure 15: Input-Output Model [137]

Assuming there are n industries, the production function for industry i is as follow:

$$x_i = z_{i1} + z_{i2} + \cdots + z_{ij} + y_i$$

$$= \sum_{j=1}^{n} z_{ij} + y_i \; ; \; \forall \, i \qquad (16)$$

The technical coefficient (multiplier) is a monetary worth of inputs from industry i per monetary worth of output of industry j as shown in (eq. 17). It is assumed that the technical coefficient is fixed after it has been calculated, so that the ratio of an industry's input and output is unchanged. In the other words, the technical coefficient is fixed, the input proportion is fixed, and the output is subject to demand change which is exogenous to the model [136][123]. The most important assumption for the model to work is that the structure of the economy is not changing, which means the set of production functions (or the model equations) do not change over time.

Thus, once the Input-Output table is constructed, it would be easier to analyze the impact of demand change in an economy through only changing the demand variables. Therefore, this led to the creation of the production function as shown in (Eq. 18) [136].

Solving for $\boldsymbol{x}$,

$$a_{ij} = \frac{z_{ij}}{x_j} \qquad (17)$$

$$\boldsymbol{Z} = \boldsymbol{A} \, diag(\boldsymbol{x})$$

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}} + \boldsymbol{y} \qquad (18)$$

Equation 3 is the production function of demand where $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is a multiplier and is known as the *Leontief inverse* $\boldsymbol{L}$, or total requirement matrix [44], and $\boldsymbol{y}$ is final demand vector. The Leontief inverse is assumed to be constant while final demand is an exogenous variable. In Leontief inverse, $\boldsymbol{I}$ is the identity matrix and $\boldsymbol{A}$ is the technical coefficient matrix. In (Eq, 18), $\boldsymbol{x}$ represents gross production for each sector or industry in an economy to satisfy the final demand $\boldsymbol{y}$**.** In other words, it measures the amount by which sector i needs to change its production to satisfy the change in one unit of the final demand from j.

To study the impact of change in a specific industry over other industries, value-added, and output, the change or shock that is subject to analysis captured in $\Delta\boldsymbol{y}$ vector. The effect of shock can be calculated in (eq. 19).

$$\Delta\boldsymbol{x} = \boldsymbol{L} \, \Delta\boldsymbol{y} \qquad (19)$$

3.3.5 Agent-Based Modelling:

Definition of Agents:

In an ABM, agents are the individual entities that constitute the system being modeled. There are 3 types of agents in the IOX-ABM:

i. Employed agents that work in the different sectors of the goods and services industries in Newfoundland & Labrador.
ii. Unemployed agents that are part of the labour market in the NL, who do not currently work but are part or the economically active population (EAP) in the Newfoundland & Labrador.
iii. Agents that are not part of the labour market/EAP of NL, but that could be part of the labour market and the EAP of NL (international immigrants, returning Canadians, out-migrants, and in-migrants from other provinces of Canada).

Figure 9 shows the flowchart of the IOX-ABM simulations, in which the I-O model extended with econometric models (IOX model) of the IOX model affect the ABM simulations in Newfoundland and Labrador: the results about employment, valued added and labor income obtained from the IOX model are inputs that the agents use to decide about working and migrating. The structure of the labor market (the composition of employment in the goods sector and the services sector) influence employment, and the age-structure affects the decision of migrating since younger agent have a higher probability and less restrictions to migrate. Unemployment agents in particular have a higher chance of migrating. The results that the ABM agents follow are detailed below.

ABM Rules:

ABM rules are rules that govern how agents interact with each other and respond to changes in the environment. There are 3 types of rules in the IOX-ABM:

i. Work Rules: for the unemployed agents that are part of the labour market in the NL, who do not currently work but are part or the economically active population (EAP) in Newfoundland & Labrador.
ii. Migration Rules: for the agents that are part of the EAP of NL who are unemployed and for agent that could be part of the EAP of NL (international immigrants, returning Canadians, out-migrants, and in-migrants from other provinces of Canada).

ABM Environment:

The environment is the space in which the agents operate and interact with each other. In the case of IOX-ABM, the environment is NL, specifically, the socio-economic environment in NL, including the labour market conditions.

ABM Emergent Behaviour:

In an ABM, emergent behavior of agents arises due to the collective results obtained from the individual actions of agents regarding the decision to employment and migration as results of shocks, specifically economic situation changes due to implementation of different policy scenarios from IOX model. Influence on emergent aggregate behavior are decision rules made by each individual agent for every simulation, and thus influenced by changes in wages per sector, GDP and its growth pattern, number of unemployment for each policy scenario, tendency to work in each sector and tendency to migrate based on age.

ABM Verification and Validation:

The IOX-ABM will be validated and verified to ensure that the IOX-ABM is reliable. In ABM, verification implies guarantying that the model is functioning correctly, while validation implies testing that the model and its simulations accurately represent the real-world conditions in NL:

- Verification checks were performed to check that the computational algorithms and the programming code of the IOX-ABM are correct and free of errors.
- Validation of the IOX-ABM was performed by comparing the simulation results of the IOX-ABM against real data in the observed baseline of employment and migration in NL. The results of the IOX-ABM simulations should be like the baseline scenario if the IOX-ABM is properly calibrated.

The mechanics of the IOX-ABM model:

1) *IOX results*: Changes in the production of oil and oil prices impact on value added and employment in NL. This impact is calculated with the IOX model (the input-output model extended with econometric regressions).
2) *Connection of the IOX model with the ABM model*: the results of the IOX model that are the input of the ABM model are: the total impact value added in 2018, the impact on employment by sector in 2018, the changes of labor income in the goods sector in 2018, and the changes of labor income in the service sector in 2018.
3) *Inputs of the ABM simulations*: The changes in value added from the IOX model are used to calculate the impact (decrease or increase) in GDP (GDP growth). The changes in labor income and the impact on employment by sector in 2018 obtained with the IOX model are used to calculate the decrease or increase in unemployment produced by the changes in the ABM environment (this is, the changes in employment in the sectors of the labour market and the changes in economic activity calculated with the IOX model).
4) *Behavior of unemployed agents*: The decision to work with unemployed agents depends on the changes in labor income (salaries) obtained from the IOX model. There are two types of unemployed agents: agents that look for a job in the good sector and agents that look for a job in the service sector. The decision to work for agents is a function of the salaries: when the salaries are higher, more agents are stimulated to work. The aggregates the emergent behavior of agents—this is, the decision of working of each agent— with the aim of calculating the overall increase in employment produced by a positive shock (an increase of oil prices and change in production) that stimulates the labor market in Newfoundland & Labrador, both in the goods sector and the service sector.
5) *Migration patterns*: The migration decisions of agents in the IOX-ABM simulations are modeled. The decision to migrate agents depends on the changes in employment,

expected salaries, and the age of the agents. Younger agents (aged 15 to 44 years old) have a higher tendency to migrate compared to older agents (aged 45 to 64 years old), and the tendency to migrate increases with the expected salary. Not all young agents decide to migrate, and not all older agents decide to not migrate. This arises because migration depends upon the individual decision of each agent in the ABM simulations, which is affected also by the salary that each agent expects to receive. The model simulates the behavior of inter-provincial in-migrants (agents that decide to migrate to NL from other provinces of Canada), international immigrants (agents that decide to migrate to NL from other countries) and returning Canadians (Canadians that decide to return to NL from other countries).

The model simulates the behavior of agents that decide to migrate from NL to go to other provinces (out-migration) or to other countries (emigration). The decision of agents to migrate outside NL depends upon their age (younger agents, aged 15 to 44 years old, have a higher tendency to migrate compared to older agents, aged 45 to 64 years old) and the expected economic situation inside NL, as compared to the situation in NL. Again, it is important to highlight that not all young agents decide to migrate, and not all older agents decide to not migrate since this decision is taken by each individual agent depending on the economic situation expected by each agent in other provinces of Canada (other than NL) or in other countries.

6) *Dynamic behavior*: The dynamic behavior of agents (the changes across time, until 2030) is captured by running the ABM functions with the rules of employment and migration each year, depending on the changes in the labor force composition (employment and unemployment) in the previous year, for each year until the year 2030.

Formally, in the rules of the ABM simulation, an agent $i = 1,2, \dots, N$ chooses a particular sub-action A (working or migration) when their utility $\mathcal{U}$ is above a utility threshold τ:

$$\text{If}\, \mathcal{U} > \tau \; (A_i = True \;\; \text{else} \;\; A_i = False) \tag{20}$$

In the case of unemployed agents, when there is a positive shock to the economy that increases the demand of employment, unemployed agents decide to work if the utility they obtain from working $\mathcal{U}_w$ is higher than the utility threshold τ_w:

$$Working_i = \begin{cases} True, & \mathcal{U}_w > \tau_w \\ False, & \mathcal{U}_w \leq \tau_w \end{cases} \tag{21}$$

In the MatLab implementation, this decision is expressed as a binary outcome of working w_i for each agent $i = 1,2, \dots, N_w$:

$$w_i = \begin{cases} 1, & \mathcal{U}_w > \tau_w \\ 0, & \mathcal{U}_w \leq \tau_w \end{cases} \tag{22}$$

And hence the total number of agents that were unemployed but decide to work is obtained by adding the decision of each agent: $W = \sum_{i=1}^{N_w} w_i$. Note that the total number of agents that decide to work W changes from simulation to simulation.

$$W_1, W_2, \dots, W_S$$

and hence the average results across multiple simulations are used to summarize the results of the ABM simulations:

$$\bar{W} = \frac{1}{S}\sum_{s=1}^{S} W_s \tag{23}$$

In the case of migration (from other countries/provinces to Newfoundland & Labrador, or from NL to other countries and provinces), agents decide to migrate if the utility they obtain from migrating $\mathcal{U}_m$ is higher than the utility threshold τ_m:

$$Migrating_i = \begin{cases} True, & \mathcal{U}_m > \tau_m \\ False, & \mathcal{U}_m \leq \tau_m \end{cases} \tag{24}$$

In the MatLab implementation, this decision is expressed as a binary outcome of migrating m_i for each agent $i = 1,2, \dots, N_m$:

$$m_i = \begin{cases} 1, & \mathcal{U}_m > \tau_m \\ 0, & \mathcal{U}_m \leq \tau_m \end{cases} \tag{25}$$

The total number of agents that migrate is obtained by adding the decision of each agent with $M = \sum_{i=1}^{N_m} m_i$. Note that the total number of agents that decided to migrate also changes from simulation to simulation: $M_1, M_2, \dots, M_S$, and hence the average results across multiple simulations are used to summarize the results of the ABM simulations:

$$\bar{M} = \frac{1}{S}\sum_{s=1}^{S} M_s \tag{26}$$

The threshold utility is equal to a continuous uniform distribution with a support between zero and one, $\tau_m \sim U(0,1)$, $\tau_w \sim U(0,1)$. The reason is epistemological since we do not have information to properly calibrate the parameters and the form of the distribution function of the utility of households in NL, we are taking what is called "the Laplace uncertainty principle": in case of uncertainty, we assign the same probability to all potential utility thresholds (hence, a uniform distribution, uniform probability to all potential thresholds). The choice of the distribution function for the utility function can be refined with household information at microlevel if this information is available. The utility of working, in turn, follows a continuous concave (beta) distribution, that is different for workers from the goods sectors and workers from the service sector. The support of the beta distribution is between 0 and 1 (just as the uniform distribution), but in contrast to the uniform distribution, the beta distribution is a flexible distribution that changes it shape and probability concentration depending on its parameters. We know, for example, that the utility of working is not uniform, but it is rather concentrated towards a positive value close to one for certain age groups and depending on the situation of the labor market, as in the presence of higher salaries or more economic opportunities people will be more willing to work, and hence the beta distribution will reflect this change by concentrating its density closest to 1 (above the utility threshold). However, not all agents decide to work, as some of them will decide that the conditions are not good enough (a situation below the utility threshold) and they may decide to migrate to other regions looking for work instead of working in NL, for example. The beta distribution reflects these changes in the utility of working depending on the changing economic environment. The beta-utility is a function of salaries in the goods sectors ω_{gs} and the salaries in the services sector ω_{ss}, as well as the tendency for working in the good sector κ_{gs} or in the service sector κ_{ss}, which a different utility for workers in the goods sector ($\mathcal{U}_{w,gs}$) and workers in the service sector ($\mathcal{U}_{w,ss}$). In the case of the good sector:

$$\mathcal{U}_{w,gs} \coloneqq \mathcal{B}(\omega_{gs}, \kappa_{gs}) = \frac{i^{\omega_{gs}-1}(1-i)^{\kappa_{gs}-1}}{\int_0^1 u^{\omega_{gs}-1}(1-u)^{\kappa_{gs}-1}du} \tag{27}$$

and hence the workers in the good sector are:

$$w_{i,gs} = \begin{cases} 1 \; if \;\; \dfrac{i^{\omega_{gs}-1}(1-i)^{\kappa_{gs}-1}}{\int_0^1 u^{\omega_{gs}-1}(1-u)^{\kappa_{gs}-1}du} > \tau_{w,gs} \\ 0 \;\; if \;\; \dfrac{i^{\omega_{gs}-1}(1-i)^{\kappa_{gs}-1}}{\int_0^1 u^{\omega_{gs}-1}(1-u)^{\kappa_{gs}-1}du} \leq \tau_{w,gs} \end{cases} \tag{28}$$

The total number of agents that were unemployed but decide to work in the goods sector is obtained by adding the decision of each agent: $W_{gs} = \sum_{i=1}^{N_{w,gs}} w_{i,gs}$. In the case of the service sector, the decision of each agent depends on the wages in the services sector ω_{ss} and the tendency for working in the service sector κ_{ss}:

$$w_{i,ss} = \begin{cases} 1 \; if \;\; \dfrac{i^{\omega_{ss}-1}(1-i)^{\kappa_{ss}-1}}{\int_0^1 u^{\omega_{ss}-1}(1-u)^{\kappa_{ss}-1}du} > \tau_{w,ss} \\ 0 \;\; if \;\; \dfrac{i^{\omega_{ss}-1}(1-i)^{\kappa_{ss}-1}}{\int_0^1 u^{\omega_{ss}-1}(1-u)^{\kappa_{ss}-1}du} \leq \tau_{w,ss} \end{cases} \tag{29}$$

The total number of agents that were unemployed but decide to work in the service sector is obtained by adding the decision of each agent: $W_{ss} = \sum_{i=1}^{N_{w,ss}} w_{i,ss}$. Finally, the total number of agents that decide to work after the positive economic shock (the total added employment) is equal to the number of agents that decided to work in the goods sector plus the total number of agents that decided to work in the service sector:

$$employment = \sum_{i=1}^{N_{w,gs}} w_{i,gs} + \sum_{i=1}^{N_{w,ss}} w_{i,ss} \quad (30)$$

In the next time period (next year) of the simulation, this number of employed people is reduced from the stock of unemployment. The salaries in the goods sector ω_{gs} and the salaries in the services sector ω_{ss} are obtained from the results of the Input-Output model, and hence change every time there is a shock in oil prices and changes in the production of the oil. In the case of the tendency for working in the good sector κ_{gs} or in the service sector κ_{ss}, it was assumed that $\kappa_{gs} < \kappa_{ss}$, this is, in general agents have higher tendency to work in the service sector compared to the goods sector (due to the large proportion of services sector employees in NL). The values of κ_{gs} and κ_{ss} were obtained by calibration to the base scenario.

In the case of migration, as argued by the Harris-Todaro theory [138], [139] individuals take their decisions of migrating or not by considering expected wages. As in these modern agent-based models for migration, not only wages affect the decision to migrate but also the social environment. This arises since individuals are also affected in the reference group in which they are included, in this case their age-group, since younger agents have less family ties and a higher propensity to migrate compared to older agents. Hence, the migration of the workers is interpreted as a process of social learning by imitation, formalized by a mathematical/computational model in [140]. Specifically, the utility to migrate to NL from other countries and other provinces of Canada is a function of the expected salary and the constraints/stimuli to migrate from their reference social group. In this research, we segregate the migrants into the following categories:

- **Inmigrants**: people that moved to NL from other regions of Canada (interprovincial migration).
- **Immigrants**: people that moved to NL from other countries (international migration)
- **Returning Canadians (returning emigrants):** Canadian nationals that went abroad (to other country) but decided to return to NL.
- **Outmigration:** people that moved to other regions of Canada from NL (interprovincial migration.
- **Emigrants**: people that moved to other countries from NL (international migration)

In the case of migration, the utility to migrate to NL from other countries and other provinces of Canada is a function of the expected salary and the constraints to migrate (such as family constraints):

$$\mathcal{U}_{m,in} \coloneqq \mathcal{B}(\omega_e, \kappa_{in}) = \frac{i^{\omega_e - 1}(1-i)^{\kappa_{in}-1}}{\int_0^1 u^{\omega_e - 1}(1-u)^{\kappa_{in}-1} du} \quad (31)$$

Agents will decide to migrate (in-migration or immigration) if the utility of migrating is higher than the utility threshold $\tau_{m,in}$

$$m_{i,in} = \begin{cases} 1\ if\ \dfrac{i^{\omega_e - 1}(1-i)^{\kappa_{in}-1}}{\int_0^1 u^{\omega_e - 1}(1-u)^{\kappa_{in}-1} du} > \tau_{m,in} \\ 0\ \ if\ \dfrac{i^{\omega_e - 1}(1-i)^{\kappa_{in}-1}}{\int_0^1 u^{\omega_e - 1}(1-u)^{\kappa_{in}-1} du} \leq \tau_{m,in} \end{cases} \quad (32)$$

And the utility of migrating is of course higher when the expected salaries ω_e are higher and when there are less constraints to κ_{in} to migrate, from the social reference group. The use of probabilistic rules—called stochastic rules in the agent-based model of [141] — allow us to ground the agent decision rules in a framework of subjective expected utility theory. Due to a lack of household survey information to properly model the family and social situation of each agent in the MatLab implementation of the ABM simulations, it is assumed that younger agents (aged 15 to 44 years) have less constraints to migrate compared to older agents (aged 45 to 64+ years). The total number of agents that decide to migrate equal to the number of younger agents that decided to migrate plus the total number of older agents that decided to migrate:

$$inmigration = \sum_{i=1}^{N_{in,15to44}} m_{in,15to44} + \sum_{i=1}^{N_{in,45to64}} m_{in,45to64} \quad (33)$$

$$immigration = \sum_{i=1}^{N_{im,15to44}} m_{im,15to44} + \sum_{i=1}^{N_{im,45to64}} m_{im,45to64} \quad (34)$$

$$returning\ canadians = \sum_{i=1}^{N_{rc,15to44}} m_{rc,15to44} + \sum_{i=1}^{N_{rc,45to64}} m_{rc,45to64} \quad (35)$$

In the case of out-migration and emigration from NL to other provinces of Canada or to other countries, respectively, the decision of agents depends on the expected economic situation inside NL and the constraints to migrate, and as before in the MatLab implementation of the ABM simulations it is assumed that younger agents (aged 15 to 44 years) have less constraints to migrate outside NL compared to older agents (aged 45 to 64+ years). The total number of agents that decide to migrate outside of NL is equal to the number of younger agents that decided to migrate plus the total number of older agents that decided to migrate:

$$emigration = \sum_{i=1}^{N_{em,15to64}} m_{em,15to44} + \sum_{i=1}^{N_{em,45to64}} m_{em,45to64} \quad (36)$$

$$outmigration = \sum_{i=1}^{N_{out,15to44}} m_{out,15to44} + \sum_{i=1}^{N_{out,45to64}} m_{out,45to64} \quad (37)$$

Note that, as before, the number of agents that decide to migrate will change from simulation to simulation, because agents learn and adapt their rules to the changing environment based on stochastic (probabilistic) decisions, as in the agent-based modelling described in [141]. The adaptative rules of the ABM simulations consider the employment and unemployment of the previous year when considering the employment and unemployment in the current year. This dynamic adaptative learning process is similar to the AR(1) adaptative learning process in the sense that is based on the information of one-period before when computing the results of the simulations. AR(1) is an Auto-Regressive model of order 1, this means, with one lag. Mathematically, let y_t be a time series variable, the equation of an AR(1) model is:

$$y_t = \theta y_{t-1} + \varepsilon_t \tag{38}$$

Where y_{t-1} is the lag one. This model is usually estimated with maximum likelihood.

In the case of GDP, uncertainty is included in the estimations for each time step $t + 1, t + 2,..., t + k$ for the k years simulated/forecasted. This uncertainty reflects the fact that as the time horizon progresses, more uncertainty exists about the future economic situation of a region and a country. In the case of the IOX-ABM, this uncertainty is reflected in a shock u_t that affects the rate of GDP growth g_t:

$$\breve{g}_t = g_t u_t^{-1} \tag{39}$$

where u_t is a random shock (a stochastic process) that follows an integer random distribution:

$$u_t \sim \mathcal{U}\big(l + (tl + d)\big) \tag{40}$$

being l a lower bound and $tl + d$ is an upper bound that depends on (and increases with) time t, for each time step $t + 1, t + 2,..., t + k$ for the k years simulated/forecasted. The justification of the rationality of this equation is to include the uncertainty about the economic conditions as the simulations move on the future time horizon.

The calibration by history matching (HM), this approach is explained by authors in [142] and involves running the model with different parameters and testing, for each case, how well the model performs by comparing the output of the model against empirical (historical) data in order to find parameter sets that minimize the model's error and can be used to provide a range of predictions or analyses. The history-matching approach constrains parameters, interactions, and decision rules in the model in line with the specific, empirically observable history of a particular industry [143]. As authors in [144] highlight, if model discrepancy is not accounted for in calibration, then the model results will reflect the uncertainty in the estimated parameters, rather than representing the meaningful quantities that the model seeks to simulate.

Figure 16 shows the Economically Active Population (EAP) and the population employed in the goods sector and in the services sector of Newfoundland & Labrador, from 1997 to 2021.

Econometric models (Vector autoregressions estimated with Bayesian methods) were used to forecast the trends of migration and the trends of the employed population up to the year 2030. Vector autoregressions (VARs) are a statistical model used in econometrics to analyze the relationships between multiple time series variables. VARs are models that capture the dynamic interrelationships among a set of variables over time, in this case, the dynamic interrelationship between the EAP and the employed population in NL. Let y_{1t} be a variable that represents the dynamics of the unemployed population across time t (years) and let y_{2t} be the employed population. In general, let y_{kt} be the $1,2,\dots,k$ variables that represent the strata of the EAP. These variables can be expressed in a vector $\mathbf{y}$:

$$\mathbf{y}_{\boldsymbol{t}} = [y_{1t} \quad y_{2t} \quad \cdots \quad y_{kt}]' \tag{41}$$

A vector autoregression (VAR) is an econometric model that exploits the fact that the variables $y_{1t}, y_{2t}, \dots, y_{kt}$ are correlated with each other and models the relationship between these variables a system of equations (since, for example, it could be expected that an increase in employment leads to a reduction in unemployment, but not necessarily in the same proportion, as other persons from the EAP may join at the same time the unemployment population). A VAR with one lag can be expressed mathematically as:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{kt} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_k \end{bmatrix} + \begin{bmatrix} \phi_{11} & \phi_{12} & \cdots & \phi_{1k} \\ \phi_{21} & \phi_{22} & \cdots & \phi_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \phi_{k1} & \phi_{k2} & \cdots & \phi_{kk} \end{bmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ \vdots \\ y_{kt-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{kt} \end{bmatrix} \tag{42}$$

Or in vector/matrix form as:

$$\mathbf{y}_{\boldsymbol{t}} = \mathbf{c} + \boldsymbol{\Phi}_{\mathbf{1}} \mathbf{y}_{\boldsymbol{t-1}} + \boldsymbol{\varepsilon}_{\boldsymbol{t}} \tag{43}$$

Where $\mathbf{c}$ is a vector of intercept terms, $\boldsymbol{\Phi}_1$ is matrix of parameters that measure the influence of the autoregressive terms $\mathbf{y}_{t-1}$, and $\boldsymbol{\varepsilon}_t$ is an error term that follows a multivariate Gaussian distribution:

$$\mathbf{c} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_k \end{bmatrix}, \qquad \boldsymbol{\Phi}_1 = \begin{bmatrix} \phi_{11} & \phi_{12} & \cdots & \phi_{1k} \\ \phi_{21} & \phi_{22} & \cdots & \phi_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \phi_{k1} & \phi_{k2} & \cdots & \phi_{kk} \end{bmatrix}, \qquad \boldsymbol{\varepsilon}_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{kt} \end{bmatrix} \tag{44}$$

As in other autoregressive models, additional lags $1,2,\dots,p$ can be added to the VAR(1) model to make a VAR(p) that captures how the dynamics of previous years $1,2,\dots,p$ affect the current situation of the variables:

$$\mathbf{y}_t = \mathbf{c} + \boldsymbol{\Phi}_1 \mathbf{y}_{t-1} + \boldsymbol{\Phi}_2 \mathbf{y}_{t-2} + \cdots + \boldsymbol{\Phi}_p \mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t \tag{45}$$

These VAR(p) models were estimated to produce forecasts of the baselines in the IOX-ABM simulations. With Bayesian estimates of the parameters $\hat{\mathbf{c}}, \widehat{\boldsymbol{\Phi}}_1, \widehat{\boldsymbol{\Phi}}_2, \ldots, \widehat{\boldsymbol{\Phi}}_p$ obtained after fitting the model to observed historical data, baseline forecasts up to the horizon year h can be calculated with:

$$\mathbf{y}_{t+h} = \hat{\mathbf{c}} + \widehat{\boldsymbol{\Phi}}_1 \mathbf{y}_{t+h-1} + \widehat{\boldsymbol{\Phi}}_2 \mathbf{y}_{t+h-2} + \cdots + \widehat{\boldsymbol{\Phi}}_p \mathbf{y}_{t+h-p} \quad (46)$$

In Figure 16, for example the forecasted EPA is displayed with a dashed red line from 2022 up to the year 2030, while the forecasts of employment from 2022 to 2030 are displayed as light color bars. These forecasted trends will be used as the baseline scenario to be compared with the results of the ABM simulations later in Figure 33 onwards. The comparison of the simulations obtained with the IOX-ABM against the baseline scenario will be used to estimate the impact that changes in oil prices and changes in oil production have on employment over time until the year 2030.

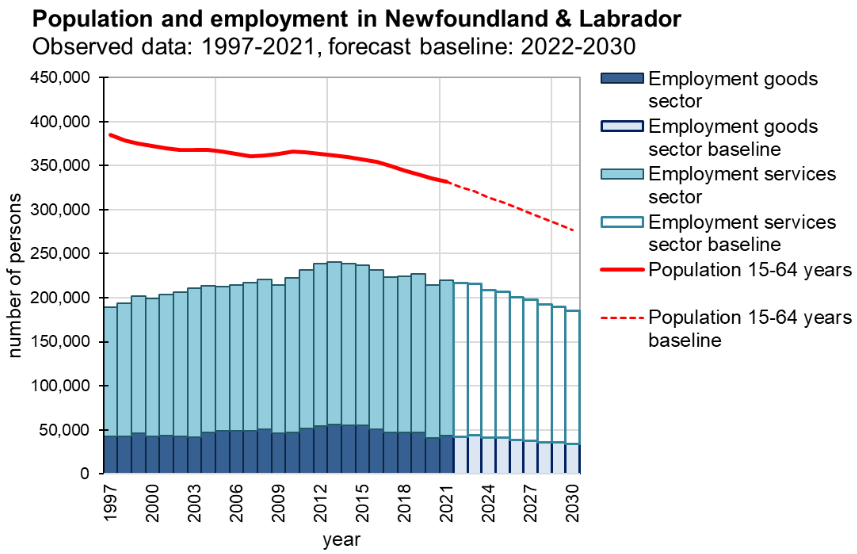


Figure 16: Economically active population (EAP), employment and forecasted baseline of EAP and forecasted baseline of employment in Newfoundland & Labrador

Figure 17 shows the labor force, employment, and unemployment trends in NL since 1976, as well as the baseline forecasts until 2030, that were obtained with VAR models. Figure 18 complements the information with the unemployment rate and shows that the unemployment rate of NL is the highest when compared to the other provinces in Canada. The historical information of employment and unemployment were used to create baseline scenarios until 2030, that are compared with the results of the ABM simulations. Figure 19 also shows the information of salaries (average weekly wages in NL), from 1991 to 2022, and the forecasts that will be used as the baseline of the ABM simulations until 2030. An increase in labor income is observed in NL, since the year 2000, in both the goods producing sector and the service sector. The projected trends of labor income were used to update until 2030 the changes in labor income obtained with the Input-Output model, since the agents in the ABM simulations take decisions based on changes in expected salaries.

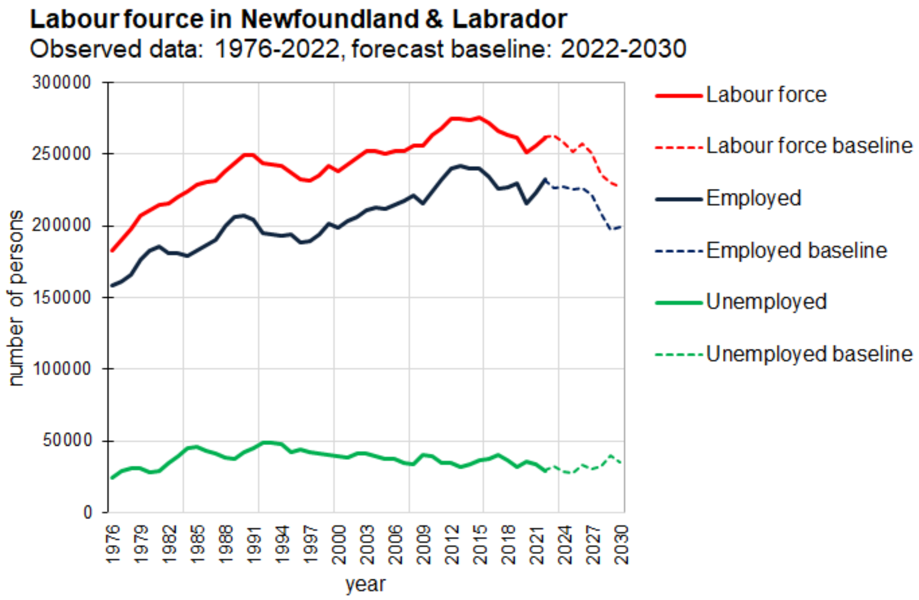


Figure 17: Labor force, employment, and unemployment in Newfoundland and Labrador

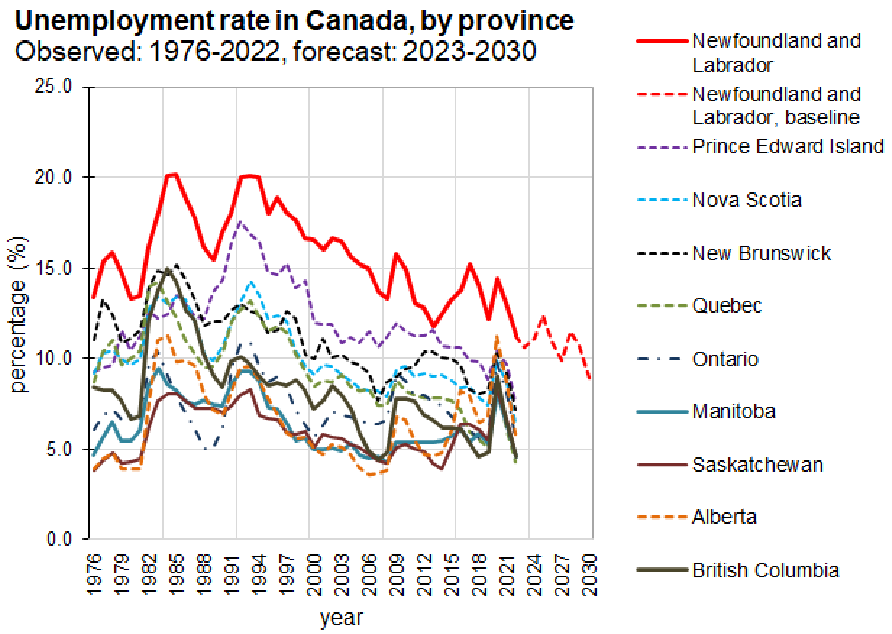


Figure 18: Unemployment rate in the provinces of Canada, by province, including Newfoundland & Labrador

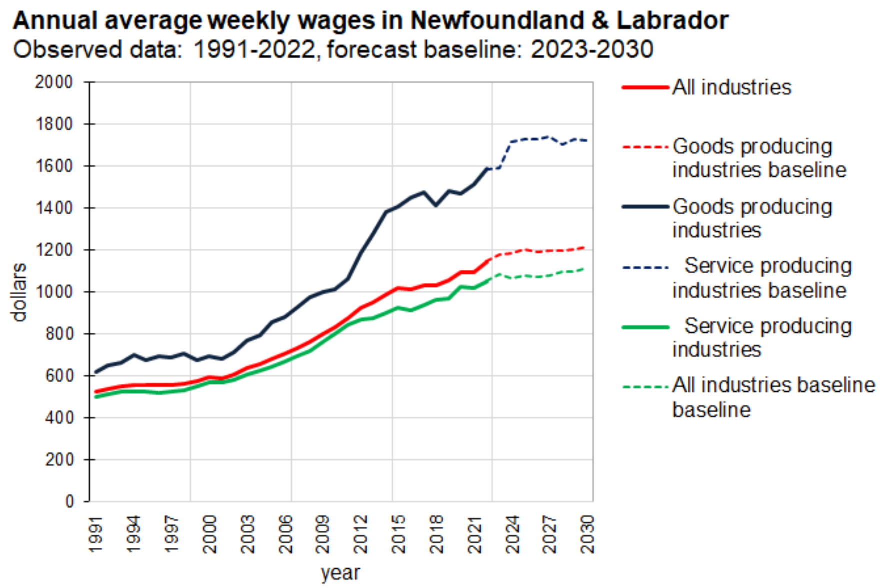


Figure 19: Average weekly wages in Newfoundland & Labrador

Figure 20 displays the information of international migration in NL, from the year 1972 up to the year 2021. The information includes the number of immigrants (the people that moved to NL from other countries), the emigrants (people who moved from NL to other countries), and the number of returning Canadians. The figure shows that net-migration was positive and has increased since the year 2020. That is, the number of immigrants is higher that the number of emigrants in NL. Based on the historical information of international migration in NL, econometric models (VARs) were used to forecast the trends of immigration, emigration and returning Canadians in NL. These forecasts are displayed as dotted lines in the figure. These forecasts will be used as a baseline against which the simulations of the IOX-ABM will be compared, with the goal of understanding the impact that shocks in oil prices and changes in production have on international migration in NL (immigrants and returning Canadians).

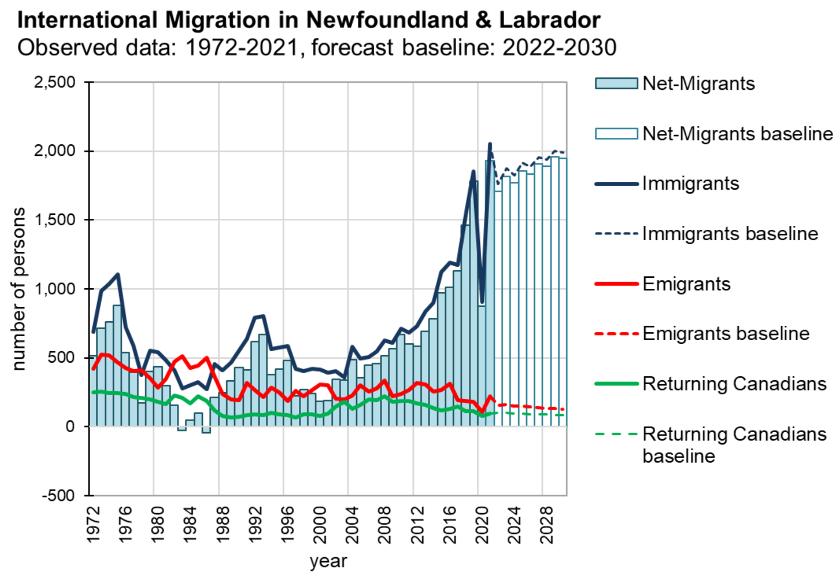


Figure 20: International migration and forecasted baseline of international migration in Newfoundland & Labrador

Figure 21 displays the historical information of interprovincial migration from NL to other provinces in Canada, from the year 1972 up to the year 2021. Net interprovincial migration has been in general negative in NL from 1972 to 2008, meaning that the number of out-migrants (people moving out to other provinces of Canada) was higher than the number of in-migrants (people moving into NL from other provinces of Canada). There have been less differences between the number of in-migrants and out-migrants in NL since the year 2008, and in the year 2021, the last year of information available, the number of in-migrants was higher to the number of out-migrants.

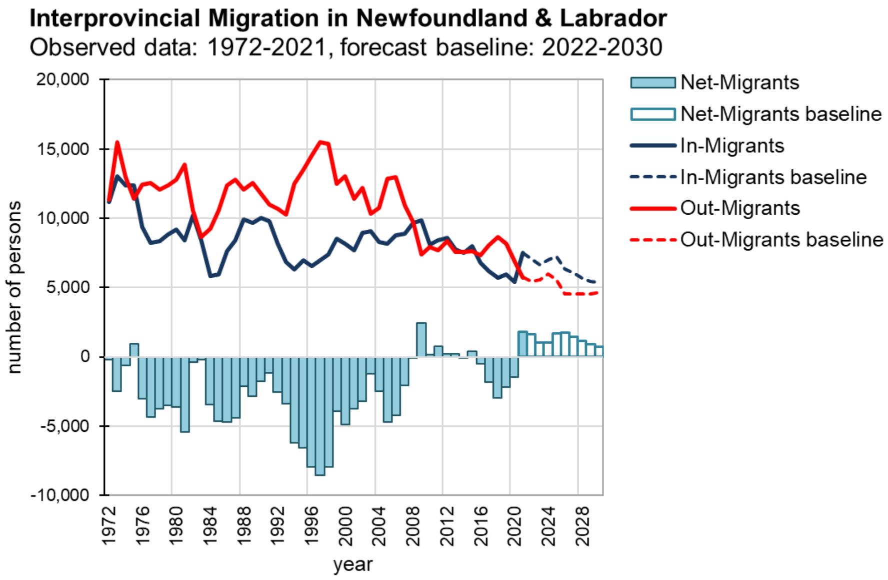


Figure 21: Interprovincial migration and forecasted baseline of interprovincial migration in Newfoundland & Labrador

Based on the historical information and the latest trends of interprovincial migration, econometric models (VARs) were estimated to forecast the trends of interprovincial migration in NL up to the year 2030. These forecasted trends are displayed as dashed lines in Figure 21. As in the case of the international migration, the forecasted trends of interprovincial migration in NL will be used as a baseline against which the simulations of the IOX-ABM will be compared, with the goal of approximating the impact that shocks in oil prices and changes in production have on migration in NL.

Finally, Figure 22 shows the age structure of the EAP in Newfoundland & Labrador (NL), from 1997 to 2022, and the baseline up to the year 2030 obtained with a moving average (MA) model applied to the historical age composition of the EPA in NL. A moving average model is a statistical model that calculates the averages of observations collected at regular intervals over time with a moving time window. The advantage of using moving averages to extrapolate population growth is that the age-composition of the population changes over time is preserved, as it remains adding to 100%, hence producing a congruent result for the years in which the agent-based model will be simulated, see the figure below how the MA produces extrapolations of population with coherent age structures.

Let for example be a_{1t} be equal to the average proportion of persons aged 15 to 19 years from the year 1997 up to the year 2022 ($T = 7$) :

$$a_{1t} = \frac{1}{T}(a_{1t-1} + a_{1t-2} + \cdots + a_{1t-T}) = \frac{1}{T}\sum_{t=1}^{T} a_{1t-i} \quad (47)$$

A similar model was applied for the composition of other age-groups (g):

$$\begin{gathered} a_{1t} = \frac{1}{T}(a_{1t-1} + a_{1t-2} + \cdots + a_{1t-T}) = \frac{1}{T}\sum_{t=1}^{T} a_{1t-i} \\ a_{2t} = \frac{1}{T}(a_{2t-1} + a_{2t-2} + \cdots + a_{2t-T}) = \frac{1}{T}\sum_{t=1}^{T} a_{2t-i} \\ \vdots \\ a_{gt} = \frac{1}{T}\left(a_{gt-1} + a_{gt-2} + \cdots + a_{gt-T}\right) = \frac{1}{T}\sum_{t=1}^{T} a_{gt-i} \end{gathered} \quad (48)$$

And forecasts up to a horizon h of the age composition in each group can be calculated based on the estimated moving averages:

$$
\begin{gathered}
a_{1t+h} = \frac{1}{T+h}(\hat{a}_{1t+h-1} + \hat{a}_{1t+h-2} + \cdots + \hat{a}_{1t+h-T}) = \frac{1}{T+h}\sum_{t=1}^{T} \hat{a}_{1t-i} \\
a_{2t+h} = \frac{1}{T+h}(\hat{a}_{2t+h-1} + \hat{a}_{2t+h-2} + \cdots + \hat{a}_{2t+h-T}) = \frac{1}{T+h}\sum_{t=1}^{T} \hat{a}_{2t+h-i} \\
\vdots \\
a_{gt+h} = \frac{1}{T+h}\left(\hat{a}_{gt+h-1} + \hat{a}_{gt+h-2} + \cdots + \hat{a}_{gt+h-T}\right) = \frac{1}{T+h}\sum_{t=1}^{T} \hat{a}_{gt-i}
\end{gathered}
\tag{49}
$$

The advantage of using moving averages to extrapolate the age-composition is that the baseline forecasted composition changes over time, but still sums to 100%, hence producing a congruent result for the years in which the IOX-ABM model will be simulated. Since there is a lack of information of the marital status of agents, the age composition is a proxy of the family situation of the agents, since it could be expected that younger agents have less dependents while older agents are expected to have more dependents (both children and elderly). The IOX-ABM model captures this idea by assigning a higher probability of migration to younger agents, compared to older agents, and assigning a lower probability of migration to older agents, compared to younger agents.

The results of the baseline extrapolation with moving average models are displayed in Figure 22. It shows an increase in the population in the stratum related to the retirement age (aged 55 to 64 years), which is not compensated with an increase of the young population (aged 15 to 29 years). It could be expected that younger individuals have a higher probability of migrating, compared to the elderly, and this information will be used to model the individual behavior of agents in the EPA and the labour market after a shock in oil prices and changes in the production of natural resources.

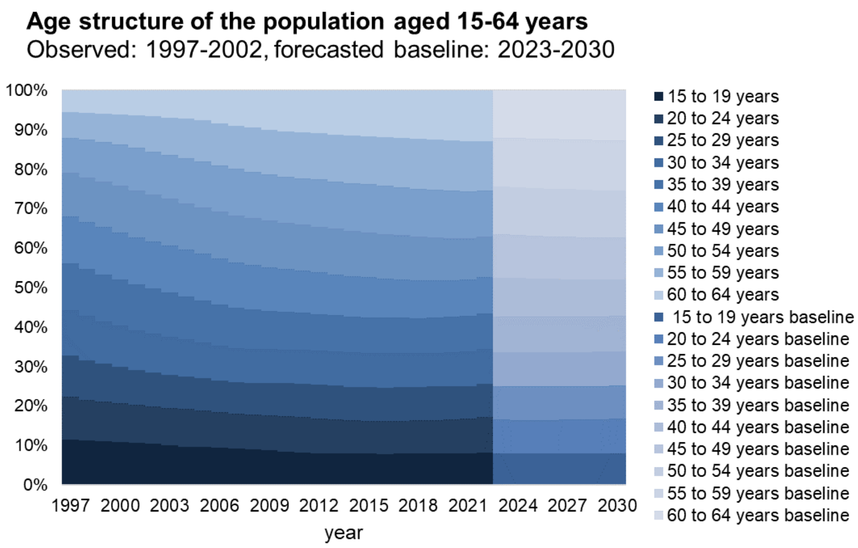


Figure 22: Age structure of the economically active population (EAP) aged 15-64 years in Newfoundland & Labrador: observed and baseline

The inputs to the ABM are shown in Figure 23, we use the forecasts above as input parameters to the IOXABM model to enforce the model follow the patterns. The input from IOX is number of employees which changes per policy scenario, wages per sector, and GDP. Only base scenario, no changes in oil price nor oil production reduction, is used to calibrate the ABM. The initial parameters for the model are presented in Appendix B. Due to the lack of household information, agents are influenced by the environment, thus economic situation. The decision rules are limited to the interaction with environment rather than among agents. However, the model's decision can be extended to include social influence, such as influence of household, friends, colleagues within same industry and cross industries, and neighbors. The number of simulations for each time step are 50, and the unit of time step is a year, analysis is for 13 years (from 2018 to 2030).

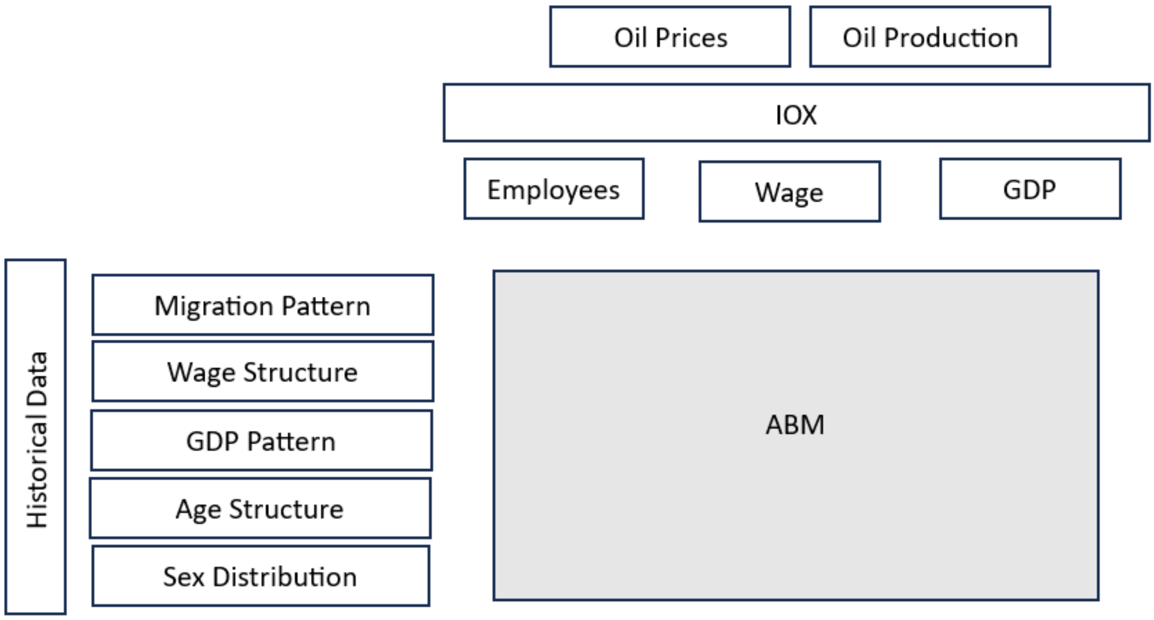


Figure 23: Inputs to ABM

Extensibility of the model is subject to the objective of the research, in this case, social influence would alter the emerged aggregate output. However, economic influence is major factor for policy scenarios impact analysis. As for the model scalability, the number of agents and complexity of the economy in term of number of industries play crucial role.

ABM is not equal to cellular automata (CA) simulations; both ABM and CA are computational modeling techniques. ABM represents a collection of individual entities, called agents, each of which has its own set of rules and behaviors. Cellular automata, on the other hand, is a discrete-time, discrete-space mathematical model of computation based on a grid of cells (that where the cellular name comes from), each of which can be in one of a finite number of states. The state of each cell in the grid is determined by a set of rules that define how the state of each cell changes over time. The key difference between ABM and CA is that ABM focuses on the behavior of individual entities within a system and their interactions, while CA focuses on the local interactions between cells in a grid. In the simulation model, there is no information of a grid that can be used to allocate the cells, and hence ABM was used as a preferred technique.

3.4 Summary:

This chapter detailed the proposed research methodology of linking three methodologies (econometric, input-output, and ABM). It highlighted each methodology individually, then explained the conceptual framework of linking them together. It also covered in details the model's equations, environment, rules, and data used for this research. It covers the socio-economic details of case-study used, Newfoundland and Labrador. In next chapter, we illustrate the empirical results of out research methodology.

Chapter 4: Empirical Results

This chapter provides the results of modelling and simulation.

4.1 NL Econometric Results:

Table 7 reveals the results of the first econometric model (Econometric Model 1), which models oil production as a function of international oil prices (WTI), US GDP, and the exchange rate of the Canadian Dollar to the US Dollar (CAD/USD). Before addressing the resultant coefficient estimate, it is important to note that the intercept value of 3.23 is positive but statistically insignificant (p-value = 0.90). This suggests that the shift in the model from the reported intercept based on the three included factors fluctuates, and that the coefficient estimates should be considered as relative to the intercept value. Looking at the coefficient estimates, the estimate of the elasticity of oil prices was 1.96, with a p-value of 0.06 (94% significance level). The positive relationship is as expected, indicating that oil production responds to oil prices. Interestingly, the coefficient of 1.96 suggests that oil production is heavily dependent on the price of oil, in that when the price of oil increases from say 50 CAD per barrel to 55 CAD per barrel – a 10 percent increase– one would expect production to rise 19.6 percent. There are, of course, some limits on the average relationship reported by this coefficient. Suppose oil prices went from 50 CAD to 150 CAD, an increase of 200 percent. This 200 percent increase would mean that production would be expected to rise 392 percent. Demand and supply considerations may dampen the regression coefficient in cases of such large changes.

The second estimated coefficient is US GDP. Surprisingly, both were statistically insignificant. Although insignificant (p-value of 0.84), the coefficient estimates on US GDP at 0.37 is consistent with the theory of demand, where internal production increases when external demand rises. The inclusion of US GDP also provides a valuable anchor in avoiding omitted variable bias and has strong theoretical underpinning. The result on the exchange rate, also statistically insignificant at a level above 90% (p-value 0.13), is important in that the result is close to statistical significance and the estimate is strongly positive at 4.87. The 4.87 value suggests that when the CAD to USD exchange rate rises by say 5 percent (meaning the CAD is losing value relative to the USD), oil production rises by 24.35 percent. This positive relationship is unsurprising, given that when the US Dollar gains value relative to the Canadian Dollar, once would expect demand to rise because purchasers in the US could purchase more oil for the same amount of US Dollars. The fact that the magnitude of the coefficient is so large may be concerning for some, but observers should keep in mind that exchange rates do not usually experience large swings in either direction over a short period of time.

Shifting to the overall model fit, the adjusted R-squared coefficient of 35% is reasonable, given the incredible volatility that oil production and prices can exhibit, and is actually quite realistic given the uncertainty present in this market. Interestingly, no evidence of serial correlation was found in the residuals, with a Ljung-Box Q serial correlation test of 0.12 (Q-stat) and a p-value of 0.73. There was also no evidence of heteroscedasticity, with an H-stat value of 0.88 and a p-value of 0.35. Also important, the results of the unit root tests and the Engle-Granger cointegration indicate that the variables of this first econometric model are integrated of order one and jointly cointegrated (the null of no cointegration in the Engle-Granger cointegration test was rejected at the 1% level, p-value = 0.0081), providing support to the quality of the estimate of the elasticity of oil prices in explaining oil production.

Table 7: Econometric Model 1

```
Estimated Coefficients:
                     Estimate      SE        tStat      pValue
                     ________    _______    _______    ________

    (Intercept)        3.2282     26.696    0.12092      0.9049
    log_Oilprices      1.9598    0.97456     2.0109    0.057348
    log_GDPUSA        0.36881     1.7995    0.20496     0.83958
    log_XrateUSD       4.8677     3.0555     1.5931     0.12608


Number of observations: 25, Error degrees of freedom: 21
Root Mean Squared Error: 0.748
R-squared: 0.428, Adjusted R-Squared: 0.346
F-statistic vs. constant model: 5.24, p-value = 0.0074

Engle-Granger cointegration test: EG-stat = -6.0932, p-value = 0.0081
Ljung-Box test of serial correlation: Q-stat = 0.1181, p-value = 0.7311
Test of heteroscedasticity: H-stat = 0.8735, p-value = 0.3500
```

Table 8 presents the second econometric model of oil exports as a function of oil production and US GDP. Overall, the estimated elasticities of both variables were found to be statistically significant at a level greater than 99% (p-value < 0.01). Both variables also exhibited the expected positive sign. On oil production, the coefficient of 0.57 indicates that when oil production rises by 10 percent, oil exports will rise by 5.7 percent. This is consistent with the operation of the oil industry, where oil prices are much more volatile than actual oil production and subsequent exports, due to the time it takes to plan production and transportation. On the relationship of oil exports with US GDP, the coefficient of 1.41 is somewhat surprising given that it indicates that when US GDP rises by say 5 percent, oil exports will rise by 7.1 percent. This is somewhat surprising in that one would think that, a priori, exports would rise by less than US GDP. The result may stem from other factors at play, such as the exchange rate between the two countries and the nature of the GDP growth in the US.

Shifting to the overall model performance, the adjusted R-squared coefficient was estimated at 69%, which indicates that around 69% of the variance in oil production can be related to oil prices and the changes in the oil demand of the USA. This is surprisingly high, given the nature of the oil industry generally. Shifting to the overall model fit, the measures suggest some caution in the contemporaneous model's fit with the sample data. First, the null hypothesis of no serial correlation in the residuals is close to being rejected at the 95 percent level (Ljung-Box Q test Q-stat of 0.0719 and a p-value of 0.7887). Second, the null hypothesis for the presence of heteroscedasticity fails to be rejected (H-stat of 0.0883, p-value = 0.7664).

Third, the results of the unit root test indicate that the variables are integrated of order one, and the null hypothesis of no cointegration in the Engle-Granger cointegration test was rejected at the 1% level (p-value = 0.0093), providing support to the quality of the estimate that oil exports are a function of oil production, which in turn is affected by oil prices.

Table 8: Econometric Model 2

```
Estimated Coefficients:
                         Estimate      SE        tStat       pValue
                         ________    _______    _______    __________

    (Intercept)          -24.701      6.0108    -4.1094    0.00050019
    log_Oilproduction    0.56557     0.13474     4.1975    0.00040521
    log_GDPUSA             1.413     0.40246     3.5109     0.0020783


Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.235
R-squared: 0.719, Adjusted R-Squared: 0.692
F-statistic vs. constant model: 26.8, p-value = 1.64e-06

Engle-Granger cointegration test: EG-stat = -5.0050, p-value = 0.0093
Ljung-Box test of serial correlation: Q-stat = 0.0719, p-value = 0.7887
Test of heteroscedasticity: H-stat = 0.0883, p-value = 0.7664
```

The third econometric model posited that employment is a function of NL GDP. Unsurprisingly, the estimated elasticity of the GDP NL is statistically significant with a p-value of less than 0.01. The positive sign of the coefficient at 0.34 is consistent with economic theory and the fact that the magnitude of the coefficient is less than one is also an encouraging finding. The 0.34 coefficient value indicates that an increase in economic activity in the province of Newfoundland & Labrador is associated with employment. The magnitude of this coefficient estimate is the most interesting finding, as it implies that employment is much less volatile than the sales-based GDP measure. This is what one would expect, as firms are generally slower to hire or fire workers than the business cycle of their sales would indicate. On the overall model fit, the values of the serial correlation test and the test of heteroscedasticity are equal to a Q-stat value of 14.223 (p-value = 0.001) and a H-stat of 5.3654 (p-value = 0.0205), respectively. The high H-stat value is concerning, in that it suggests that the model suffers from heteroskedasticity. This suggests that the next version of this model should include time-series lags in its construction. Regardless, the current version works well for the contemporaneous-intended use of the model. The adjusted R-squared coefficient of 0.58 indicates that the economic activity of the province of the NL region explains around 60% of the variance in the employment level of NL. The null of no cointegration in the Engle-Granger cointegration test can be rejected at the 10% but not at

5% level (p-value = 0.0977), providing marginal support to the cointegration between these variables.

Table 9: Econometric Model 3

```
Estimated Coefficients:
                   Estimate      SE       tStat      pValue
                   ________   ________   ______   __________

    (Intercept)     1.9274     0.61441   3.1369    0.0049803
    log_GDP_NL     0.33736    0.059813   5.6403   1.3444e-05


Number of observations: 23, Error degrees of freedom: 21
Root Mean Squared Error: 0.0355
R-squared: 0.602, Adjusted R-Squared: 0.583
F-statistic vs. constant model: 31.8, p-value = 1.34e-05

Engle-Granger cointegration test: EG-stay = -2.5454, p-value = 0.0977
Ljung-Box test of serial correlation: Q-stat = 14.223, p-value = 0.001
Test of heteroscedasticity: H-stat = 5.3654, p-value = 0.0205
```

4.2 NL Input-Output Model Results:

To capture the current economic activities of NL and the interdependencies of its industries, an input-output model is constructed. Then, the results area used to identify those industries that contribute greatly to NL economy. The supply and use tables are obtained from industry account division from *Statistics Canada* and are based on 2018 data. Table 10 shows the list of NL industries categorized according to Canadian Input-Output Industry Code, which in turn is built based on North America Industry Classification System (NAICS) [145].

Table 10: NL Industries

BS11A	Crop and animal production
BS113	Forestry and logging
BS114	Fishing, hunting and trapping
BS115	Support activities for agriculture and forestry
BS210	Mining, quarrying, and oil and gas extraction
BS220	Utilities
BS22A	Residential building construction
BS22B	Non-residential building construction
BS22C	Engineering construction
BS22D	Repair construction
BS22E	Other activities of the construction industry
BS3A0	Manufacturing
BS410	Wholesale trade
BS4A0	Retail trade
BS3B0	Transportation and warehousing

BS510	Information and cultural industries
BS4B0	Finance, insurance, real estate, rental and leasing and holding companies
BS53C	Owner occupied dwellings
BS540	Professional, scientific and technical services
BS560	Administrative and support, waste management and remediation services
BS610	Educational services
BS620	Health care and social assistance
BS710	Arts, entertainment and recreation
BS720	Accommodation and food services
BS810	Other services (except public administration)
FC100	Repair, maintenance and operating and office supplies
FC200	Advertising, promotion, meals, entertainment, and travel
FC300	Transportation margins
NP000	Non-profit institutions serving households
GS610	Government education services
GS620	Government health services
GS911	Other federal government services

From the Input-Output table, the production functions of each industry are formulated using equation 6. The bar chart in the figure below provides a snapshot of each industries contribution (gross production) to the NL economy. Natural resources related industries such as mining, quarrying, and oil and gas extraction, engineering constructions that are mostly associated with natural resources related projects, and manufacturing that are related to the refined petroleum, food processing, fabricated metal manufacturing, nickel processing and newsprint are the main players. This confirms the fact that NL economy heavily dependent on natural resources as main economic activities. Thus, the economy is prone to volatility of global market prices/demands.

Figure 24 shows the exports in the province of Newfoundland and Labrador, by industry, calculated with the I-O model without econometric extensions. These exports are expressed in millions of dollars. The main exports come from the industries related to mining, quarrying, and oil and gas extraction, and manufacturing.

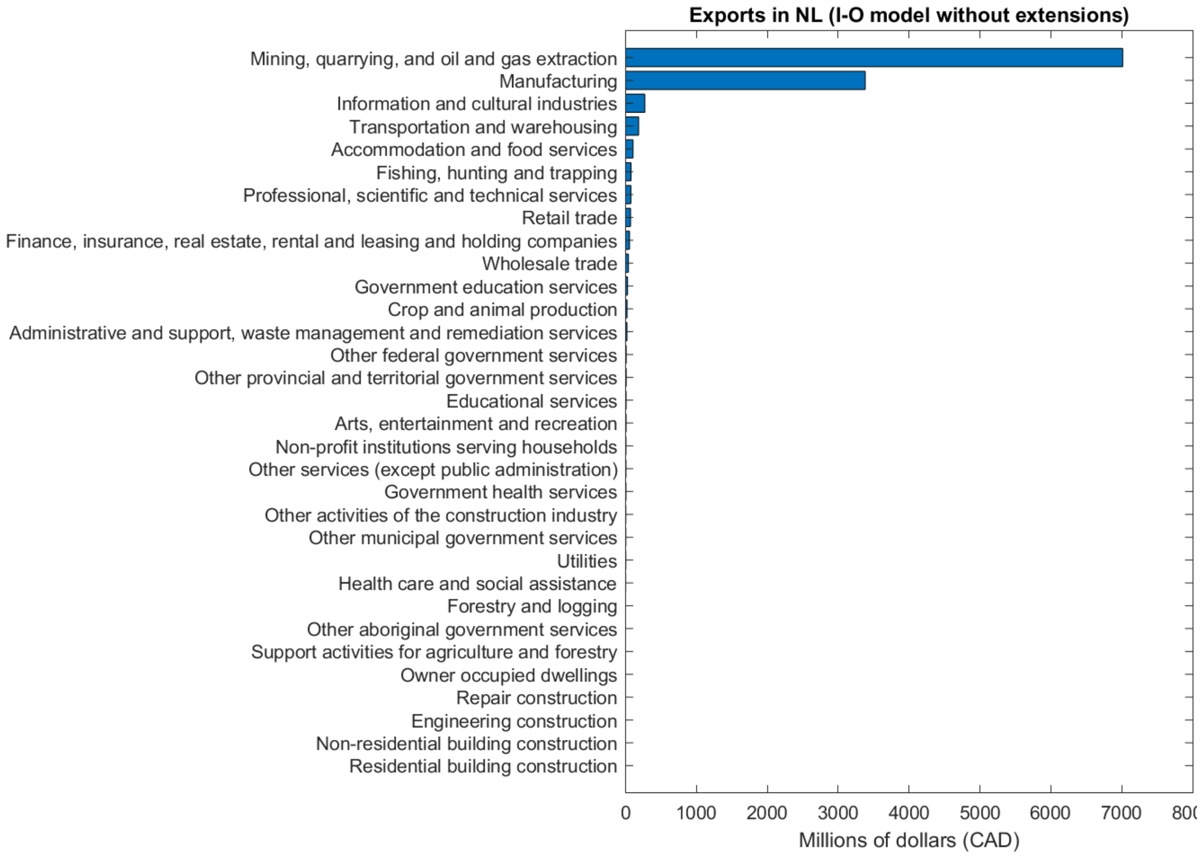


Figure 24: NL Export per Industry

Figure 25 and Figure 26 show the value added and the multipliers of value added in the year 2018 for the NL province. Mining, quarrying, and oil and gas extraction are the main industries producing value added in millions of dollars in NL, according to the estimates obtained with the I-O model calculated with data of the Supply and Use Tables of 2018. However, the value-added multipliers show that the highest multiplier by unit of CAD is produced by the manufacturing sector, revealing the importance of this industry in the goods-producing sector, besides the contributions of the financial services, mining, quarrying, and oil and gas extraction, transportation, professional and technical services, and retail trade sectors.

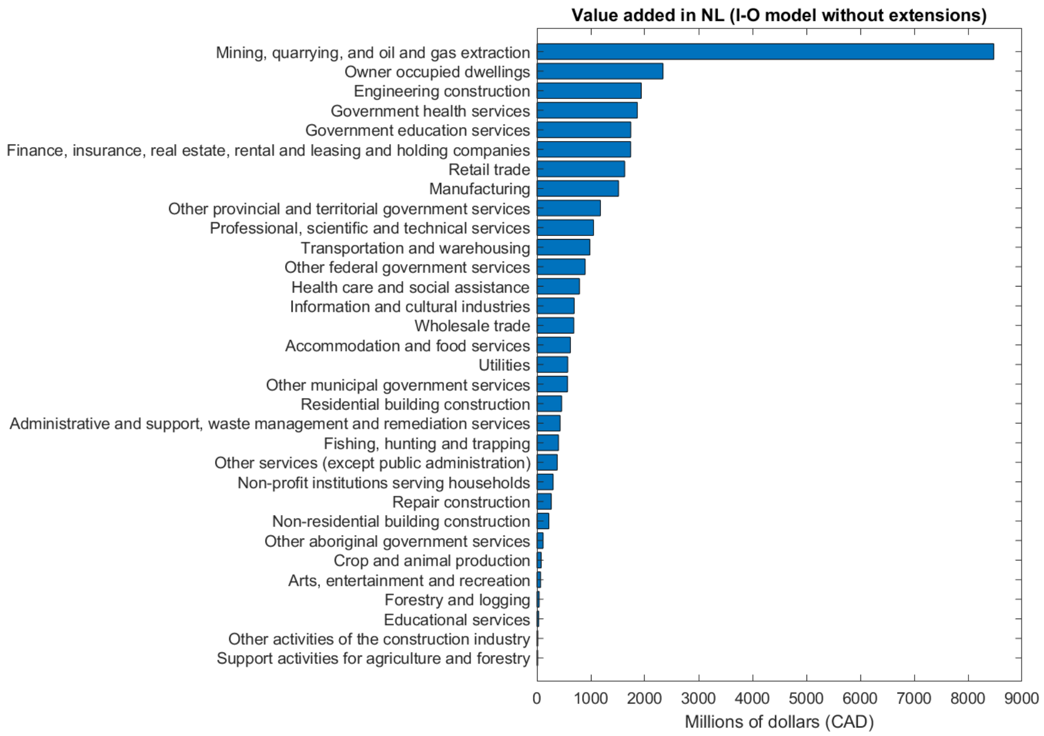


Figure 25: NL Value-Added per Industry

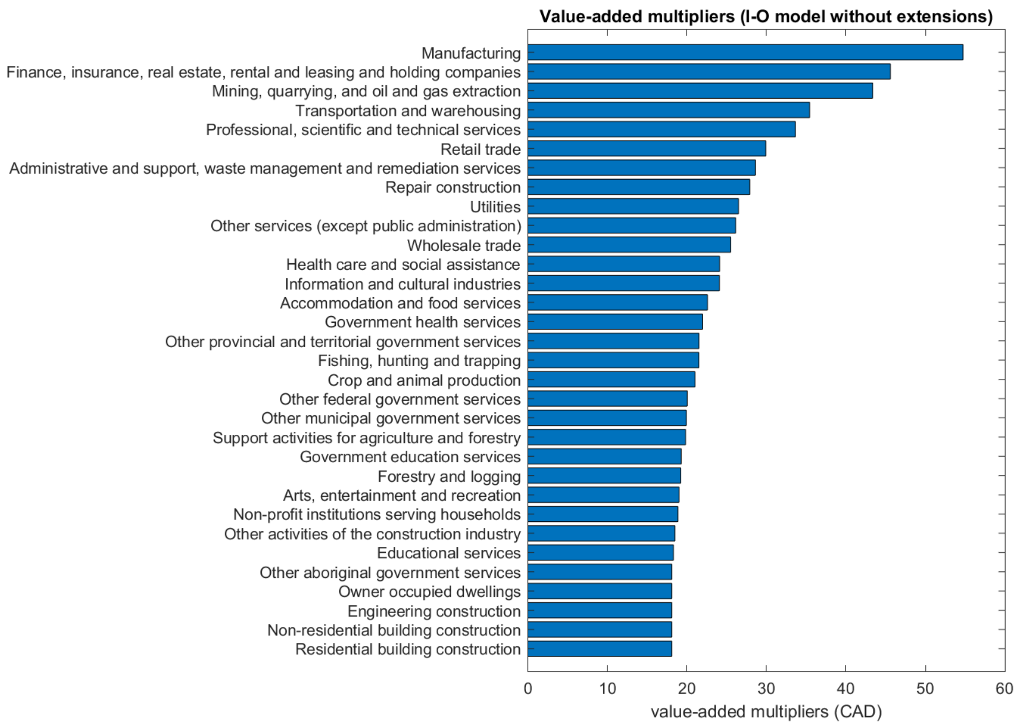


Figure 26: NL Value-Added Multiplier per Industry

4.3 NL Input-Output Model extended with Input-Output Model (IOX) Results:

The elasticities in the IOX model are estimated with the econometric models that were combined with the input-output model for the purpose of measuring how oil prices (expressed as USD per barrel) and changes in the production of oil production (in percentage) affect value added and employment in the province of NL.

In order to estimate elasticities in the econometric regressions, all variables are expressed in logarithms, such that the econometric regressions are estimated with the variables in natural logarithms: log(exports), log(production) and log(employment). However, when connecting the econometric models to the IO model, the information need not be expressed in logarithms of exports, production and employment. Hence, anti-logarithms—this is, the exponential of log(exports), log(production) and log(employment)—is applied to recover the values for exports, production, and employment. In the first econometric model, for example, the oil production is calculated with the anti-logarithm (the exponentiation with the Euler's number) of the logarithmic results obtained with the estimated elasticities $\hat{\alpha}_1$, $\hat{\alpha}_2$, $\hat{\alpha}_3$, $\hat{\alpha}_4$ and the variables of price GDP USA and the exchange rate expressed in logarithms:

$$\mathrm{Prod} = \exp\left(\hat{\alpha}_1 + \hat{\alpha}_2 \ln PRICE + \hat{\alpha}_3 \ln GDPUSA + \hat{\alpha}_4 \ln XRATEUSD\right) \quad (50)$$

Further, the total production is the result of the production and the changes in oil production, $\Delta\mathrm{Prod}$, is defined in the simulation scenarios of green growth and degrowth:

$$Production = \mathrm{Prod} + \Delta\mathrm{Prod} \quad (51)$$

Oil exports in turn are calculated using the conditional formula:

$$\mathrm{Exports} = \begin{cases} \exp\left(\hat{\beta}_1 + \hat{\beta}_2 \ln Production + \hat{\beta}_3 \ln GDPUSA\right) & \text{if} \quad \text{production} > 0 \\ 0 & \text{if} \quad \text{production} = 0 \end{cases} \quad (52)$$

where exports are equal to zero when there is no oil production, and when there is oil production, exports are equal to the anti-logarithm (the exponentiation) of the values estimated with the elasticities of the second econometric regression $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$. The variables of production and GDP USA are expressed in logarithms:

$$\mathrm{Exports} = \exp\left(\hat{\beta}_1 + \hat{\beta}_2 \ln(\mathrm{Prod} + \Delta\mathrm{Prod}) + \hat{\beta}_3 \ln GDPUSA\right) \quad (53)$$

where $\Delta\mathrm{Prod}$ is defined by the degrowth and green growth scenarios and Prod is affected by oil prices through the first econometric regression. The anti-logarithms (exponentiation) is applied to recover the values of exports in monetary units instead of logarithms, since the variables of the I-O model are expressed in monetary values.

The result of exports estimated with the second econometric regression (which in turn is affected by the first econometric regression and the production scenarios ΔProd) is included in the vector of exports of $\mathbf{e}$ in the I-O equation to calculate value-added ($\mathbf{v}$):

$$\mathbf{v} = \mathbf{h}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{d} + \mathbf{e} \tag{54}$$

where $(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$ is the Leontief inverse matrix, in which $\mathbf{I}$ is an identity matrix, $\mathbf{A}$ is the matrix of technical coefficients, $\mathbf{d}$ is the domestic final demand, and $\mathbf{h}$ is a matrix obtained with the diagonalization of the vectors of value added and the gross output vector $\mathbf{x}$:

$$\mathbf{h} = \frac{\text{diag}(\mathbf{v})}{\text{diag}(\mathbf{x})} \tag{55}$$

Domestic demand is assumed to be constant (no changes in d), hence private consumption and public (government) consumption are assumed to be constant. The impact on value added is compared to the baseline scenario of the values of value added in the year 2018, as this is the year for which there is I-O information for NL. Finally, the changes in value added (Δv) between the baseline and simulated scenarios are assumed to be approximately equal to changes in the GDP in NL, and hence these changes are used to estimate the impact on employment through the estimated elasticities $\hat{\theta}_1$ and $\hat{\theta}_2$ of the third econometric model:

$$\Delta\text{v} \cong \Delta\text{GDPNL}$$
$$EMPLOYMENT = \exp\left(\hat{\theta}_1 + \hat{\theta}_2 \ln(\Delta\text{GDPNL} + \text{GDPNL})\right) \tag{56}$$

where GDPNL is the GDP of NL and ΔGDPNL is the change in GDP in NL. This last equation reflects how changes in the economic activity of the industries in NL affect employment in this province. To obtain estimates of the impact on employment at sector level, the total employment effect obtained with the econometric regression was distributed with the convex combination of the coefficients that measure the changes in the structure of value added by industry and the baseline structure of employment in these industries:

$$\text{employment effects by sector} = EMPLOYMENT[\alpha\Delta sva + (1-\alpha)\Delta semp] \tag{57}$$

where $EMPLOYMENT$ is the total employment effect obtained with the econometric model, Δsva are the vector of coefficients that measure the changes in the structure of value added by industry in the simulated scenario, $\Delta semp$ are the vector of coefficients in the baseline scenario of employment by sector. To calculate the coefficients in Δsva, we simply divide the value of each sector by the total value added, and to calculate the coefficients in $\Delta semp$, I simply divide the employees in each sector by the total number of employees in all industries. This provides us with a measure of the structure (and the changes in the structure) of value added and employment, by sector, weighted by a convex combination through a parameter α that measures the structure of employment in the goods-producing sector compared to the service-producing sector. In the case of NL, the information of value added and employment by industry in the year 2018 (the base year of the model) indicates that 20.6% of employment in NL is allocated to the good sector ($\alpha = 0.206$), and 79.4% is allocated to the service sector (see Appendix B).

The publication of The Economy of NL from the year 2020 also shows the structure of GDP in the year 2018 (see Appendix Box A). In the year 2018, oil extraction was equal to the 18.2% of the total GDP of NL, while mining was equal only to 5.5% of total GDP, below construction (9.9%). the second most important sector of the goods-producing sector of GDP in the year 2018.

The equation of labor wages equation ($\mathbf{w}$) is obtained by modifying the vector of value-added coefficients $\mathbf{h}$ in the equation of value-added ($\mathbf{v}$) (Eq.43), by replacing the value-added coefficients $\mathbf{h}$ by labor income coefficients $\mathbf{u}$:

$$\mathbf{w} = \mathbf{u}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{d} + \mathbf{e} \tag{58}$$

Table 6 from chapter 3 shows the values of oil prices and changes in production that were used in the scenarios of the simulation. The changes in production are divided in a green growth and a degrowth scenarios, with low, middle, and high levels of production reduction, with the more severe production reduction the high degrowth scenario equal to a reduction of -24% in oil production. Scenarios of low oil prices (40.32 USD/barrel), middle oil prices (65.83 USD/barrel) and high oil prices (142.27 USD/barrel) are combined with the scenarios of changes in oil production, to simulate the joint impact that oil prices and reductions in oil production have on value added and employment in the province of Newfoundland and Labrador.

Table 11 and Table 12 shows the results of the simulations obtained with the IOX model:

- Table 11A shows the impact on value added in millions of dollars, measured as the difference between the baseline scenario (2018) and the different results obtained with the simulation scenarios.
- Table 11B shows the impact on value added expressed as a percentage change between the baseline scenario (2018) and the different results obtained with the simulation scenarios.
- Table 12A shows the impact on employment in thousands of persons, measured as the difference between the baseline scenario (2018) and the results obtained with the simulation scenarios.
- Table 12B shows the impact on employment expressed as a percentage change between the baseline scenario (2018) and the results obtained with the simulation scenarios.

The results show that a scenario of low oil prices (40.32 USD/barrel) and low reduction in production (green growth = -2%) produces an overall reduction in value added in NL equal to -23%, and a reduction in employment equal to 21%. A middle oil price (65.83 USD/barrel) and the highest reduction in production (degrowth = -18%) reduces overall value added by -3.4%, and total employment -2.16%. However, in the presence of high oil prices (142.27 USD/barrel), the overall value added, and total employment, increases even in a low degrowth scenario and a high green growth scenario, in which production reduction is equal to -6%. In this case, the high oil price stimulates economic activity and value-added increases in 45.83%, while total employment increases in 21.5%.

Table 11: Impact on value added

A (Difference between the baseline scenario in millions of dollars)

	Scenarios of changes in the production of oil							
Scenarios of NR prices	**Current Growth**	**Green Growth (-2%)**	**Green Growth (-4%)**	**Green Growth (-6%)**	**Degrowth (-12%)**	**Degrowth (-18%)**	**Degrowth (-24%)**	**Baseline scenario**
middle ($65.83)	116.1	-14.5	-146.4	-279.4	-686.0	-1104.9	-1537.3	
high ($147.27)	15635.6	15328.6	15018.9	14706.4	13751.0	12766.9	11751.0	32087.46
low ($40.32)	-4705.1	-4780.9	-4857.5	-4934.8	-5149.6	-5320.6	-5497.2	

B (Difference between the baseline scenario in percentage)

	Scenarios of changes in the production of oil							
Scenarios of NR prices	**Current Growth**	**Green Growth (-2%)**	**Green Growth (-4%)**	**Green Growth (-6%)**	**Degrowth (-12%)**	**Degrowth (-18%)**	**Degrowth (-24%)**	**Baseline scenario**
middle ($65.83)	0.36%	-0.05%	-0.46%	-0.87%	-2.14%	-3.44%	-4.79%	
high ($147.27)	48.73%	47.77%	46.81%	45.83%	42.85%	39.79%	36.62%	0%
low ($40.32)	-14.66%	-14.90%	-15.14%	-15.38%	-16.05%	-16.58%	-17.13%	

Table 12: Impact on employment

A (Difference between the baseline scenario in thousands of persons)

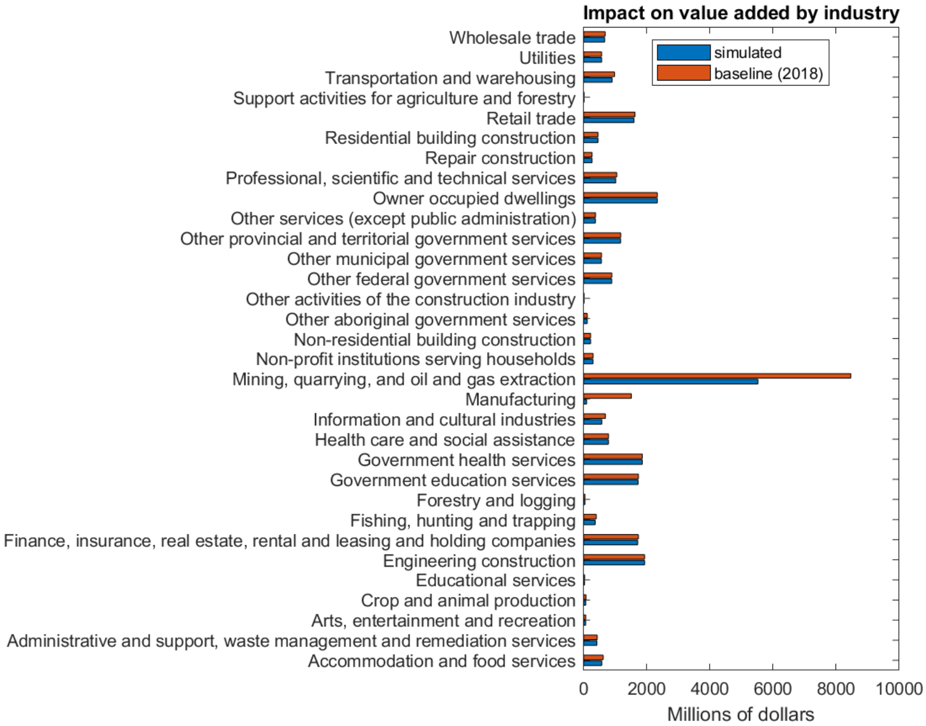
	Scenarios of changes in the production of oil							
Scenarios of NR prices	**Baseline growth**	**Green growth (-2%)**	**Green growth (-4%)**	**Green growth (-6%)**	**Degrowth (-12%)**	**Degrowth (-18%)**	**Degrowth (-24%)**	**Baseline scenario**
middle ($65.83)	0.5	-0.1	-0.6	-1.2	-3.0	-4.8	-6.8	
high ($147.27)	50.8	50.0	49.2	48.3	45.8	43.1	40.3	224.3
low ($40.32)	-22.9	-23.3	-23.7	-24.2	-25.5	-27.0	-28.5	

B (Difference between the baseline scenario in percentage)

Scenarios of NR prices	Scenarios of changes in the production of oil							Baseline scenario
	Baseline growth	**Green growth (-2%)**	**Green growth (-4%)**	**Green growth (-6%)**	**Degrowth (-12%)**	**Degrowth (-18%)**	**Degrowth (-24%)**	
middle ($65.83)	0.22%	-0.03%	-0.28%	-0.53%	-1.33%	-2.16%	-3.04%	0%
high ($147.27)	22.63%	22.28%	21.92%	21.55%	20.42%	19.22%	17.95%	
low ($40.32)	-10.19%	-10.39%	-10.58%	-10.77%	-11.38%	-12.02%	-12.69%	

Below set of figures 27-31 show the results disaggregated by industry and employment sectors. A low-price scenario (40.32 USD/Barrel) combined with a low green growth (-2%) scenario, Figure 27 produce the highest reduction in value added when compared to the baseline scenario This is as expected in the sector of mining and oil and gas extraction, but these sectors are also affected by the low oil prices, and the reduction in production are found in manufacturing and transportation. A reduction in employment among these sectors (mining, quarrying and oil and gas extraction, and manufacturing) is also observed, as a result of the low oil price and the reduction of production of natural resources in the low green growth scenario.

Figure 28 in turn, shows that no significant changes in valued added and employment are observed with a medium price (65.83 USD/Barrel) and medium green growth (-4%). However, Figure 31 shows that a medium price (65.83 USD/Barrel) and a medium degrowth (-16%) does produce a reduction in mining, quarrying and oil and gas extraction, besides a reduction in manufacturing. On the contrary, a high oil price (142.27 USD/Barrel) stimulates production and exports even if there is a high degrowth (-24%) tempering production levels. In this scenario (Figure 32), mining, quarrying and oil and gas extraction increases when compared to the baseline scenario, and manufacturing increases appear to be stimulated by the inter-relation between the industries of the economy in the province of NL. This boost to economic activity also stimulates employment, such that the simulated scenario of high oil prices produces an increase with respect to the baseline scenario, particularly in the sectors of mining, quarrying and oil and gas extraction, and manufacturing, and also in the services sectors as health care, retail trade and construction.



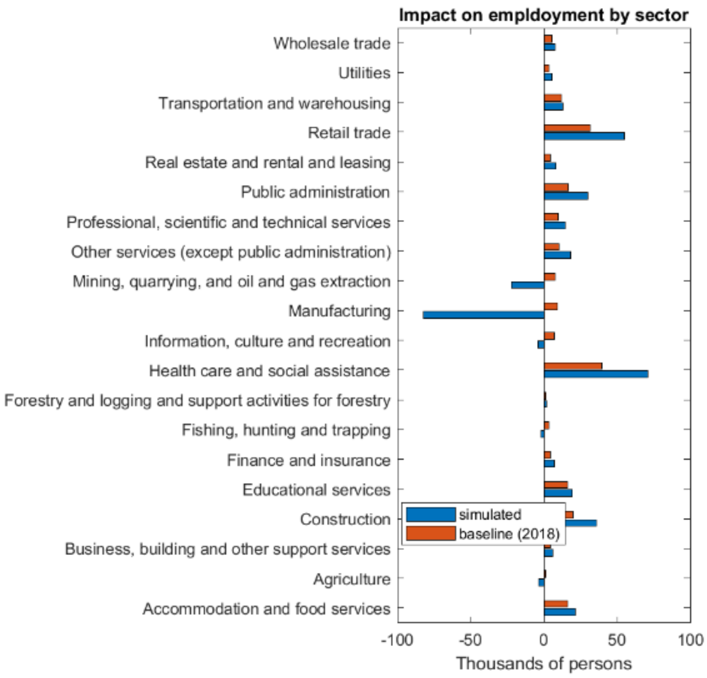
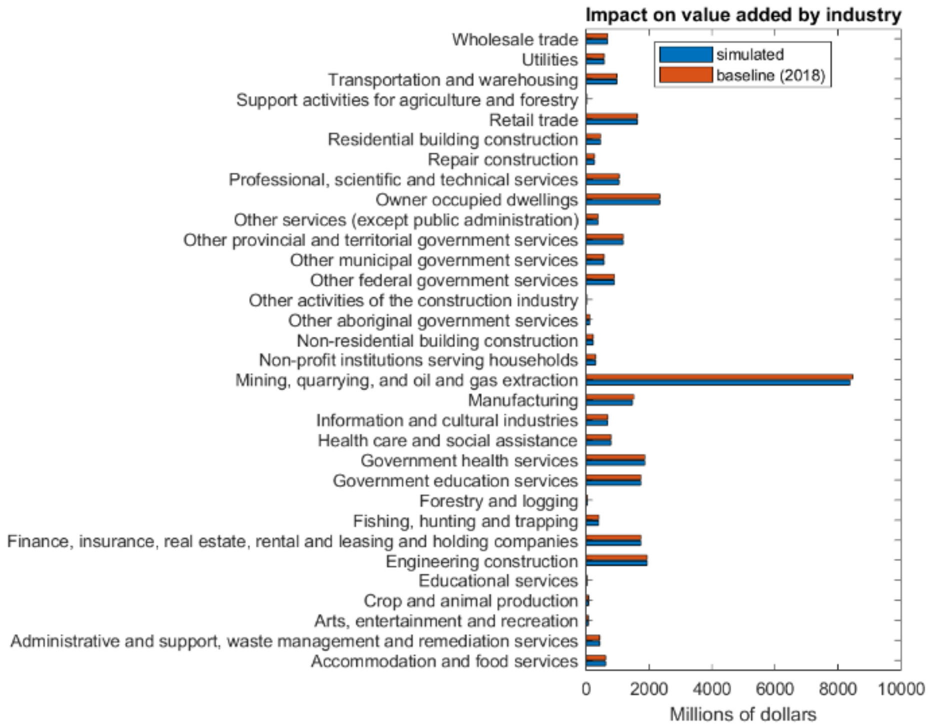


Figure 27: Impact on value added and employment by industry and sector (scenario 6)

Low price (40.32 USD/Barrel), low green growth (-2%)



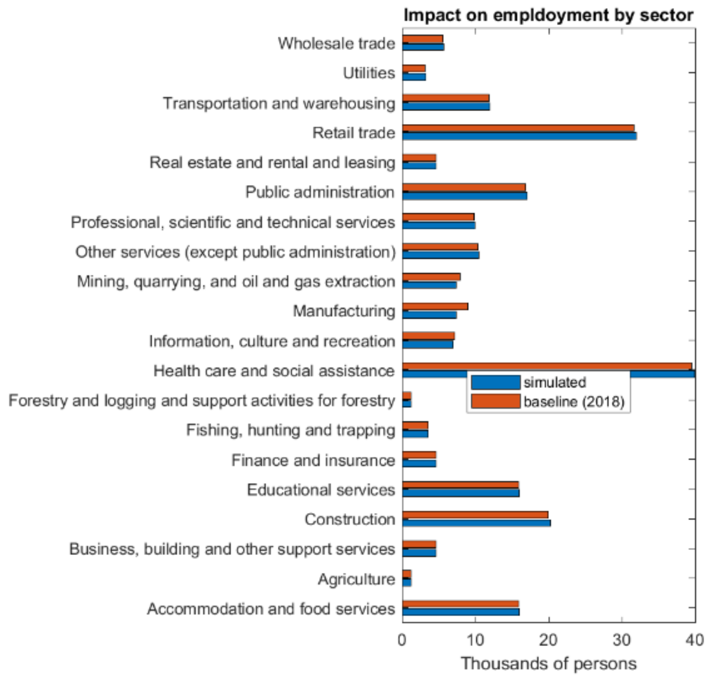
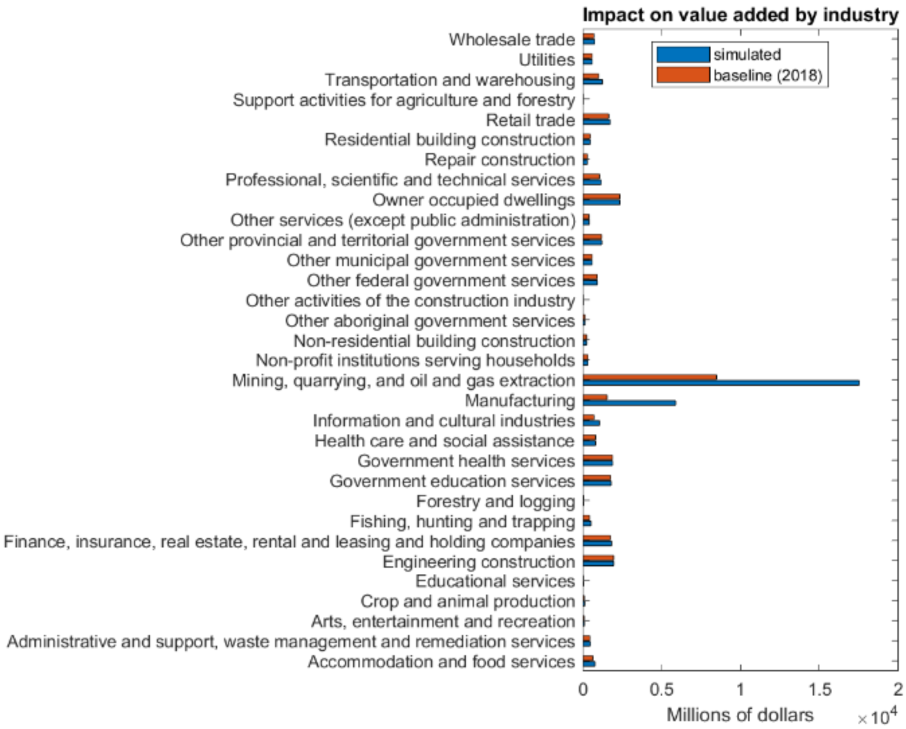


Figure 28: Impact on value added and employment by industry and sector (scenario 7).

Middle price (65.83 USD/Barrel), middle green growth (-4%)



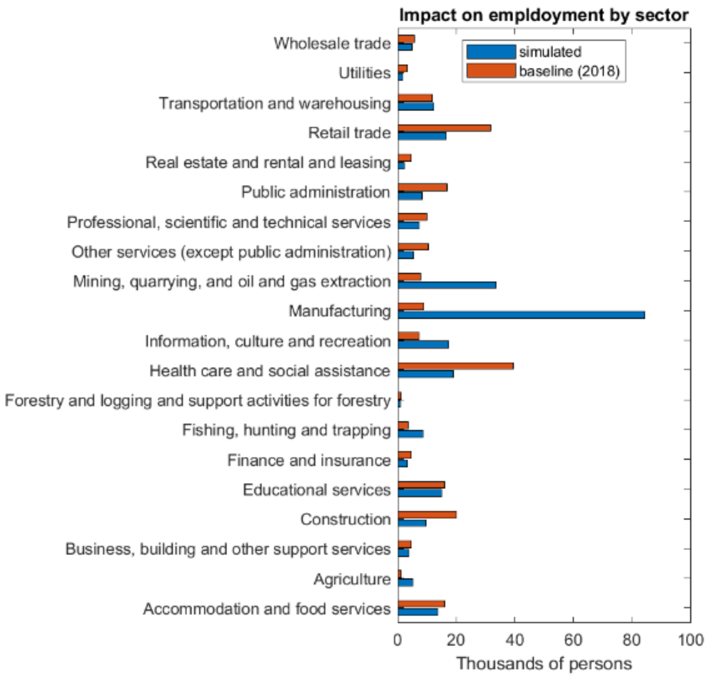
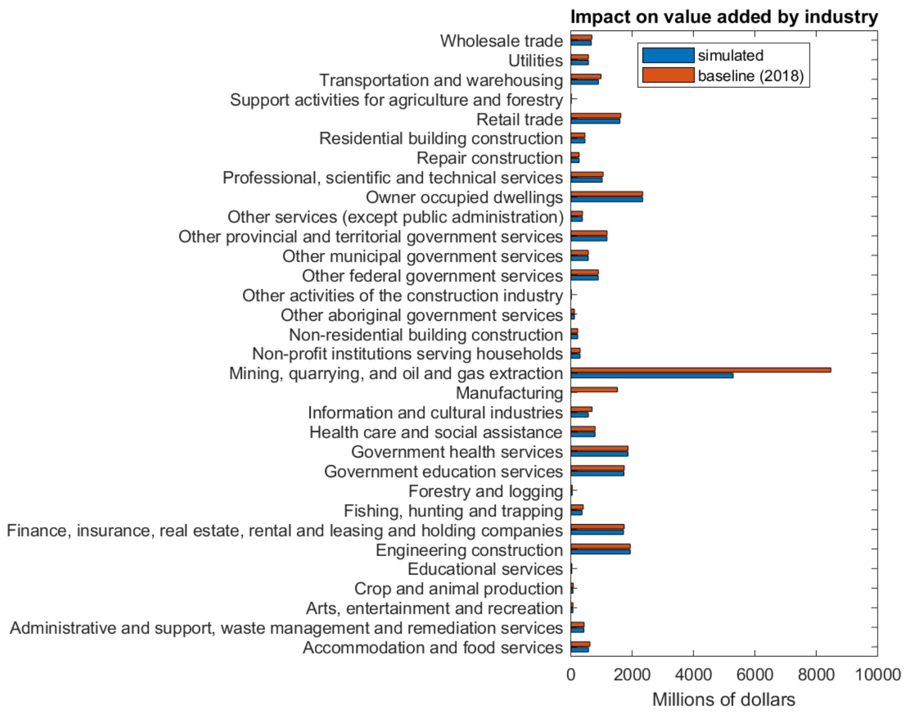


Figure 29: Impact on value added and employment by industry and sector (scenario 11)

High price (147.27 USD/Barrel), high green growth (-6%)



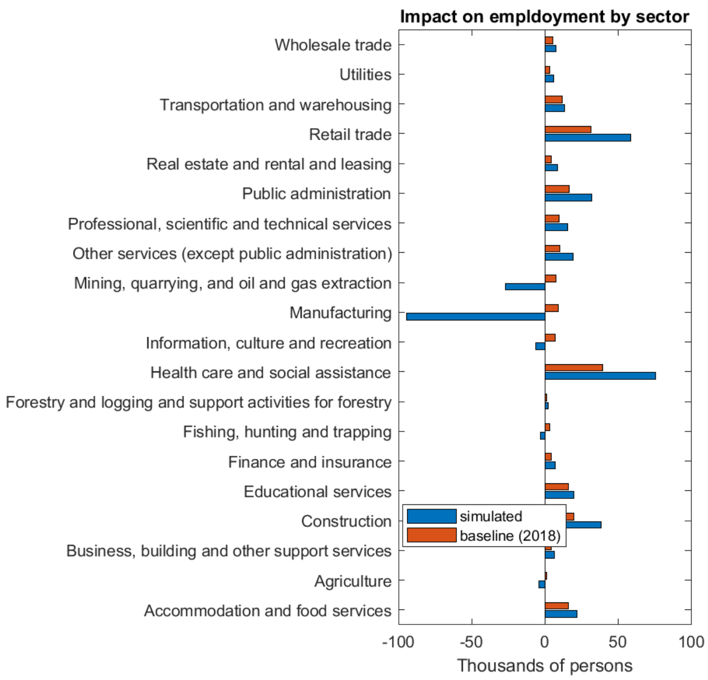
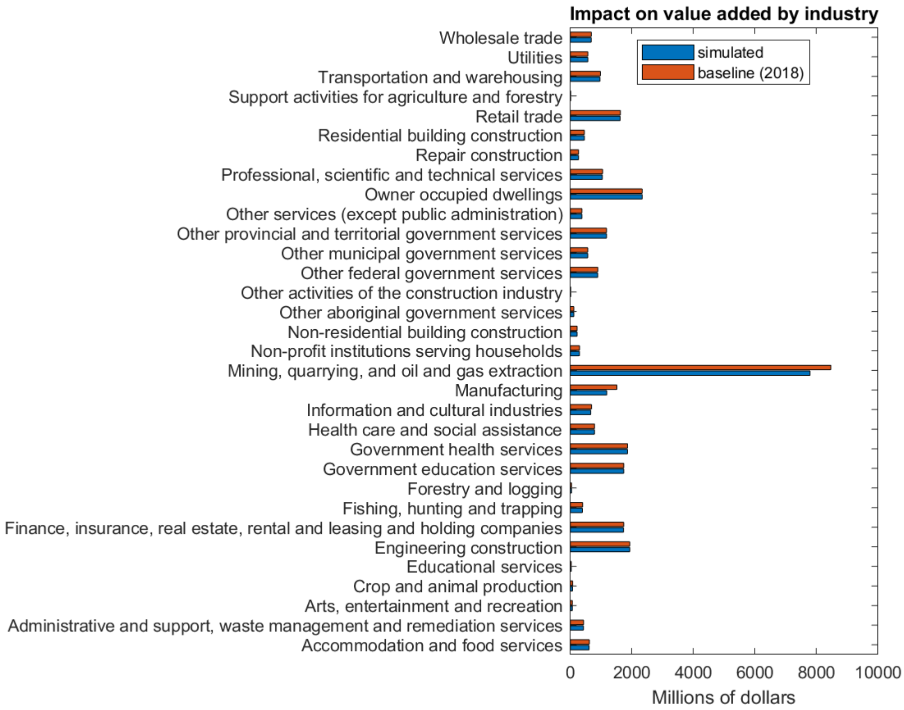


Figure 30: Impact on value added and employment by industry and sector (scenario 15)

Low price (40.32 USD/Barrel), Low degrowth (-12%)



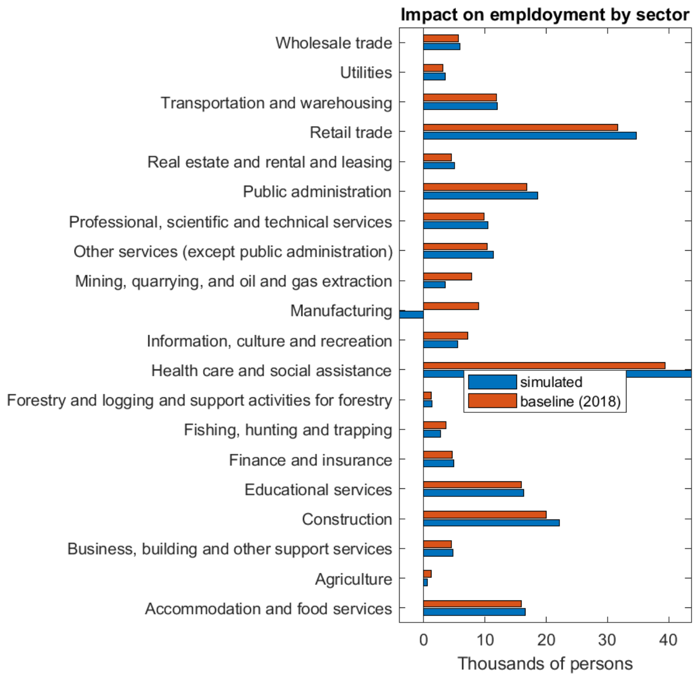
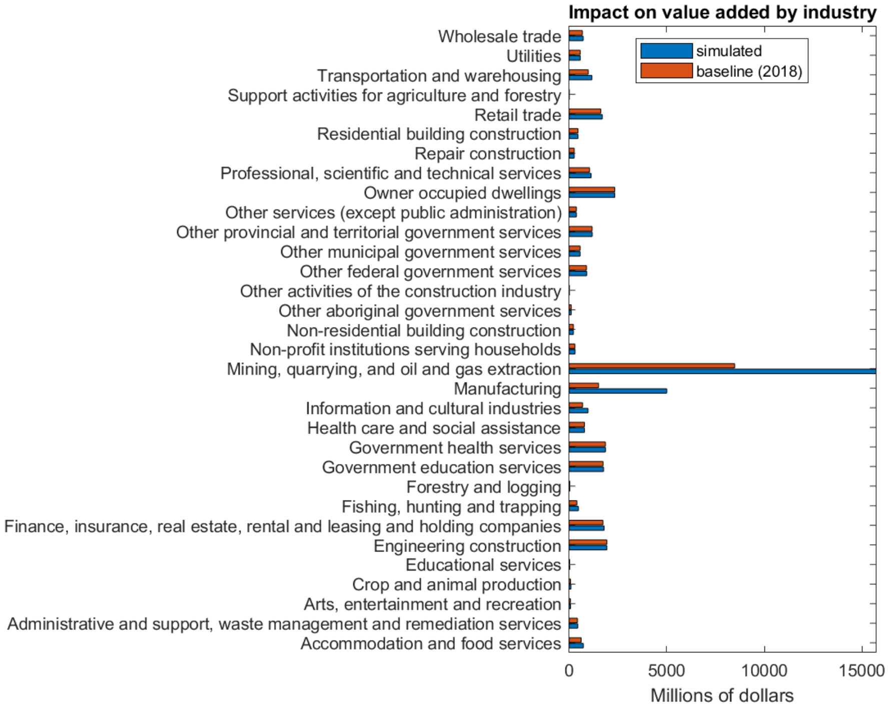


Figure 31: Impact on value added and employment by industry and sector (scenario 16)

Medium price (65.83 USD/Barrel), Medium degrowth (-18%)



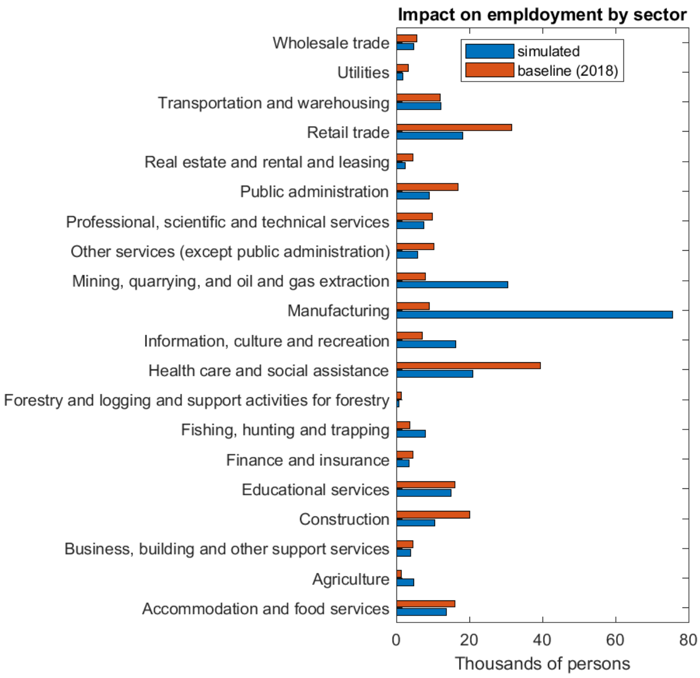


Figure 32: Impact on value added and employment by industry and sector (scenario 20)

High price (142.27 USD/Barrel), high degrowth (-24%)

4.6 NL Agent-Based Model Result:
IOX-ABM simulations were calculated using MatLab can be used to do ABM simulations because Matlab is a powerful programming language and computational tool that provides many built-in functions that can be used to model the utilities of agents and their decision rules; appendix C presents the pseudo-code. MatLab has as well excellent support for matrix operations, which is useful in simulations that involve large amounts of data as in the case of Input-Output matrices that need to be connected to individual employment and migration decisions of thousands of agents. Some scientific studies that have used MatLab for agent simulations are [146]–[149].

Figure 33 shows the results of validating the results of the IOX model, extended with ABM simulations (henceforth, IOX-ABM) in the base scenario. Here, the oil price (WTI) is equal to 65.23 USD/barrel, as in the year 2018, the base year of the Input-Output model, and the change in production is equal to zero (0%). Appendix B shows the initialization parameters of the IOX-ABM simulations, and the parameters that were calibrated to replicate the baseline scenario of the model. The results of the IOX-ABM simulations are equal to the trends in the base scenario of unemployment and migration (interprovincial in-migrants, international immigrants, returning Canadians, interprovincial out-migrants, and international emigrants). This result indicates that the IOX-ABM simulations are properly calibrated and can be used to produce simulations of changes in employment and migration patterns that arise in response to increases in oil prices above 65.23 USD/barrel (positive shock) or decreases in oil prices below 65.23 USD/barrel (negative shocks), combined with increases in the production of natural resources (above 0%, positive shock) or reductions in the production in the production of natural resources (below 0%, negative shock).

The baseline trends are important to remember, as the baseline calibrated model assumes the unemployment level reaches a low of about 27000 in 2025, and then rises to a high of 40000 in 2019. This scenario is interesting because the high unemployment level aligns with the annual unemployment level in 2017. On the baseline in-migration from interprovincial forecast, the model assumes a baseline, calibrated forecast going up slightly from a 2023 low to a peak in 2025 at around 7000 and then precipitously declining to a low of about 5500 in 2030. Shifting to the international immigration calibrated forecast, the model assumes slowly upward trending growth in international migration from its current value of about 1750 in 2022, reaching a level of almost 2000 by 2030. The 2030 level of 2000 is close to its recent high of a little over 2000 in 2021.

On the forecast for returning Canadians, the forecast has the number of returning Canadians continually declining from their current 2022 values, reaching a low of around 25 by 2030. Shifting attention to the interprovincial out-migration, the calibrated forecast has out-migration from the province to other provinces floating close to historically low values at around 4700 by 2030. The low level of out-migration suggests that, over the period of the forecast, NL may outperform surrounding providences, at least based on the baseline forecast. Lastly, on international emigrants, the baseline model presumes the number of international emigrants slowing continually from their current levels, slowing to about 125 by 2030. This baseline forecast suggests, as with the other economic measures, that NL has a relatively strong short-term baseline forecast relative to the other places workers could live.

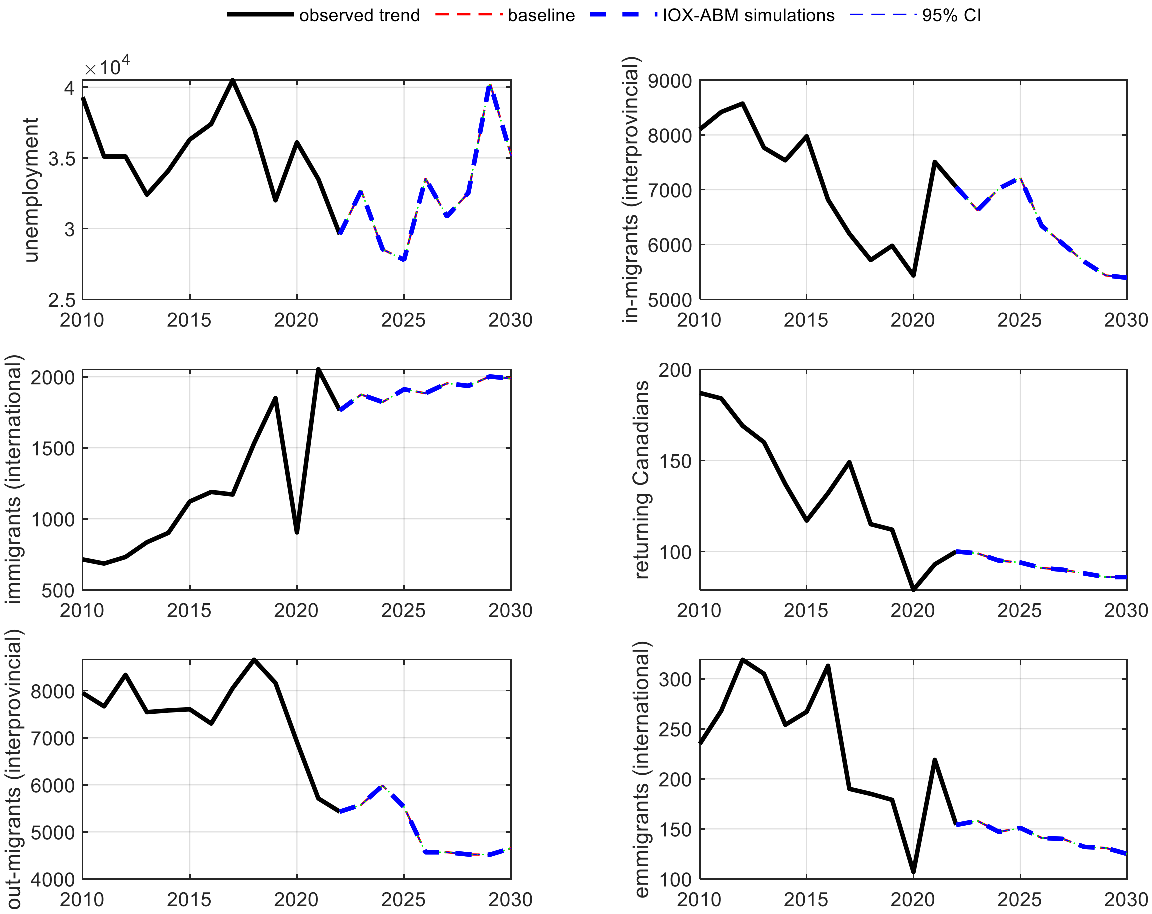


*Figure 33: IOX-ABM simulations: impact of shocks in prices and changes in the production of natural resources in Newfoundland & Labrador, 2023-2030 – **Calibration***

(Oil price = 65.23 USD/barrel, increase in production = 0%)

A summary of all these results is displayed in Table 13 and Table 14, in a percentage and an absolute basis respectively. The first set of results are for employment. The simulation closest to the current price of oil is the 65.83 USD/barrel simulation. In this simulation, the scenario with the least amount of change is the low green growth scenario (-2% drop in production), which sees employment drop by -.33%. The decrease in employment gets progressively worse as one moves from left to right in the table – i.e., from the low green growth scenario to the high degrowth scenario. In the worst situation of the 65.83 USD/barrel simulation, employment drops by 5.99%.

Shifting to the next set of scenario results, the assumption on the price of oil changes from 65.23 USD/barrel to 147.27 USD/barrel. Interestingly, the low green growth scenario produces the highest employment growth with this assumption at 4.50%. The scenario with the smallest increase in employment is the high degrowth scenario, with employment rising

3.05%. This result is somewhat surprising given that the degrowth scenario assumes a drop in oil production of 24%. One might think that a reduction in production would lead to a decrease in employment, given the decrease in oil industry demand for labor, but the rise in oil prices by such a large amount presumably keeps oil producers whole – and potentially even more profitable – as demand increases in other areas of the economy.

The third result for employment assumes an oil price of 40.32 USD/barrel. Using this simulating assumption, the scenario with the largest change in employment is the high degrowth scenario, with employment declining by 20.66%. This enormous depression-level drop in employment stems from the large drop in demand for employees in the oil industry and its corresponding multiplier effect on directly and indirectly connected industries. Interestingly, all six scenarios produce incredibly large drops in employment of over 18%, which is indicative of the sensitivity of employment to the health of oil producers.

The next set of reported results is for emigration from NL. Intriguingly, the moderate change in the price of oil simulations produce only moderate changes in emigration, ranging from a low of 0.00% in the low and medium green growth scenarios to a high of 4.26% in the high degrowth scenario. On the high oil price simulations, the change in emigration is large, ranging from a low of -34.75% in the high degrowth scenario to a high of -47.52% in the low green growth scenario. The very large drop in emigrants is consistent with the view that individuals decide to stay in NL to work rather than emigrate to other places. On the low oil price assumption, emigration moves in the opposite direction, albeit to a lesser degree. Overall, emigration increases from a low of 19.86% in the low green growth scenario to a high of 24.82% in the high degrowth scenario. The large jump in emigration is consistent with the view that NL will see depression-type economic activity in the low oil price simulations, and pursuing a high degrowth policy would lead to a large increase in individuals leaving the area.

Shifting attention to the out-migration simulation results, as one would expect, the out-migration results are very similar to the emigration results, and given that the storyline is virtually identical, no further discussion is presented here.

The fourth reported results are for returning Canadians. In the simulations assuming very little change in the price of oil, the largest change shows up in the high green growth, low degrowth, medium degrowth, and high degrowth scenarios, with all four scenarios producing a reduction in returning Canadians of -1.09%. The drop of 1.09% for all four scenarios is somewhat odd, especially given that the low and medium green growth scenarios produce no change in returning Canadians. However, one must remember that the baseline is just 92 individuals, which implies that a one person declines to 91 (-1.09%) is basically consistent with virtually no change. For the high oil price simulations, the number of returning Canadians rises from 9.37% (high degrowth scenario) to 13.01% (low green growth scenario). One would expect these increases given the importance of the oil industry to NL. Lastly, in the simulations assuming low oil prices, the number of returning Canadians drops from a low of -2.23% in the high green growth scenario to a high of -3.69% in the high degrowth scenario. The small drop in the number of returning Canadians when oil prices are low is somewhat surprising and presumes that the return of Canadians is relatively inelastic at low oil prices.

The next two set of results are for immigrants and in-migrants. The results for both are virtually identical, as one would expect given the definitions of the two measures. Unsurprisingly, when the oil price stays relatively unchanged (the 65.83 USD/barrel oil price assumption simulations), the number of immigrants and in-migrants are relatively unchanged, with the largest change occurring in the high degrowth scenario (both down about 1%). The high oil price simulations produced drops in immigrants and in-migrants from around 9% in the high degrowth scenario to 13%/14% in the low green growth scenario. This result suggests that when oil prices are high, the optimal policy is a low green growth policy. A similar conclusion holds for the low oil price assumption. When oil prices are assumed to be low, the percentage change in the number of immigrants and in-migrants declines by between 3% and 4%, with the smallest drop occurring in the low degrowth scenario.

The last area reported in these tables are net migration. Quite surprisingly given the moderate changes in the other variables when the price of oil is virtually unchanged, when a high degrowth policy is pursued in an unchanged oil price simulation, net migration drops by more than 9%, and net migration drops by 3.58% and 6.06%, respectively, in the low and medium degrowth scenarios. These relatively high figures suggest that if oil prices remain unchanged, pursuing degrowth strategies would produce suboptimal results.

Shifting to the results where the price of oil is high (147.27 USD/barrel), net migration rises very quickly, from 83.68% in the high degrowth scenario to 115.41% in the low green growth scenario. The massive jump suggests the relatively elastic nature of migration to the price of oil. One might find this surprising given that the low green growth scenario has oil production declining, and thereby implies a lower demand for workers producing oil, but the higher oil price brings money into the area that works its way through the rest of the NL economy. This is an important assumption behind the validity of the model and would require careful examination to ensure its accuracy should a policy of low growth be adopted in times of high oil prices.

Lastly, the low oil price simulations produce drops in net migration from a drop of 41.79% in the low green growth scenario to a high of -51.11% in the high degrowth scenario. This finding, which represents around 1200 to 1300 individuals, indicates the sensitivity of the NL economy to the price of oil. One should keep in mind in these figures that migration is one of the most heavily sensitive demographic group to economic conditions, and when economic conditions deteriorate, migration is one of the first areas the effects will show up.

Table 13: Percentage Change Results of the IOX-ABM simulations
Average of simulations between 2023-2030 (number of persons) on a percentage change basis.

	Baseline (base scenario)	Scenarios of NR prices (USD)	Scenarios of changes in the production of natural resources					
			Green growth low (-2%)	Green growth medium (-4%)	Green growth high (-6%)	Degrowth low (-12%)	Degrowth medium (-18%)	Degrowth high (-24%)
Employment	216662	65.83	-0.33%	-0.82%	-1.32%	-2.83%	-4.38%	-5.99%
		147.27	4.50%	4.68%	4.28%	3.77%	3.47%	3.05%
		40.32	-18.01%	-18.29%	-18.58%	-19.38%	-20.01%	-20.66%
Emigrants	141	65.83	0.00%	0.00%	0.71%	1.42%	2.84%	4.26%
		147.27	-47.52%	-46.81%	-46.81%	-41.84%	-38.30%	-34.75%
		40.32	19.86%	20.57%	20.57%	22.70%	24.11%	24.82%
Out-migrants	4990	65.83	0.04%	0.26%	0.52%	1.38%	2.44%	3.71%
		147.27	-47.80%	-46.65%	-46.19%	-42.32%	-38.74%	-35.11%
		40.32	20.04%	20.62%	20.98%	22.46%	24.23%	24.97%
Returning Canadians	92	65.83	0.00%	0.00%	-1.09%	-1.09%	-1.09%	-1.09%
		147.27	13.04%	13.04%	11.96%	10.87%	9.78%	8.70%
		40.32	-4.35%	-3.26%	-3.26%	-4.35%	-4.35%	-4.35%
Immigrants	1922	65.83	0.00%	-0.10%	-0.21%	-0.47%	-0.73%	-1.14%
		147.27	13.01%	12.80%	12.43%	11.86%	10.41%	9.37%
		40.32	-3.28%	-3.33%	-3.23%	-3.49%	-3.49%	-3.69%
In-migrants	6218	65.83	-0.02%	-0.10%	-0.21%	-0.48%	-0.76%	-1.08%
		147.27	13.91%	12.87%	13.07%	11.58%	10.71%	9.75%
		40.32	-3.23%	-3.23%	-3.44%	-3.46%	-3.51%	-3.68%
Net migration	3101	65.83	-0.10%	-0.68%	-1.45%	-3.58%	-6.06%	-9.06%
		147.27	115.41%	111.32%	110.74%	100.90%	92.29%	83.68%
		40.32	-41.79%	-42.76%	-43.70%	-46.40%	-49.40%	-51.11%

Table 14: Results of the IOX-ABM simulations
Average of simulations between 2023-2030 (number of persons)

	Baseline (base scenario)	Scenarios of NR prices (USD)	Scenarios of changes in the production of natural resources					
			Green growth low (-2%)	Green growth medium (-4%)	Green growth high (-6%)	Degrowth low (-12%)	Degrowth medium (-18%)	Degrowth high (-24%)
Employment	216662	65.83	215937	214875	213806	210532	207162	203685
		147.27	226413	226806	225936	224833	224188	223271
		40.32	177641	177026	176406	174679	173311	171890
Emigrants	141	65.83	141	141	142	143	145	147
		147.27	74	75	75	82	87	92
		40.32	169	170	170	173	175	176
Out-migrants	4990	65.83	4992	5003	5016	5059	5112	5175
		147.27	2605	2662	2685	2878	3057	3238
		40.32	5990	6019	6037	6111	6199	6236
Returning Canadians	92	65.83	92	92	91	91	91	91
		147.27	104	104	103	102	101	100
		40.32	88	89	89	88	88	88
Immigrants	1922	65.83	1922	1920	1918	1913	1908	1900
		147.27	2172	2168	2161	2150	2122	2102
		40.32	1859	1858	1860	1855	1855	1851
In-migrants	6218	65.83	6217	6212	6205	6188	6171	6151
		147.27	7083	7018	7031	6938	6884	6824
		40.32	6017	6017	6004	6003	6000	5989
Net migration	3101	65.83	3098	3080	3056	2990	2913	2820
		147.27	6680	6553	6535	6230	5963	5696
		40.32	1805	1775	1746	1662	1569	1516

Baseline Scenarios:

The baseline scenarios, scenario 1, 2, and 3, represent no policy implementation regarding change in oil production. The baseline unemployment forecast has unemployment bottoming out in 2025 at around 2.8 percent, followed by a trend upwards until peaking in 2019 at around 4 percent. On the baseline forecast for in-migrants, the baseline model has interprovincial migration slowing after a short peak in 2025. The international immigration forecast is quite different than the interprovincial in-migration, with anticipated growth through the period of the forecast. The other three forecasts (returning Canadians, out-migration, and international emigration) are generally trending down from their 2022 estimated actual.

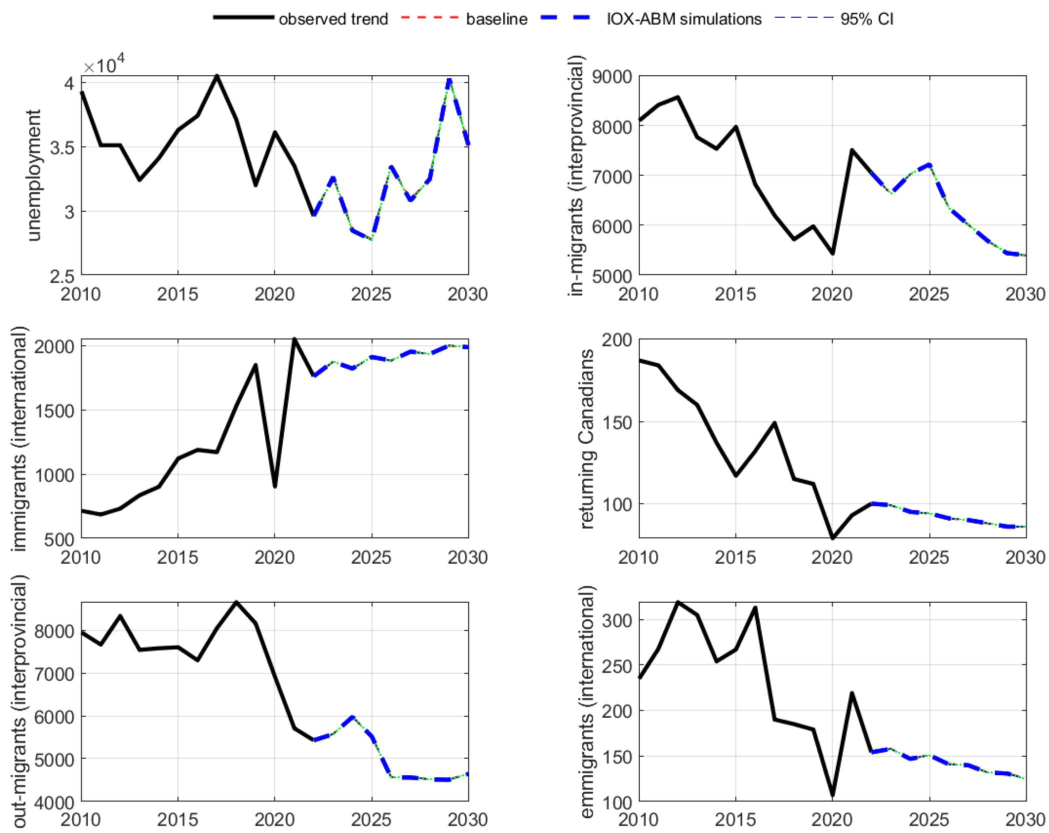
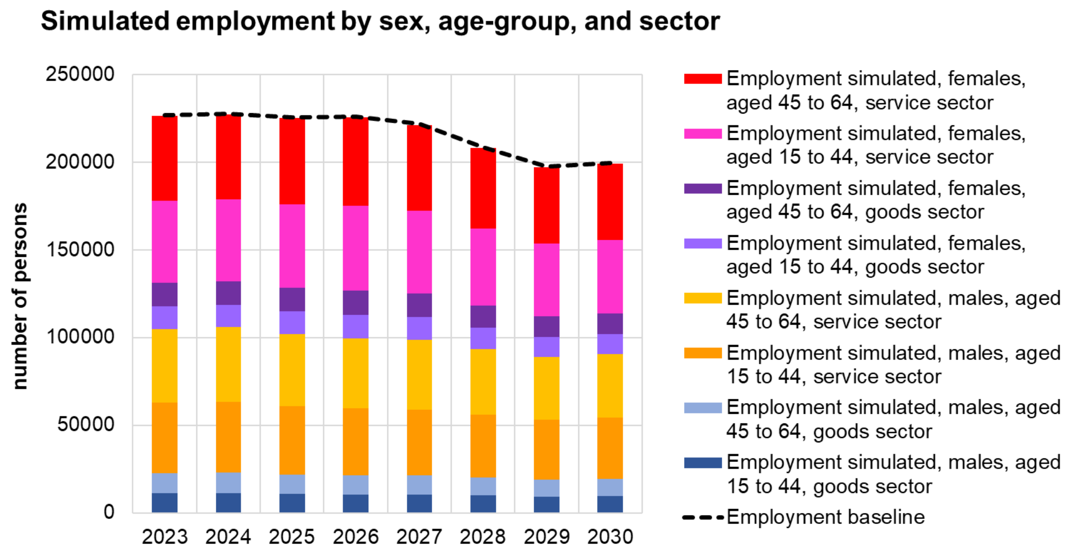


Figure 34a: Scenario 1 (Oil price = 64.83 USD/barrel, change in production = 0%)



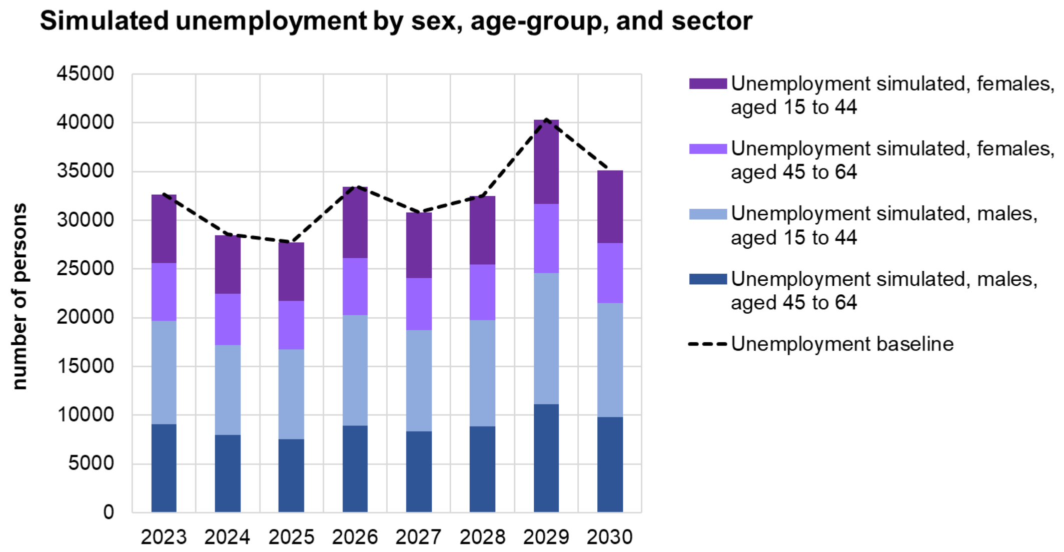


Figure 34b: Scenario 1 (Oil price = 64.83 USD/barrel, change in production = 0%)

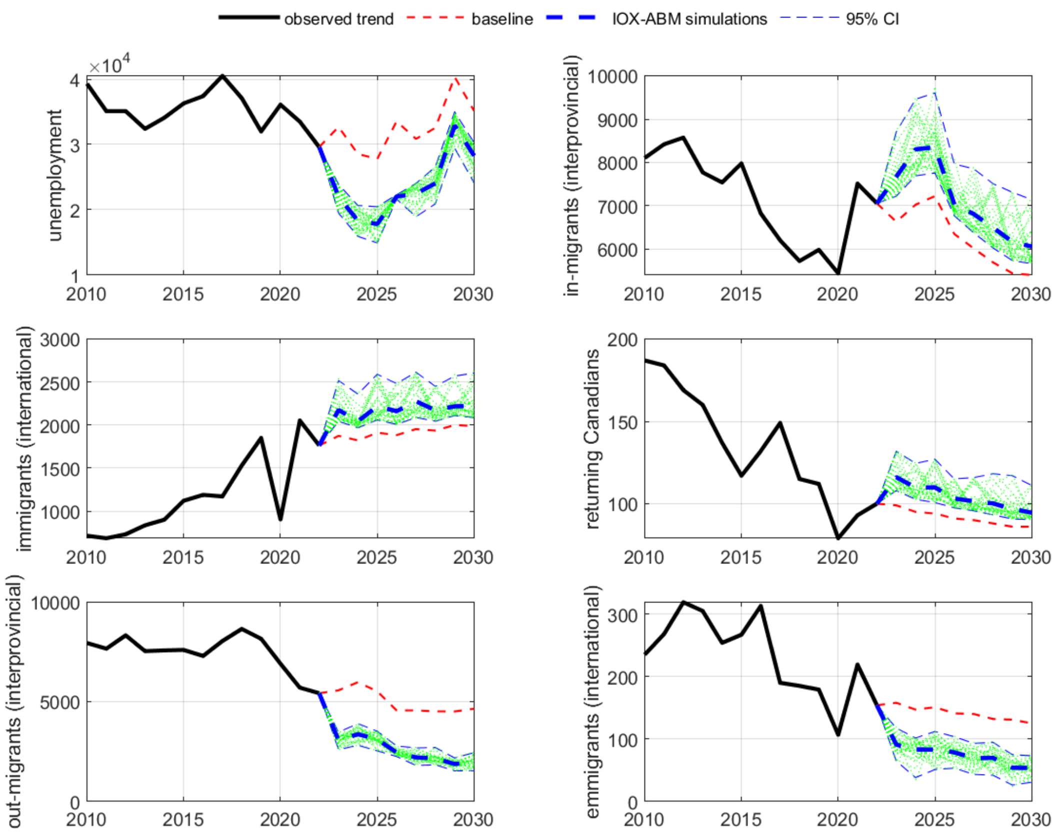


Figure 35a: Scenario 2 (Oil price = 147.27 USD/barrel, change in production = 0%)

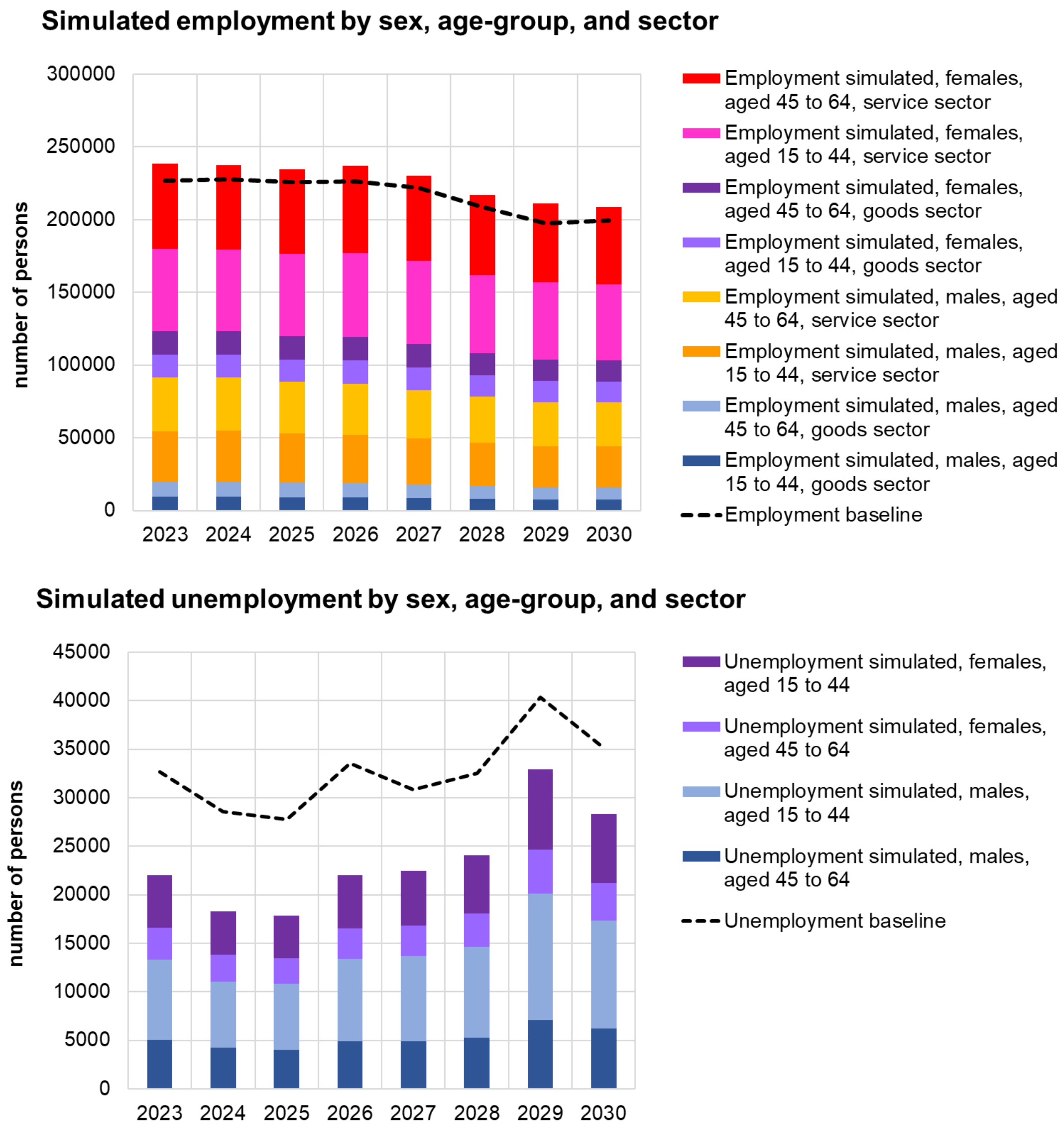


Figure 35b: Scenario 2 (Oil price = 147.27 USD/barrel, change in production = 0%)

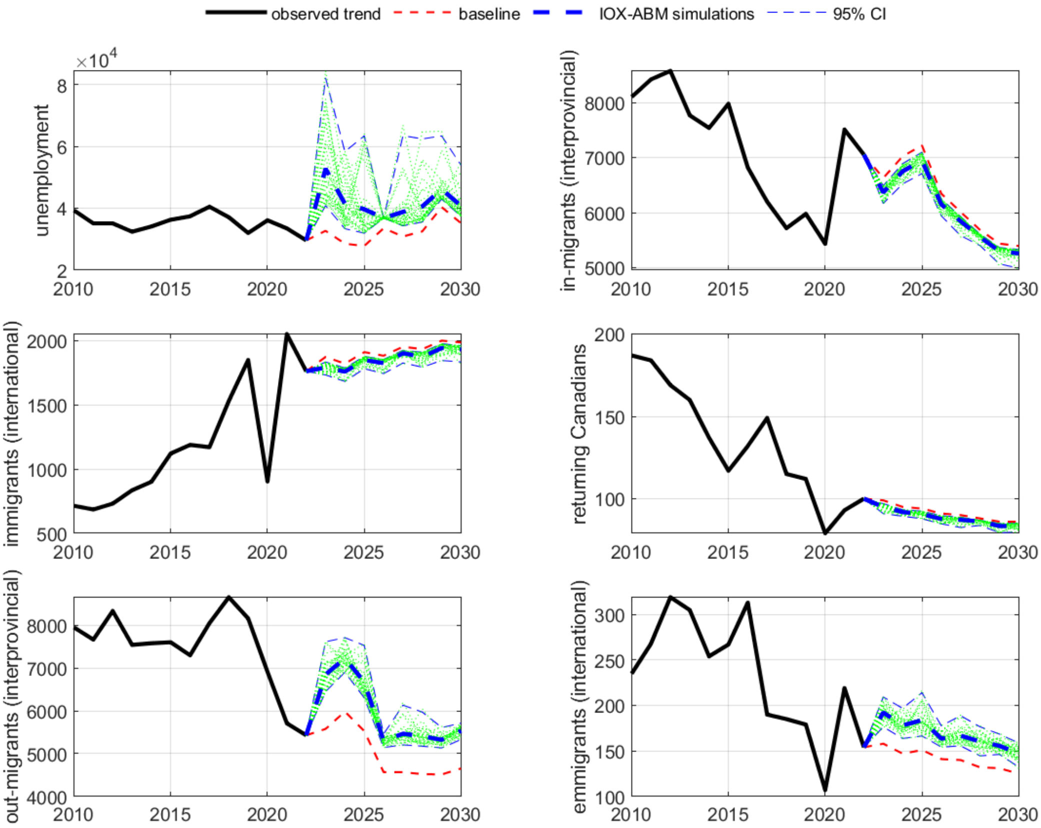


Figure 36a: Scenario 3 (Oil price = 40.32 USD/barrel, change in production = 0%)

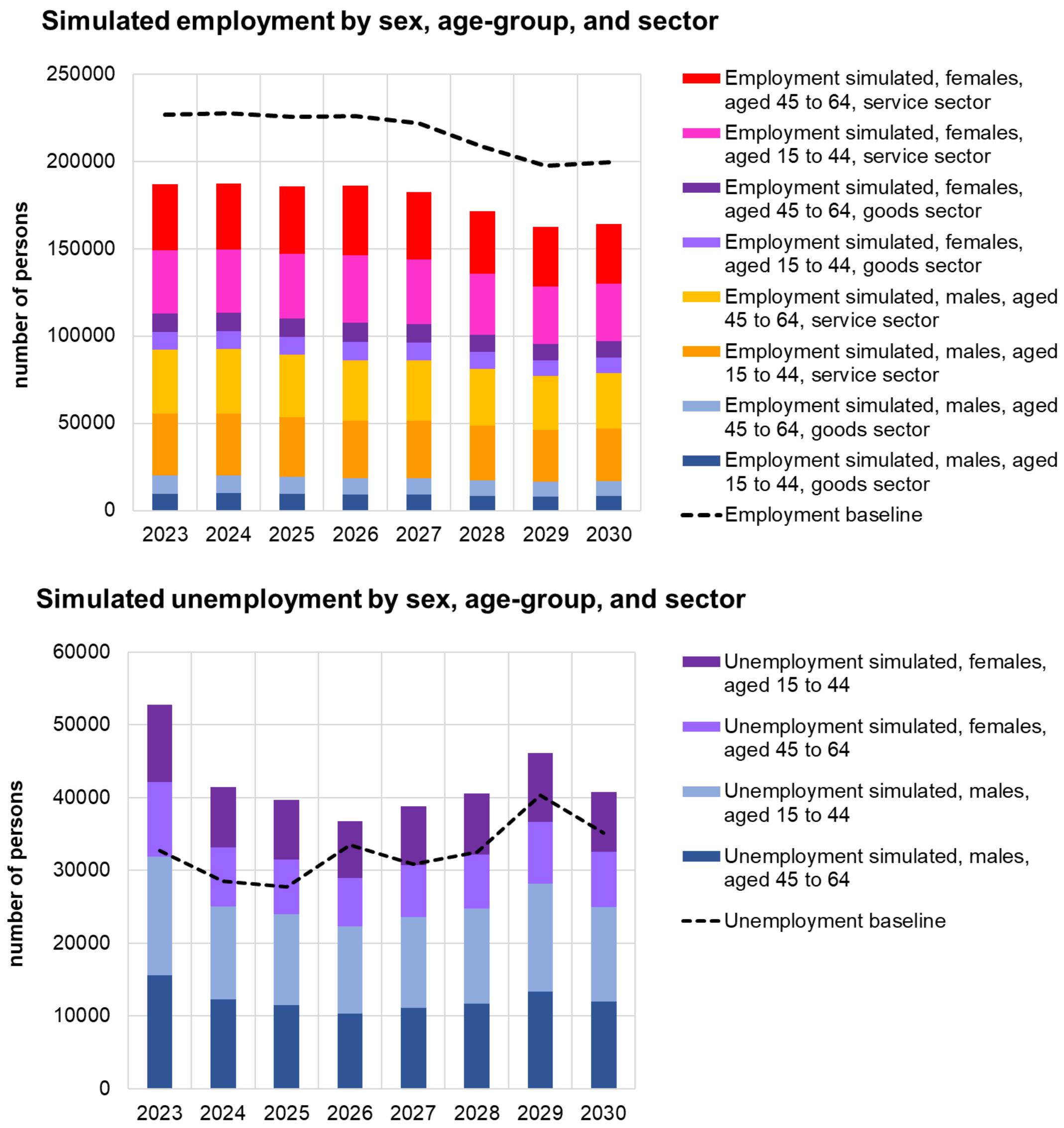


Figure 36b: Scenario 3 (Oil price = 40.32 USD/barrel, change in production = 0%)

Green-Growth scenarios:

Policy 1 is to reduce the production of oil and gas by 2%, depending on the energy market situation to replace that shortage, the prices vary therefore, scenarios 4 ,5, and 6 are presented below.

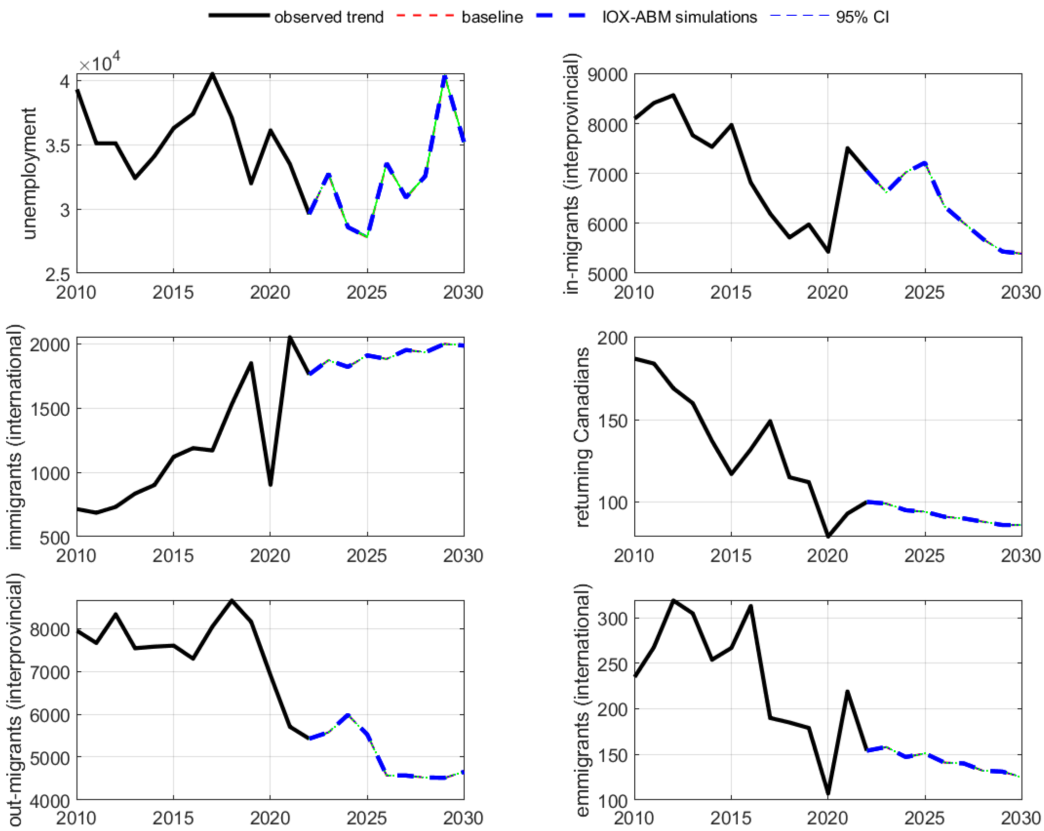
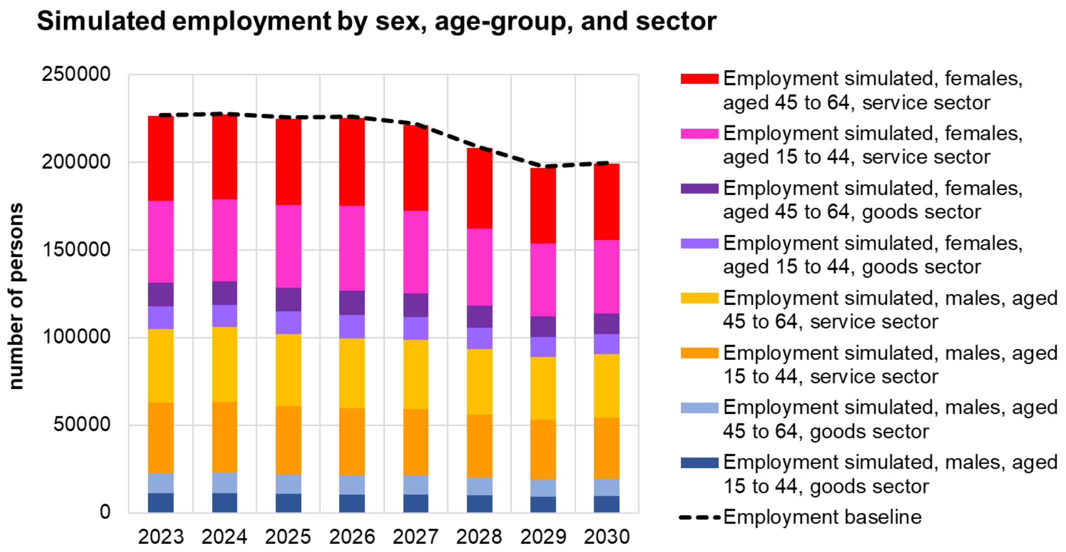


Figure 37a: Scenario 4 (Oil price = 65.83 USD/barrel, change in production = -2%)



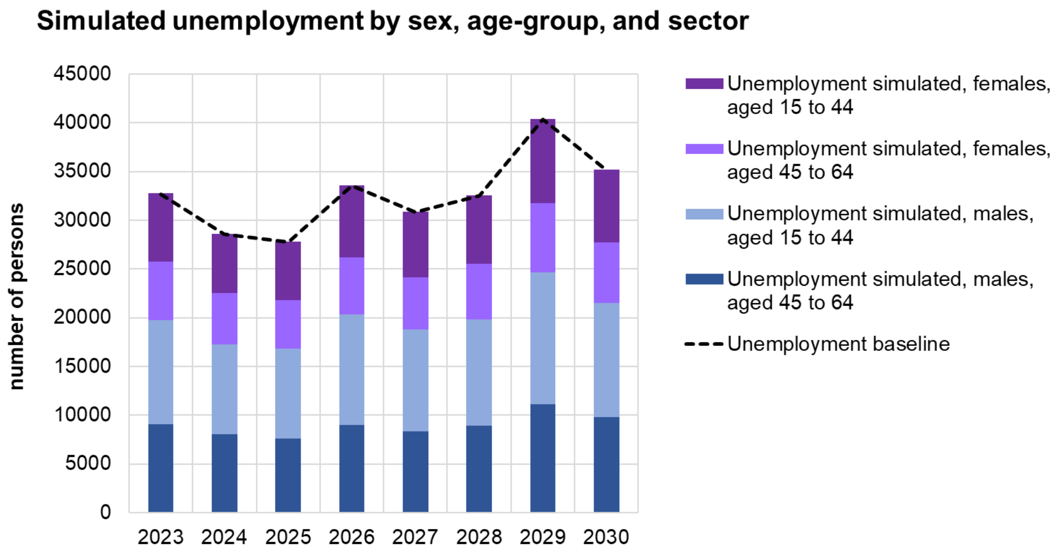


Figure 37b: Scenario 4 (Oil price = 65.83 USD/barrel, change in production = -2%)

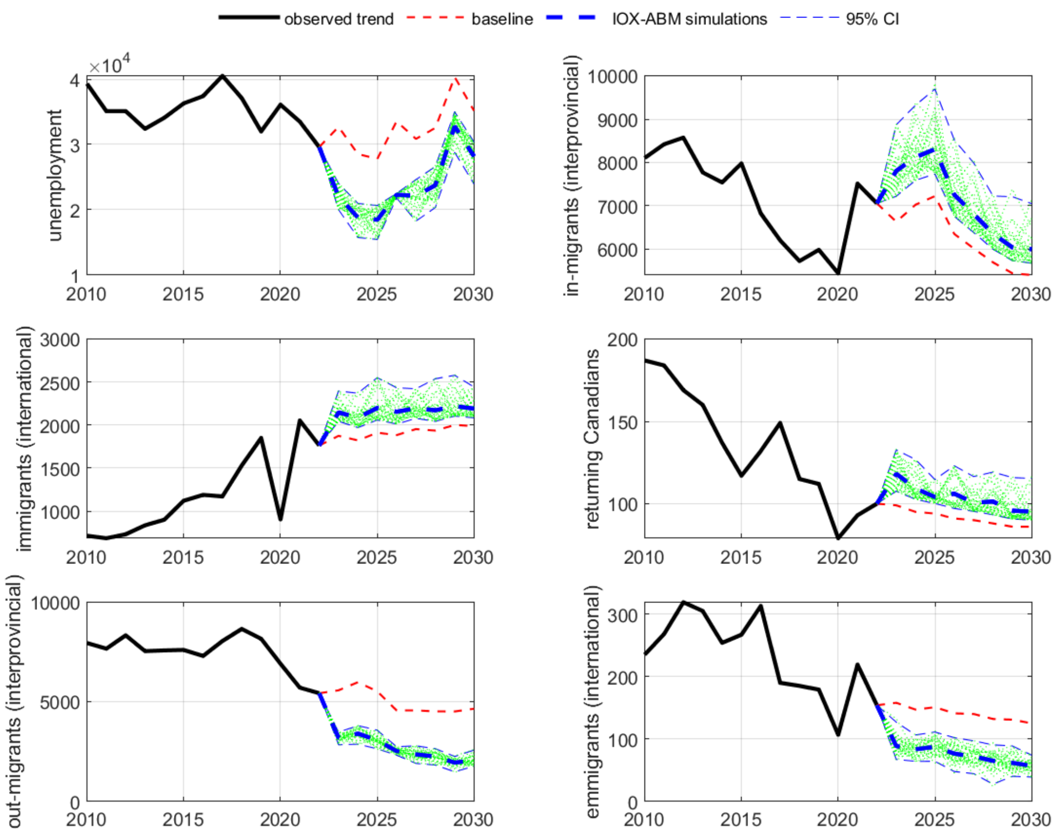
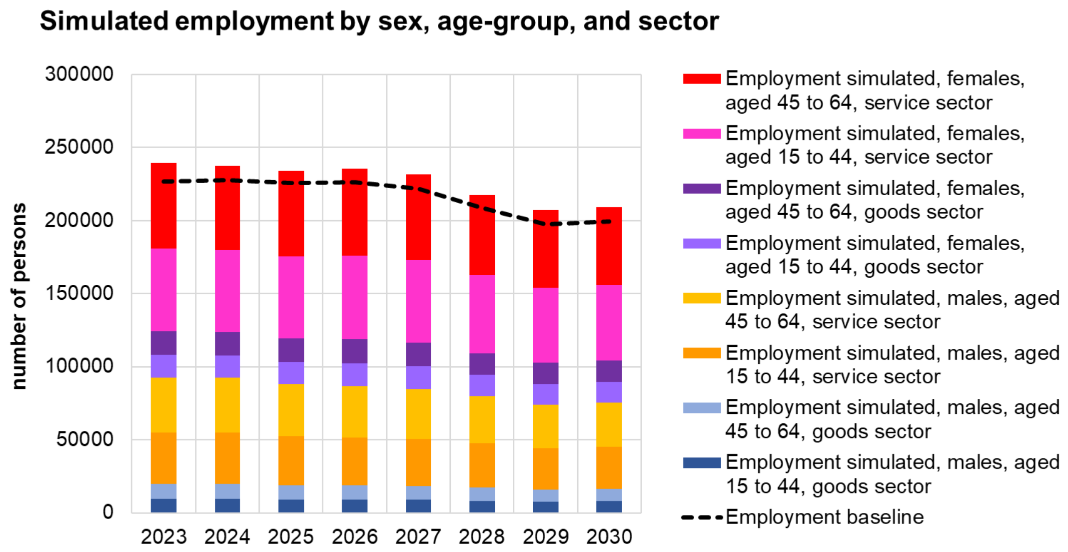


Figure 38a: Scenario 5 (Oil price = 147.27 USD/barrel, change in production = -2%)



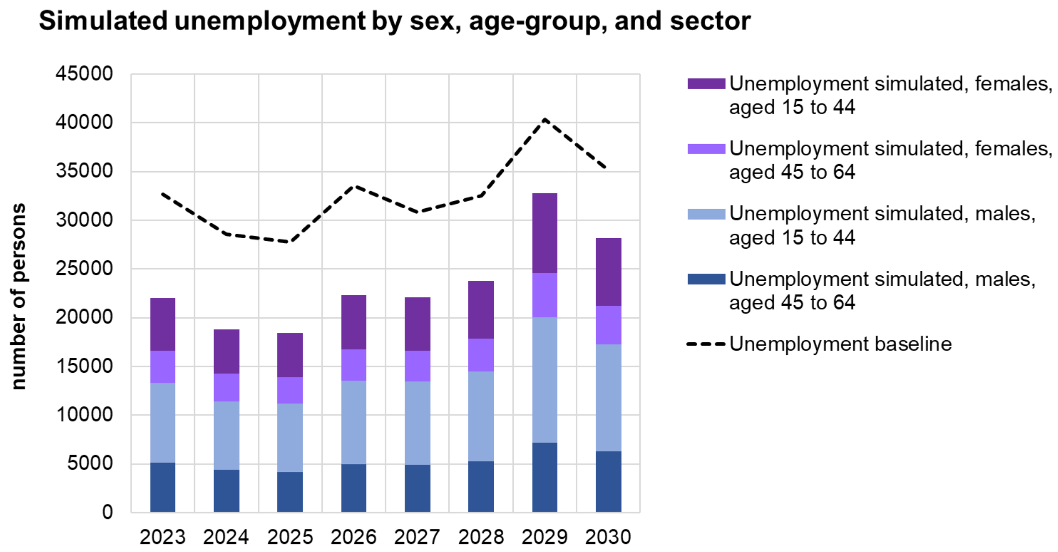


Figure 38b: Scenario 5 (Oil price = 147.27 USD/barrel, change in production = -2%)

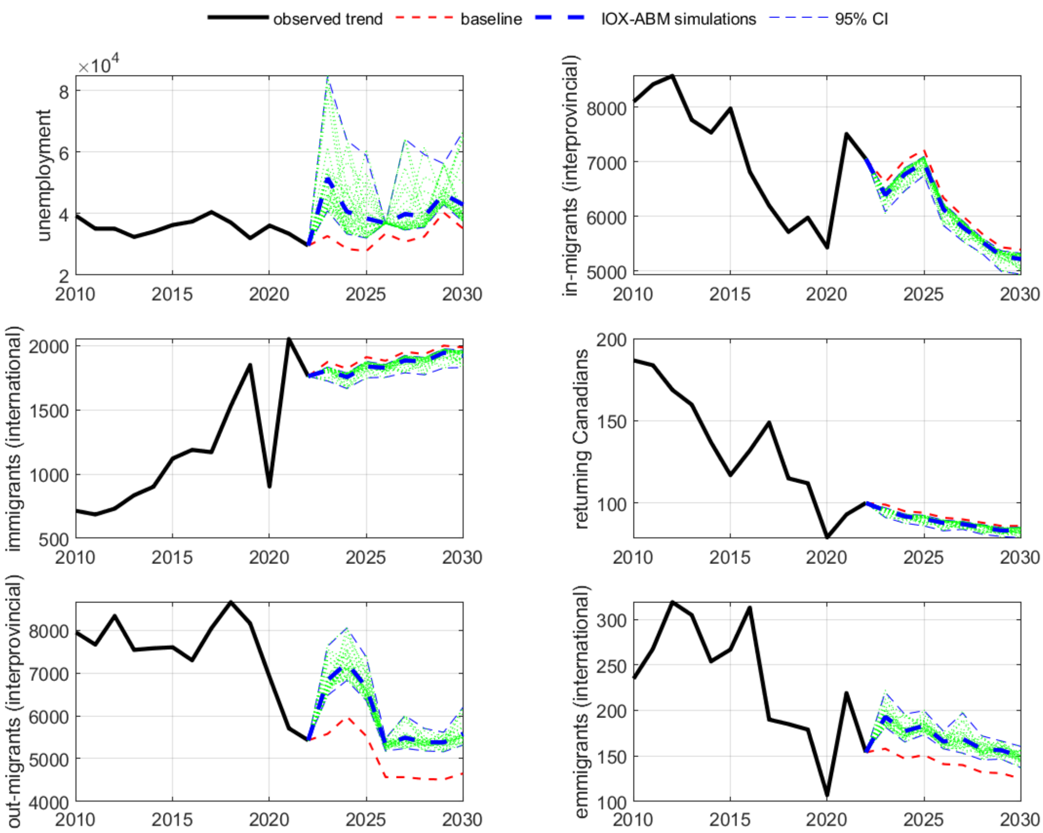


Figure 39a: Scenario 6 (Oil price = 40.32 USD/barrel, change in production = -2%)

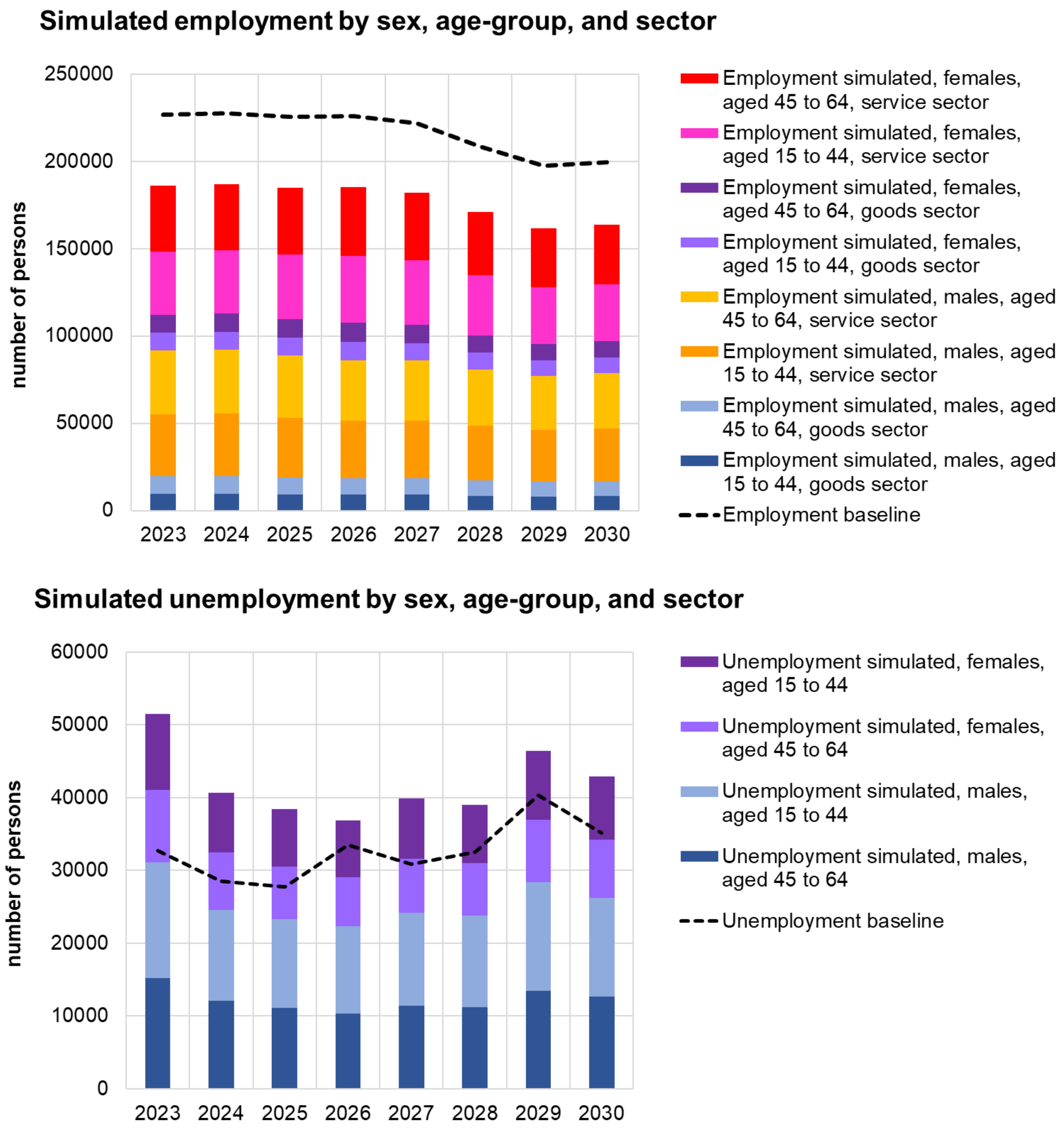


Figure 39b: Scenario 6 (Oil price = 40.32 USD/barrel, change in production = -2%)

Policy 2 is to reduce the production of oil and gas by 4%, depending on the energy market situation to replace that shortage, the prices vary therefore, scenarios 7 ,8, and 9 are presented below.

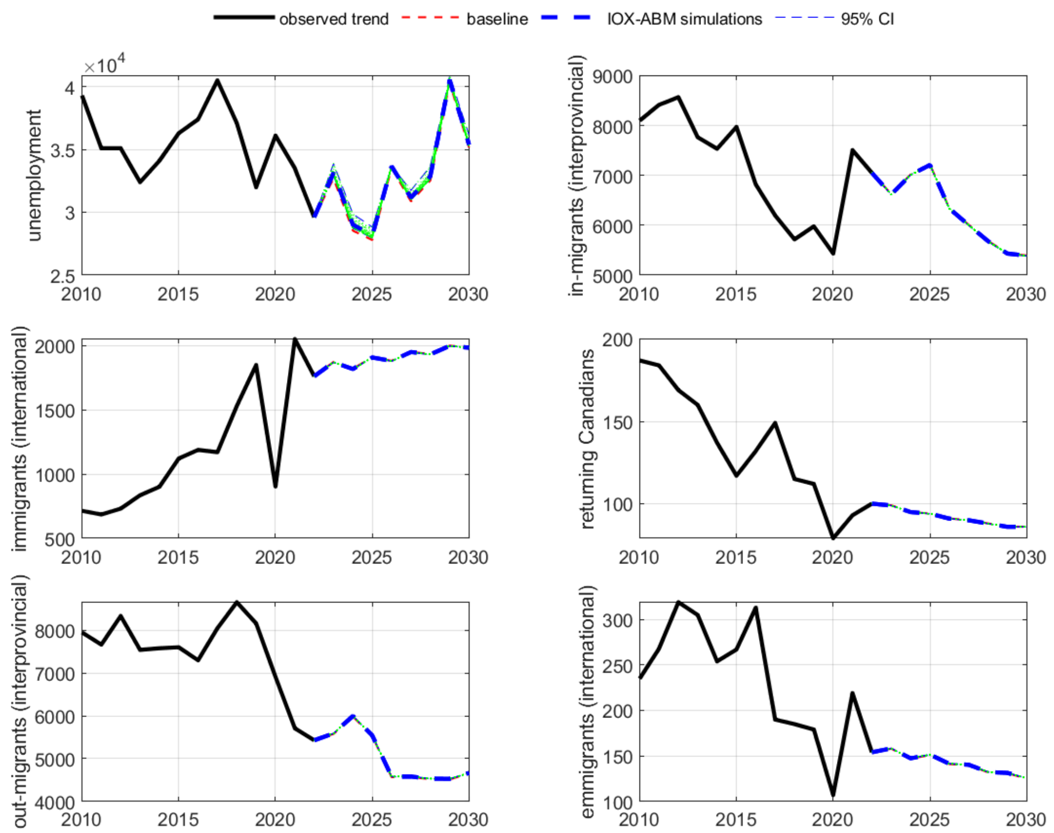
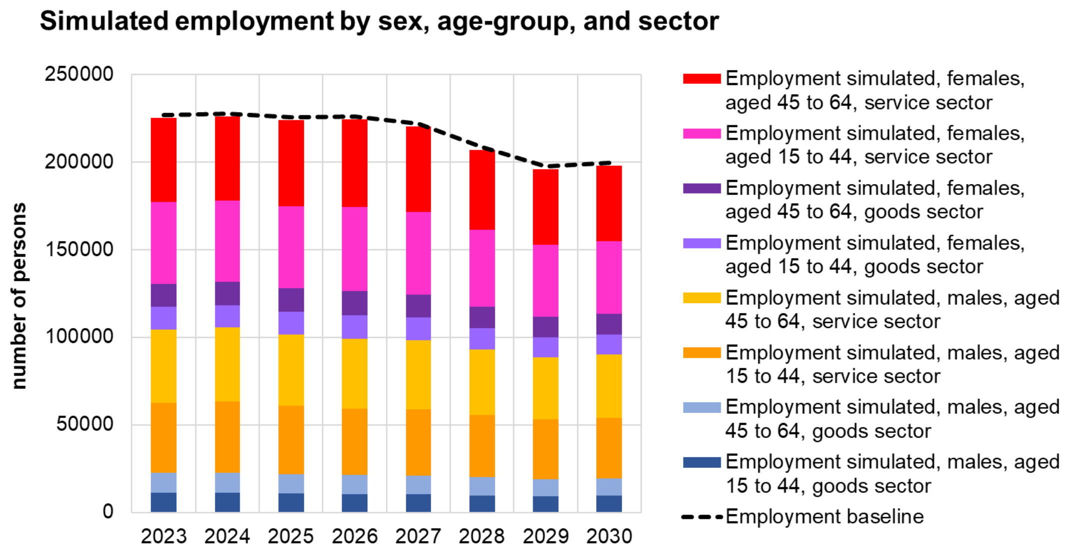


Figure 40a: Scenario 7 (Oil price = 65.83 USD/barrel, change in production = -4%)



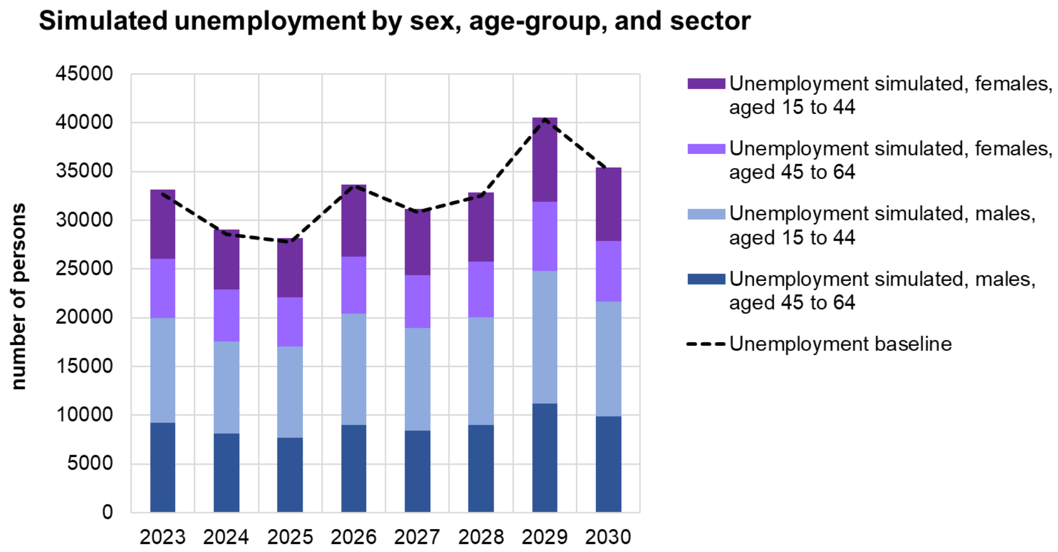


Figure 40b: Scenario 7 (Oil price = 65.83 USD/barrel, change in production = -4%)

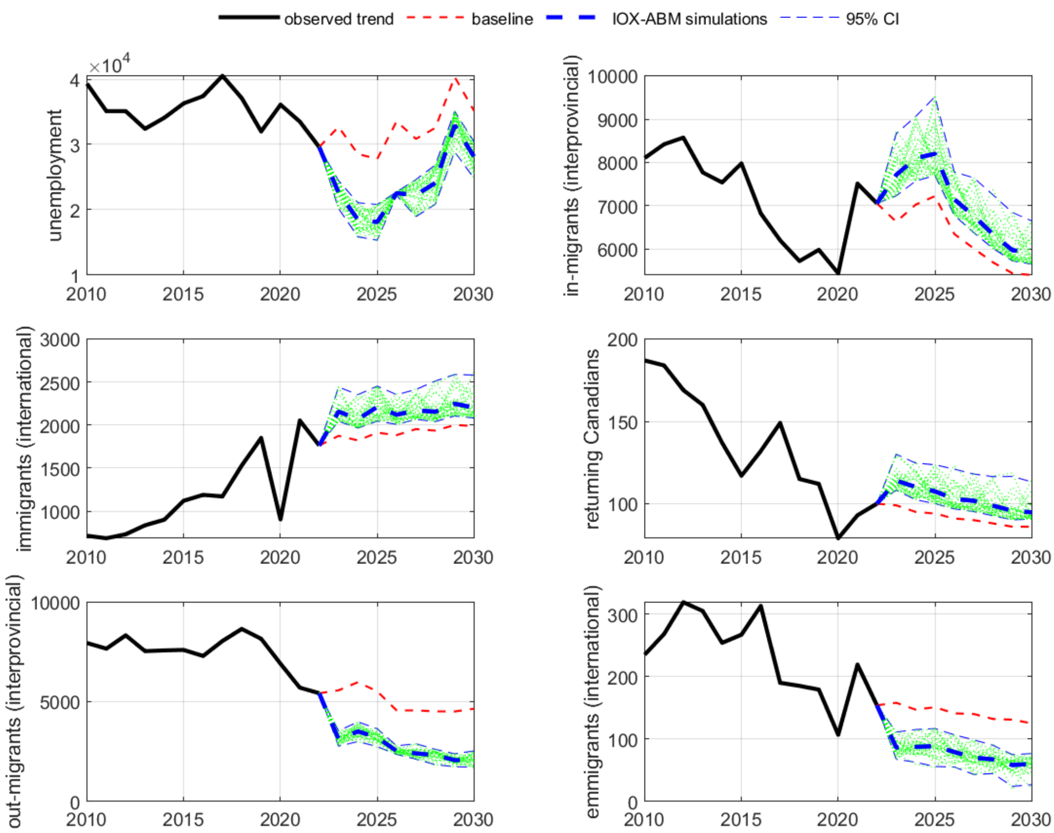
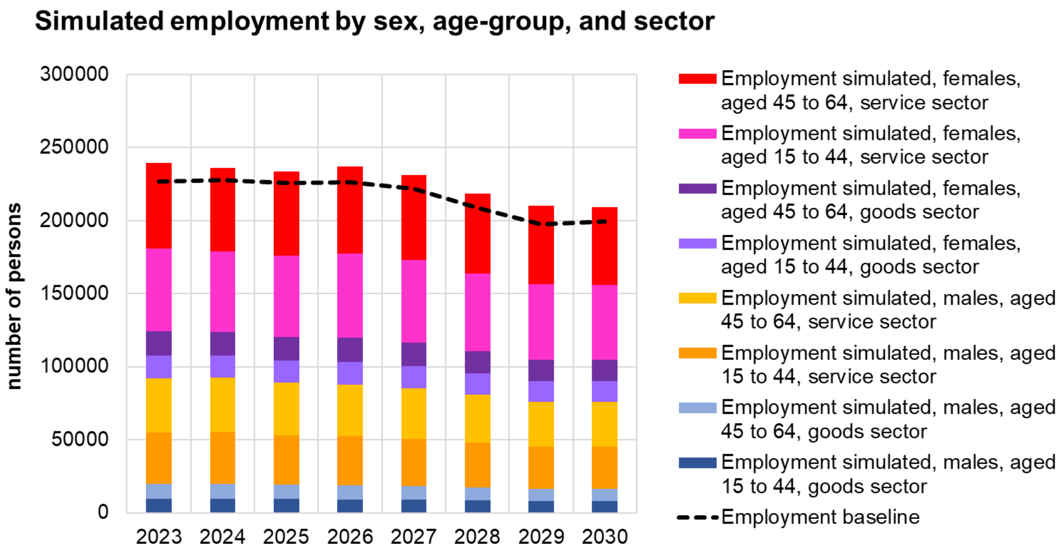


Figure 41a: Scenario 8 (Oil price = 147.27. USD/barrel, change in production = -4%)



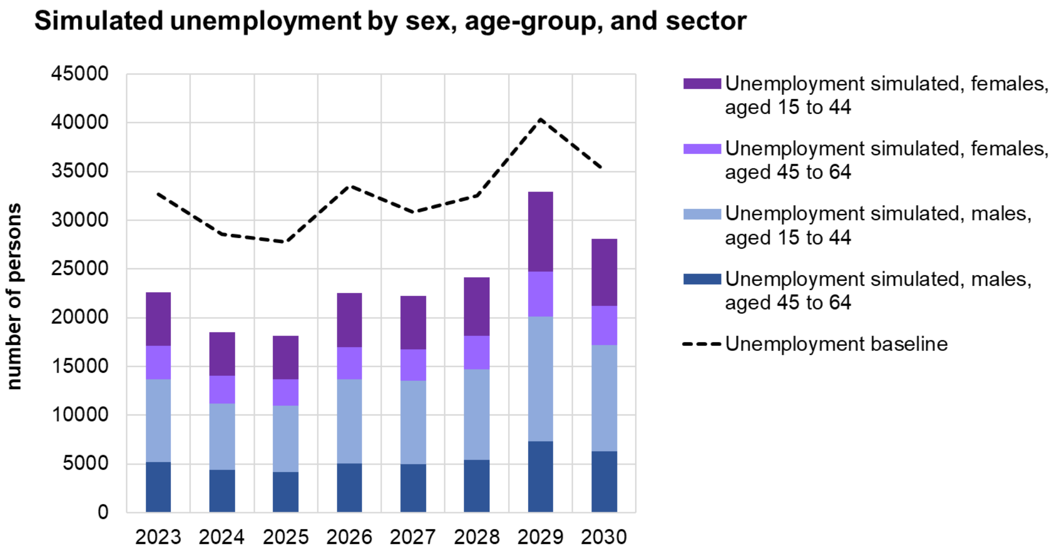


Figure 41b: Scenario 8 (Oil price = 147.27. USD/barrel, change in production = -4%)

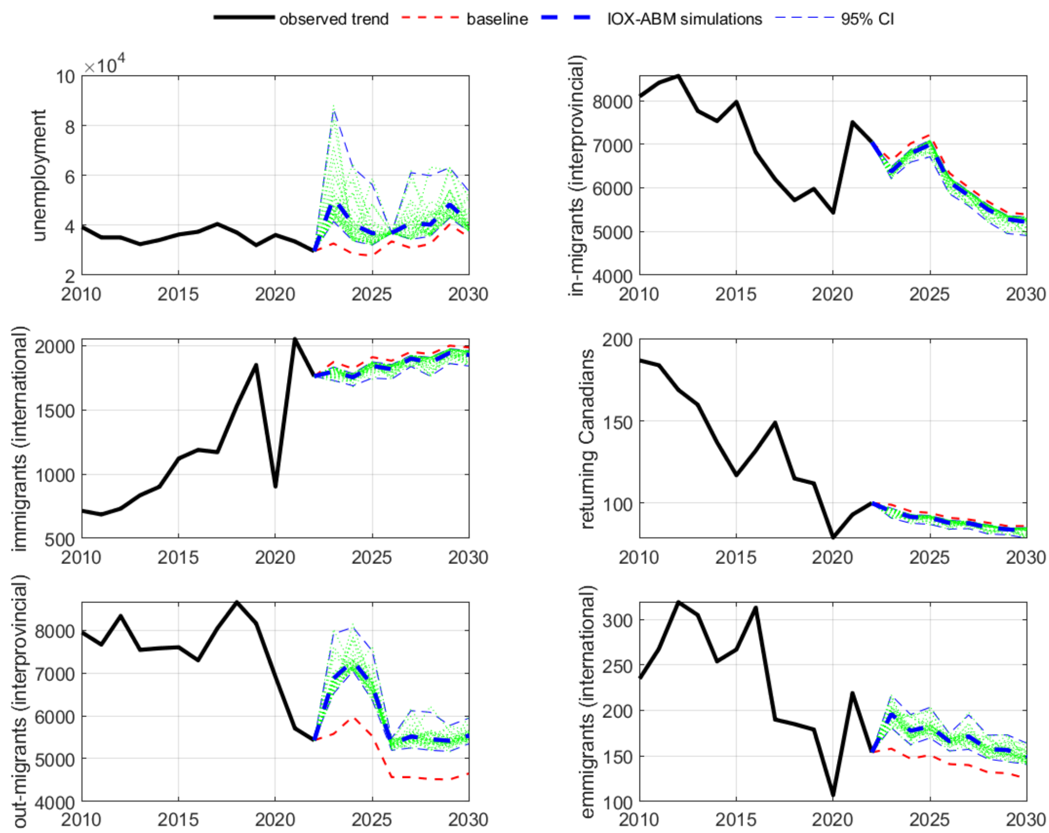
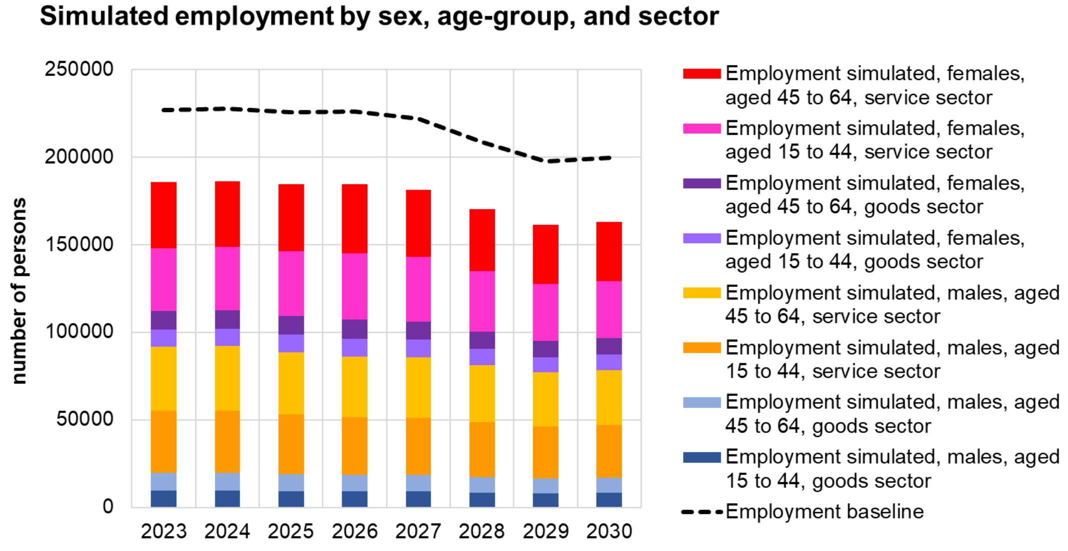


Figure 42a: Scenario 9 (Oil price = 40.32. USD/barrel, change in production = -4%)



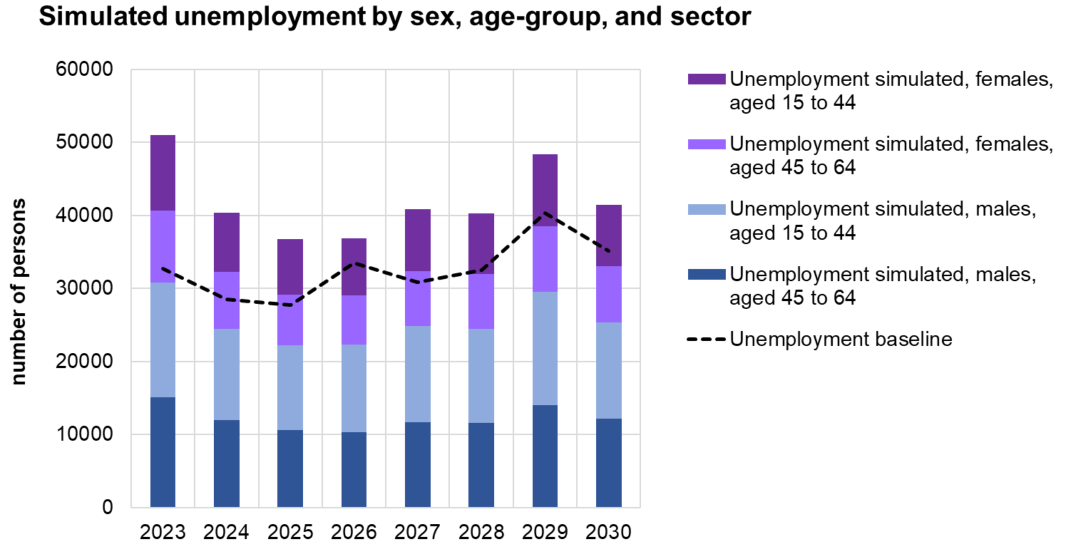


Figure 42b: Scenario 9 (Oil price = 40.32 USD/barrel, change in production = -4%)

Policy 3 is to reduce the production of oil and gas by 6%, depending on the energy market situation to replace that shortage. The price varies, therefore scenarios 10 ,11, and 12 are presented below.

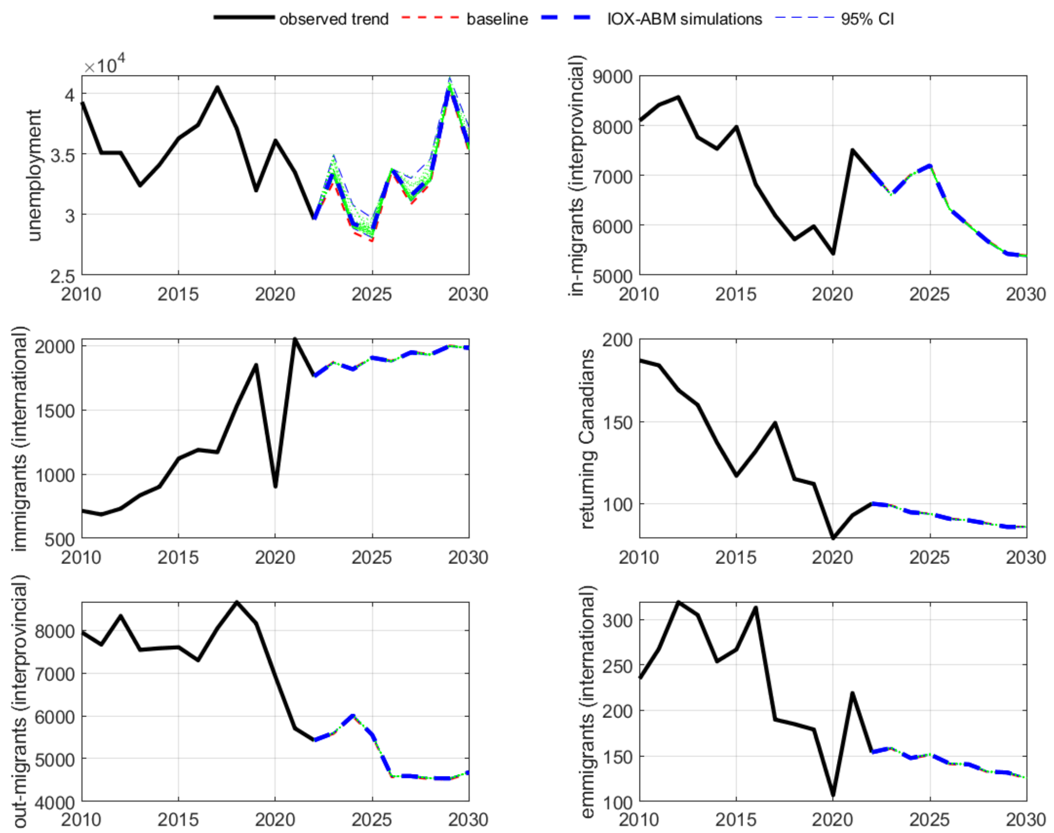
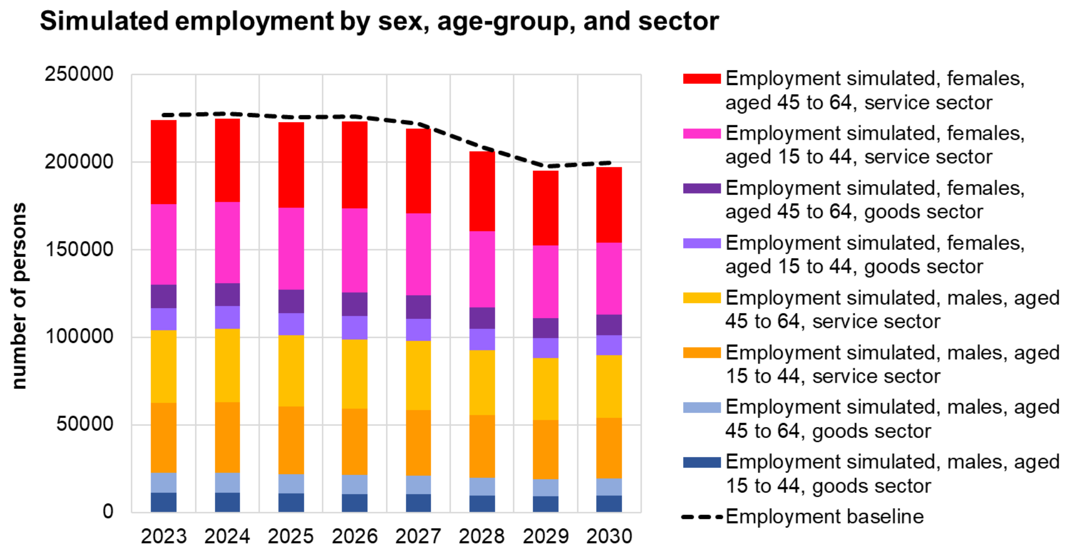


Figure 43a: Scenario 10 (Oil price = 65.83 USD/barrel, change in production = -6%)



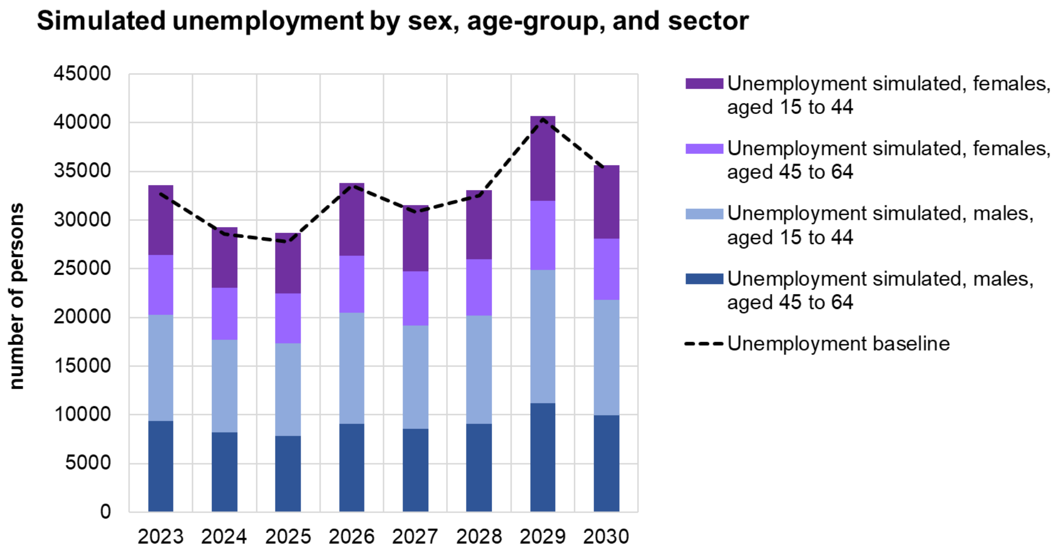


Figure 43b: Scenario 10 (Oil price = 65.83 USD/barrel, change in production = -6%)

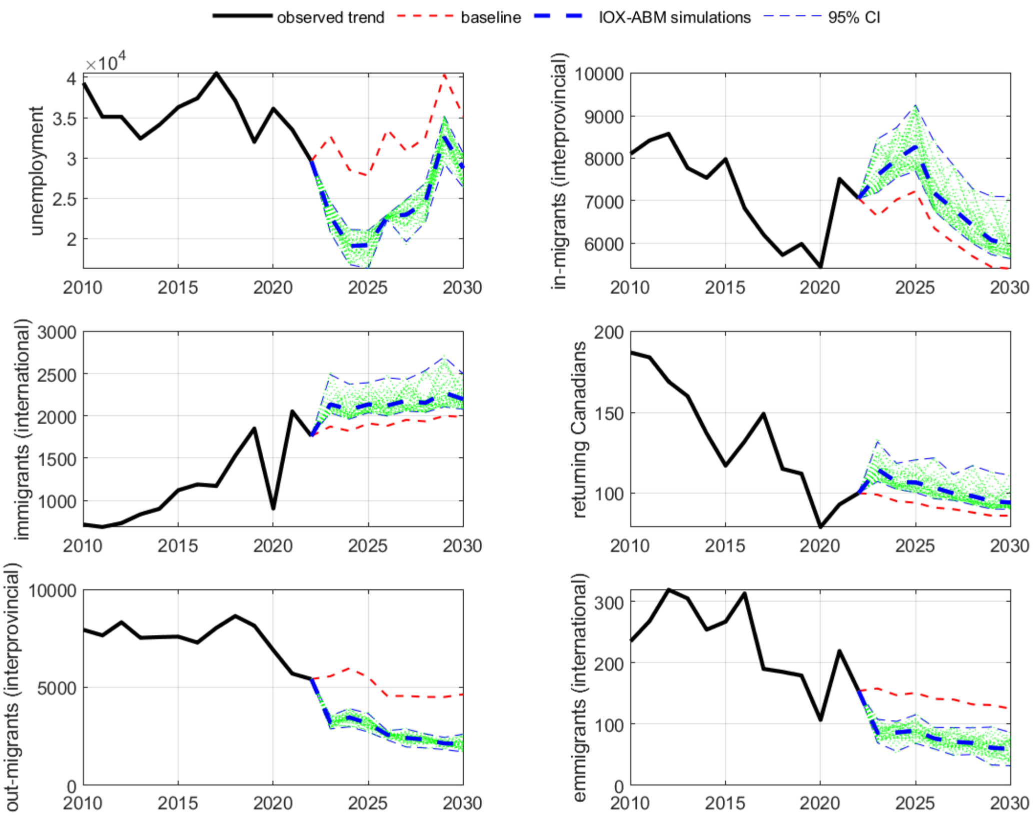


Figure 44a: Scenario 11 (Oil price = 147.27 USD/barrel, change in production = -6%)

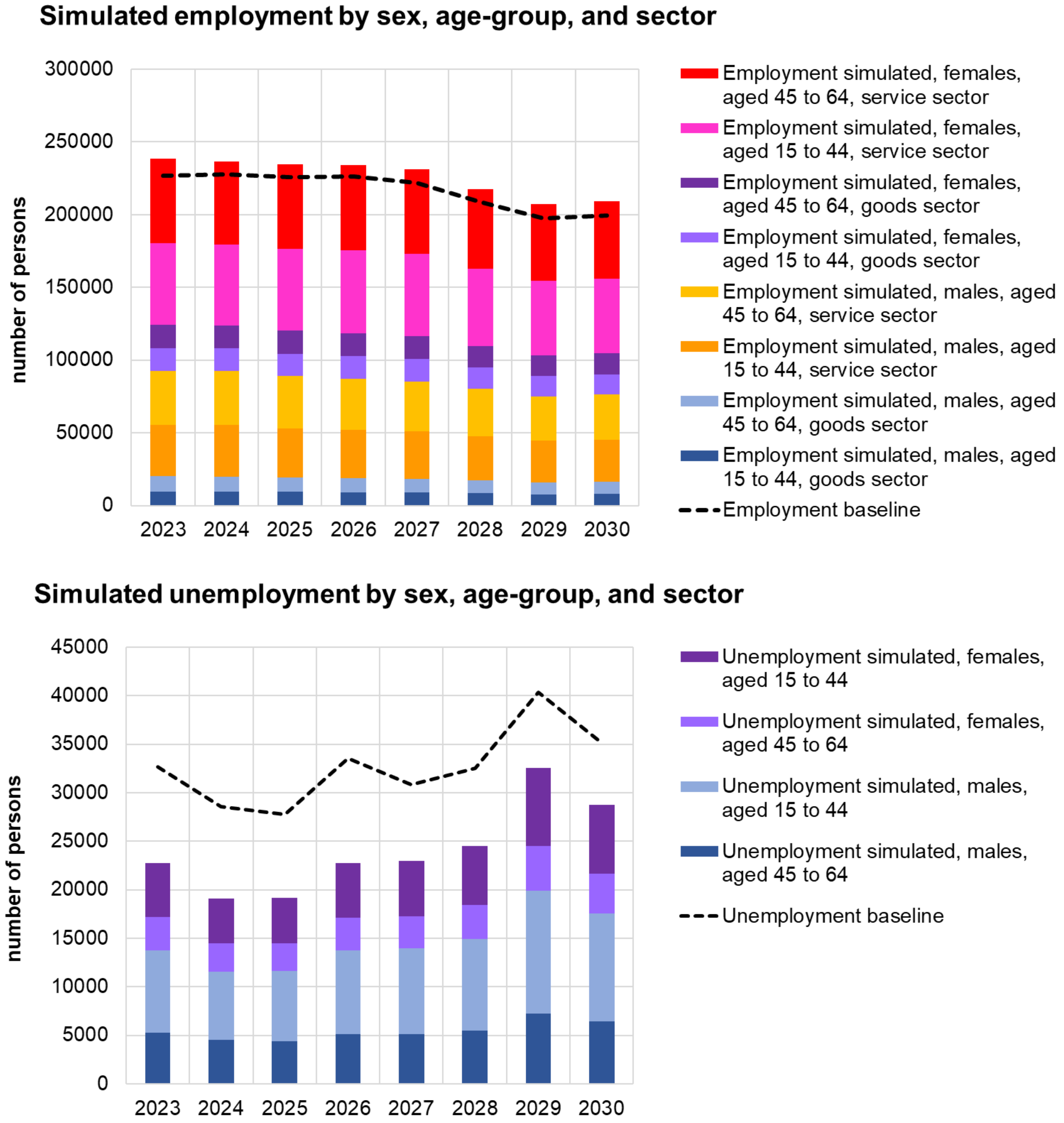


Figure 45b: Scenario 11 (Oil price = 147.27. USD/barrel, change in production = -6%)

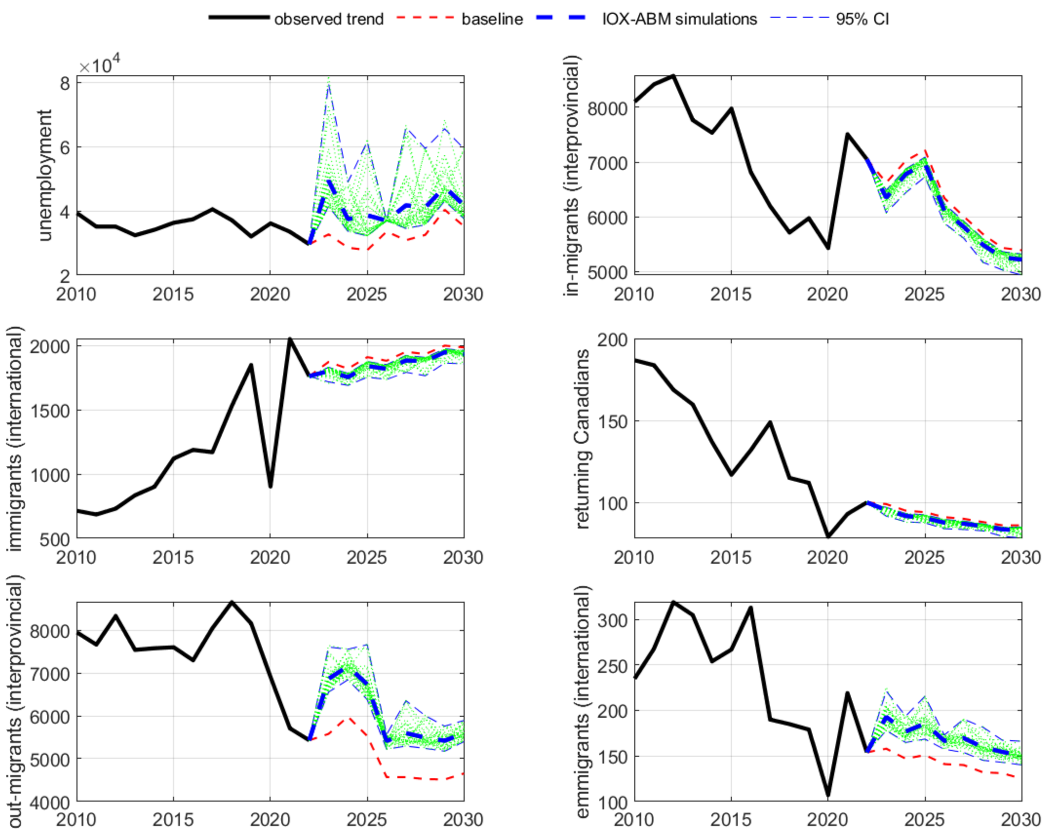
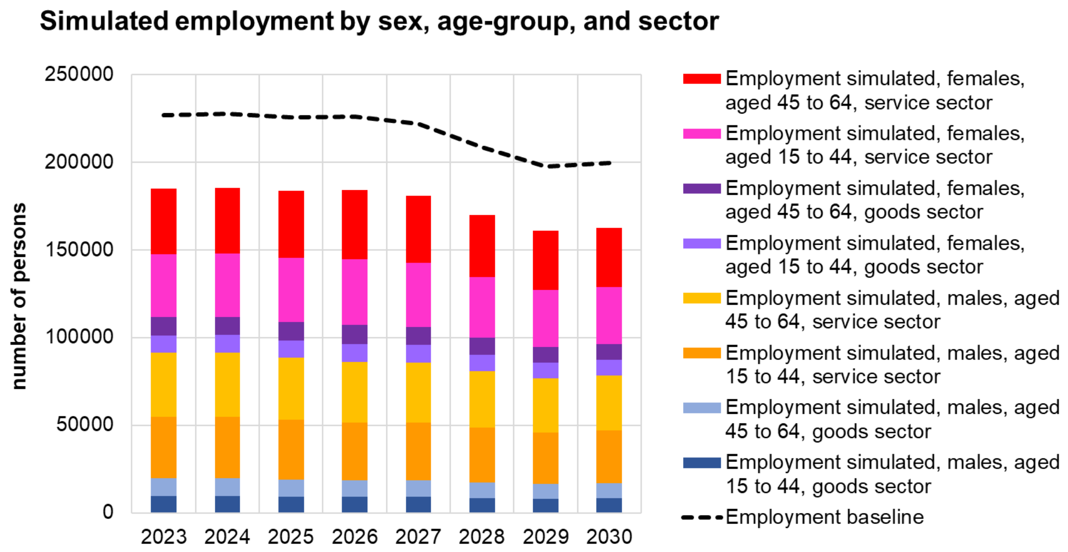


Figure 45a: Scenario 12 (Oil price = 40.32 USD/barrel, change in production = -6%)



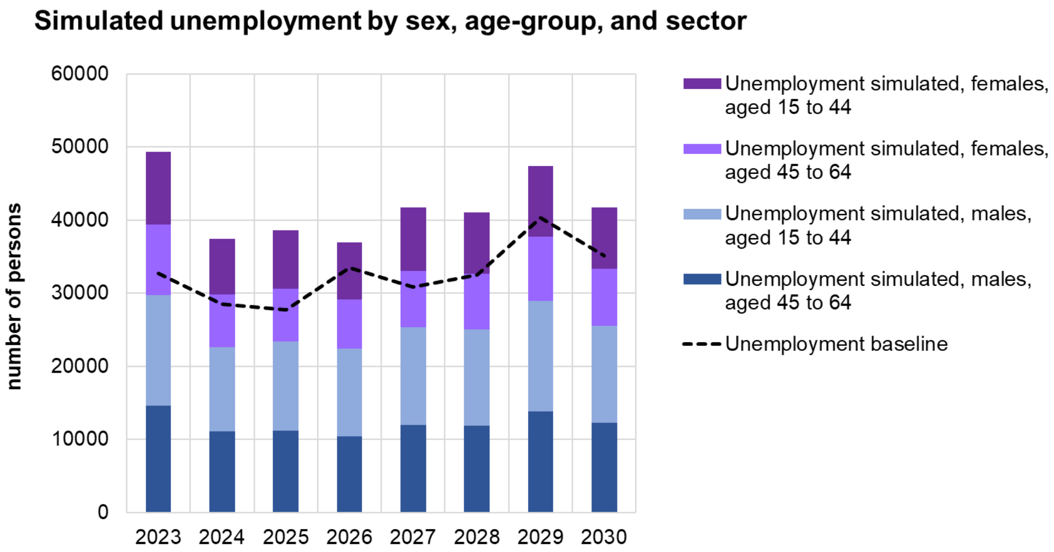


Figure 45b: Scenario 12 (Oil price = 40.32 USD/barrel, change in production = -6%)

Degrowth scenarios:

Policy 4 is to reduce the production of oil and gas by 12%, depending on the energy market situation to replace that shortage. The price varies, therefore, scenarios 13 ,14, and 15 are presented below.

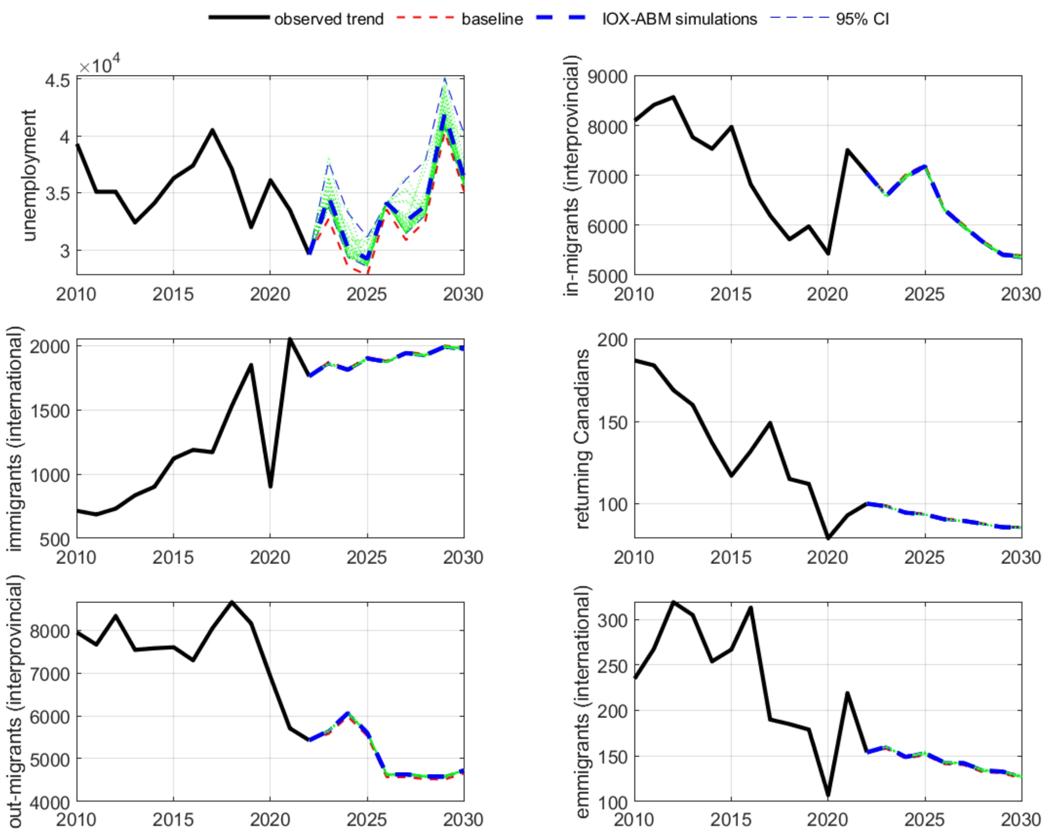
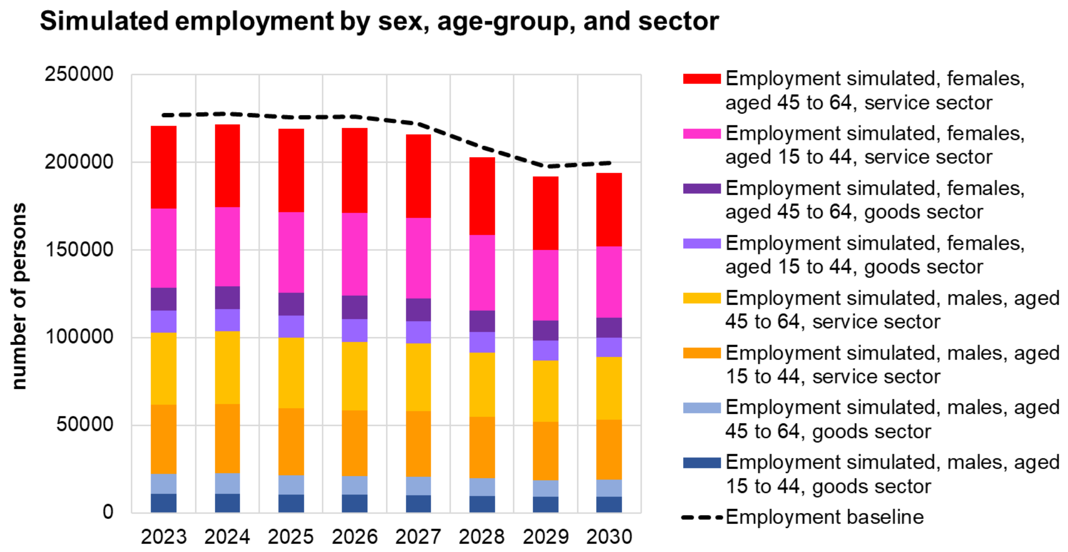


Figure 46a: Scenario 13 (Oil price = 65.83 USD/barrel, change in production = -12%)



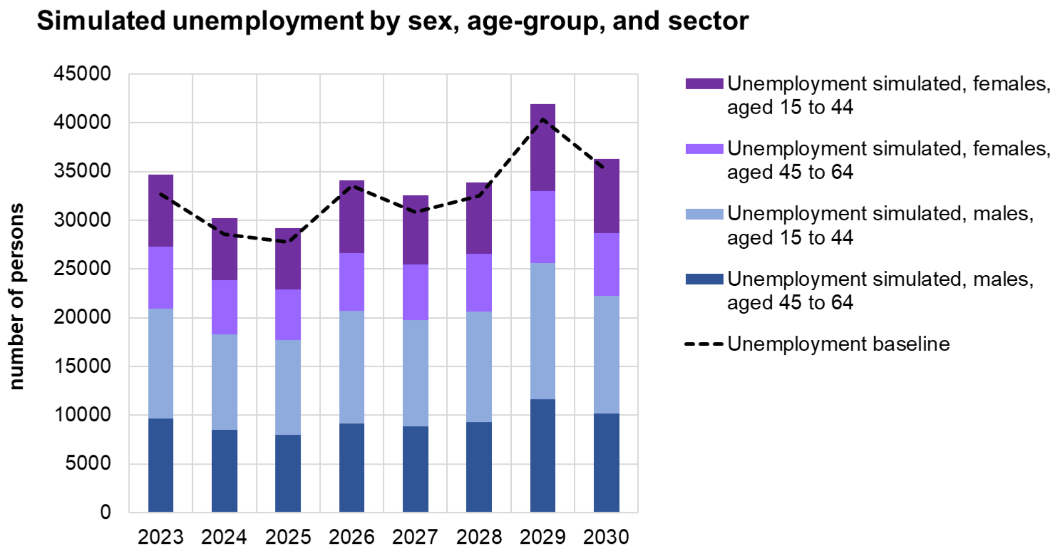


Figure 46b: Scenario 13 (Oil price = 65.83 USD/barrel, change in production = -12%)

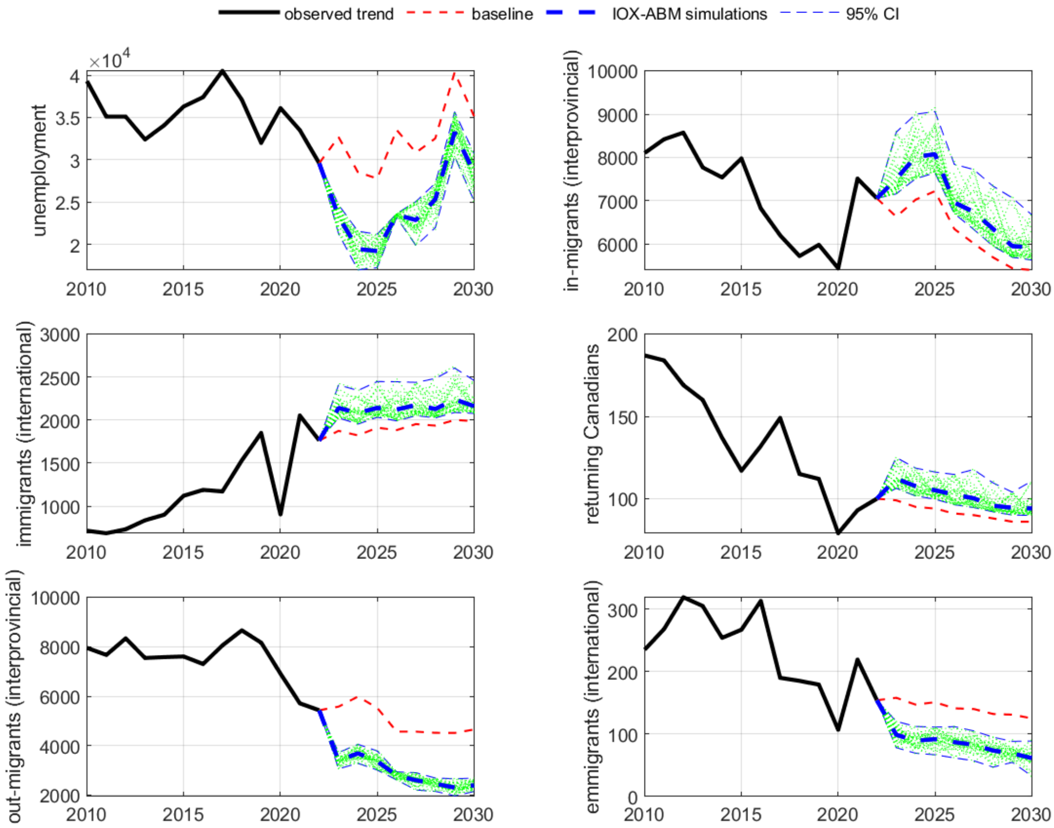
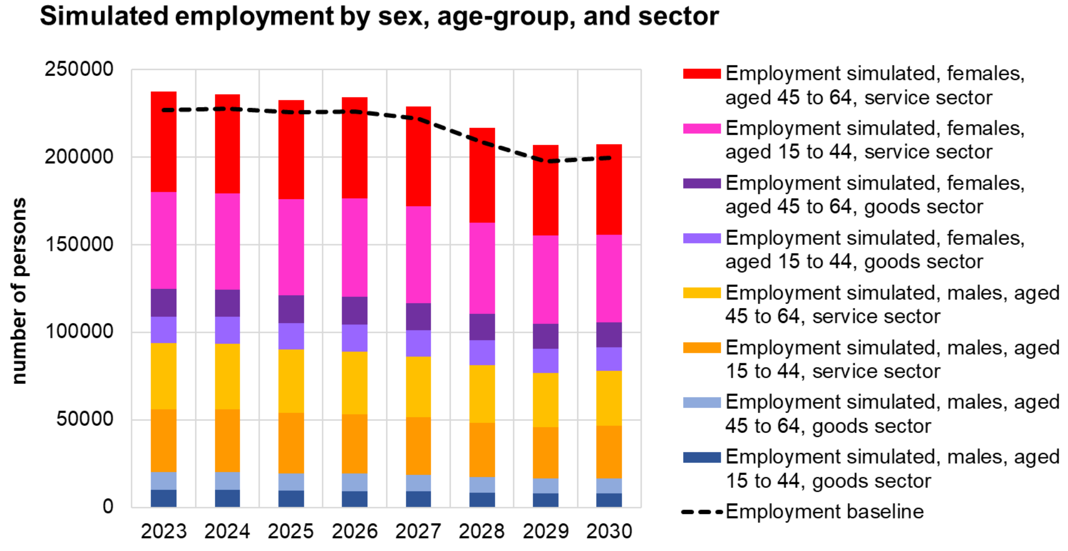


Figure 47a: Scenario 14 (Oil price = 147.27 USD/barrel, change in production = -12%)



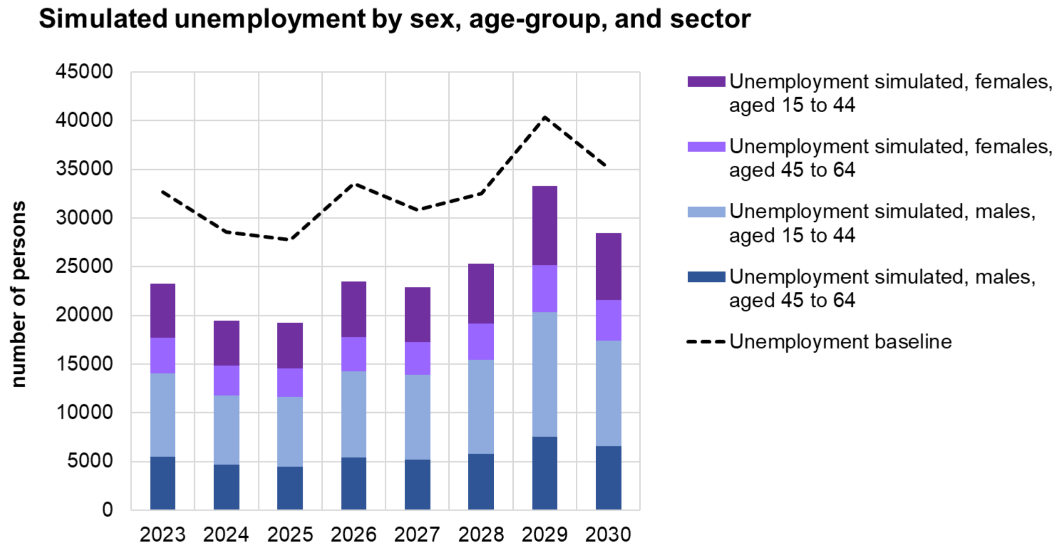


Figure 47b: Scenario 14 (Oil price = 147.27 USD/barrel, change in production = -12%)

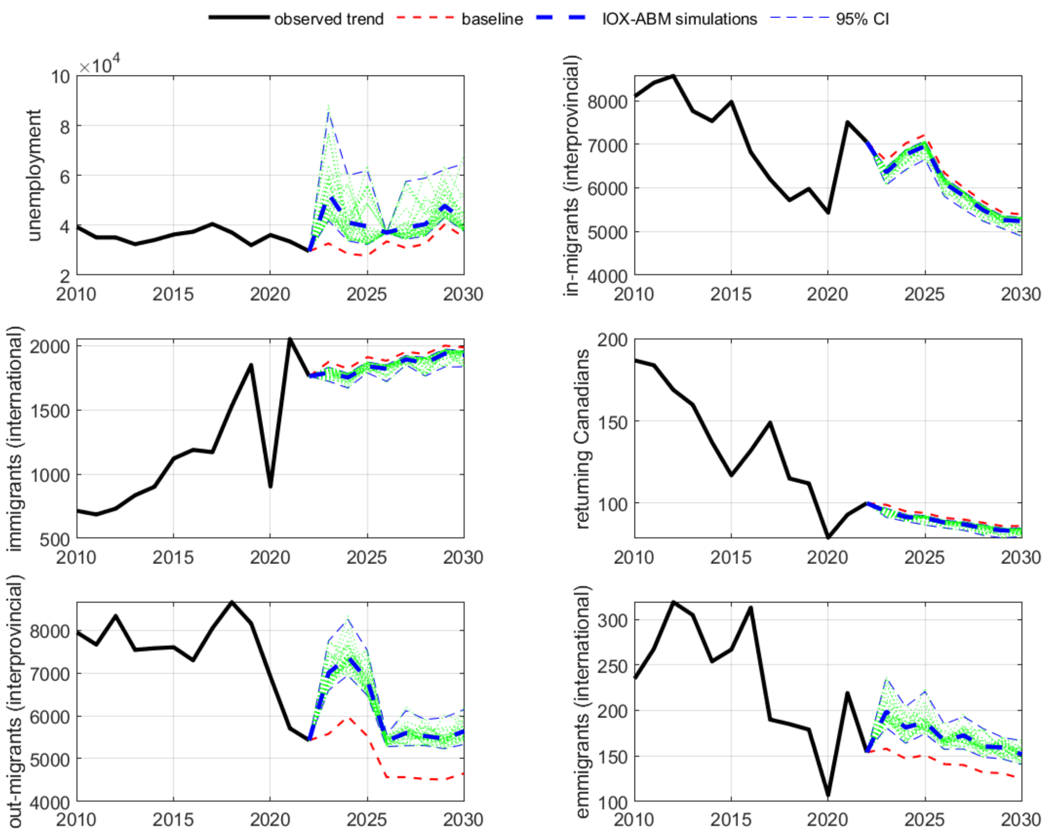


Figure 48a: Scenario 15 (Oil price = 40.32. USD/barrel, change in production = -12%)

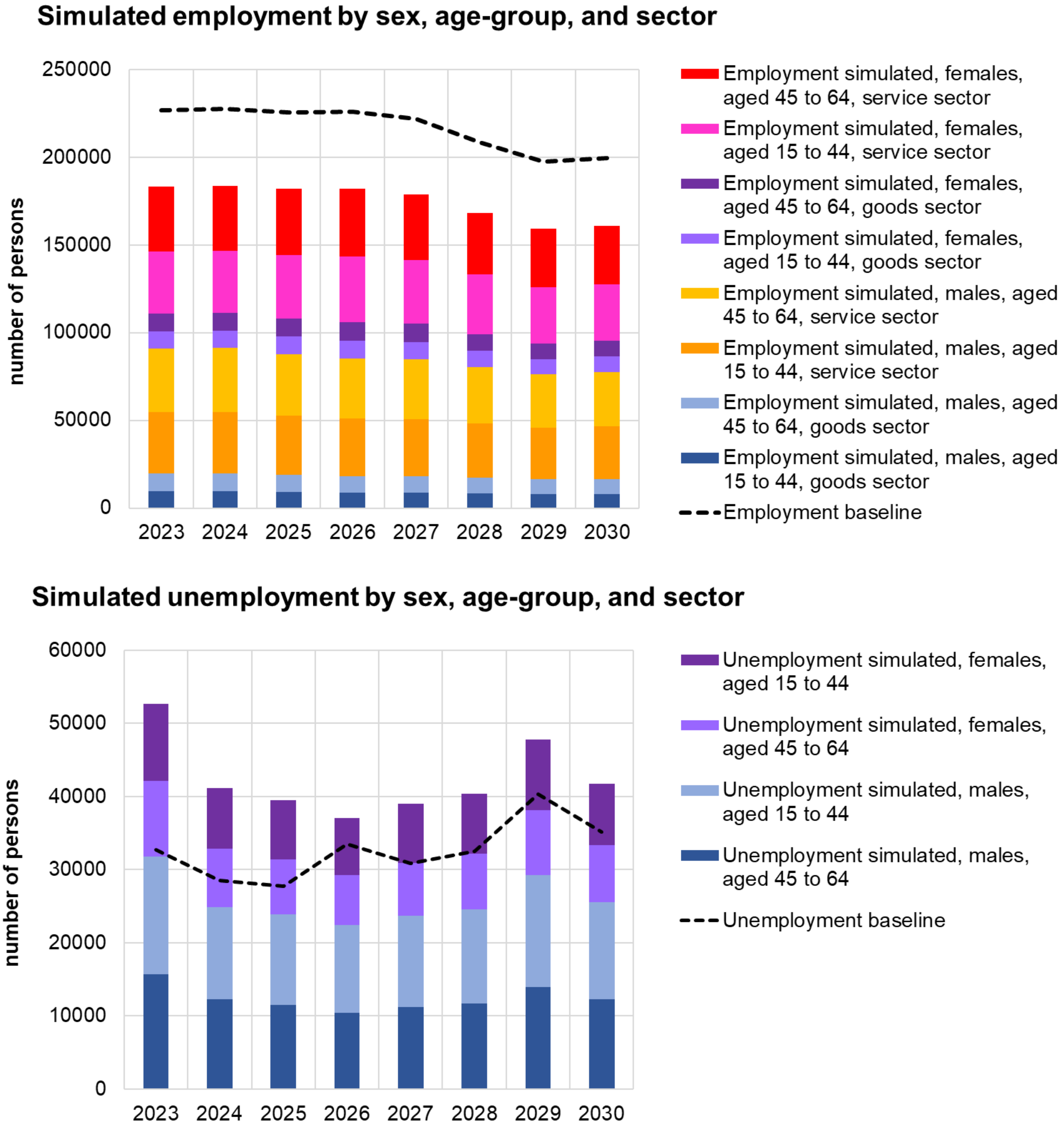


Figure 48b: Scenario 15 (Oil price = 40.32 USD/barrel, change in production = -12%)

Policy 5 is to reduce the production of oil and gas by 18%, depending on the energy market situation to replace that shortage. The price varies, therefore scenarios 16 ,17, and 18 are presented below.

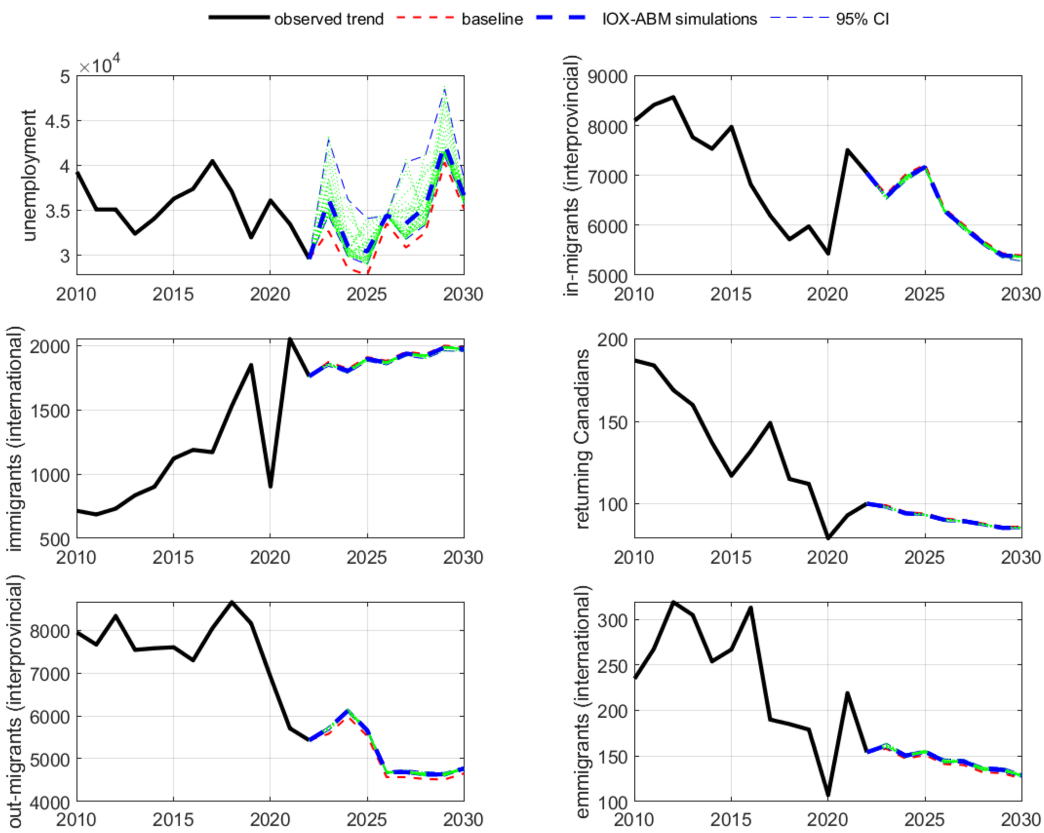
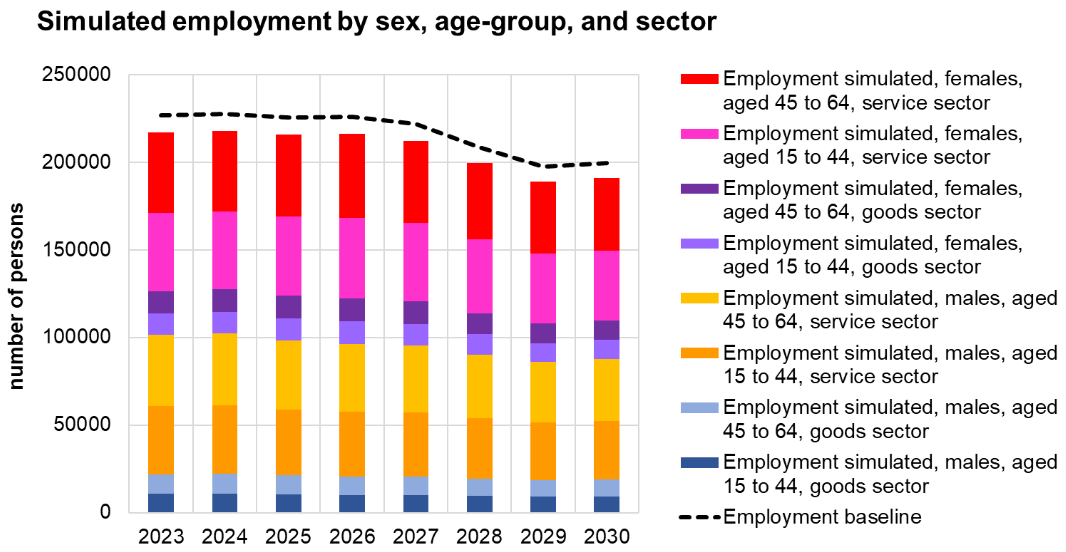


Figure 49a: Scenario 16 (Oil price = 65.83 USD/barrel, change in production = -18%)



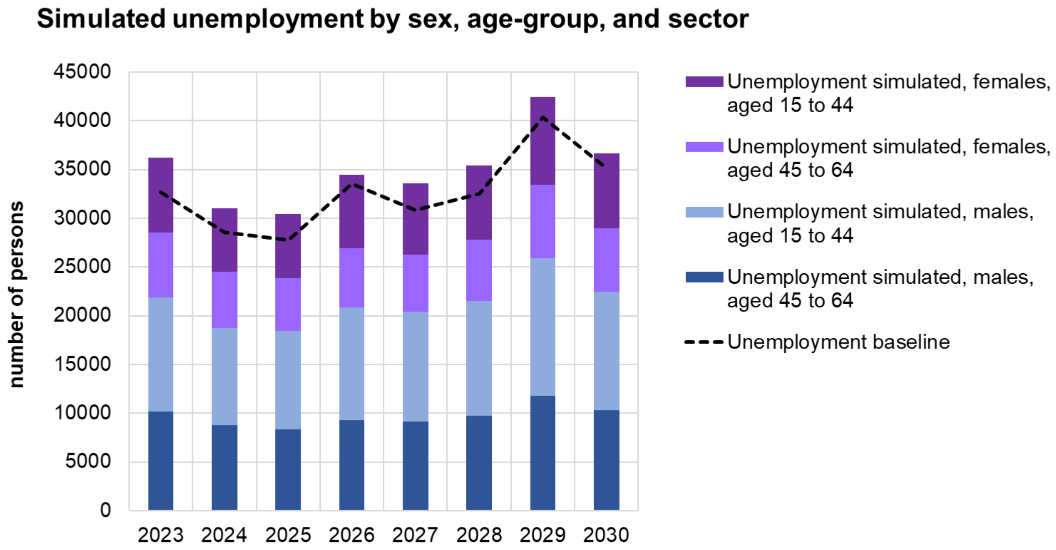


Figure 49b: Scenario 16 (Oil price = 65.83 USD/barrel, change in production = -18%)

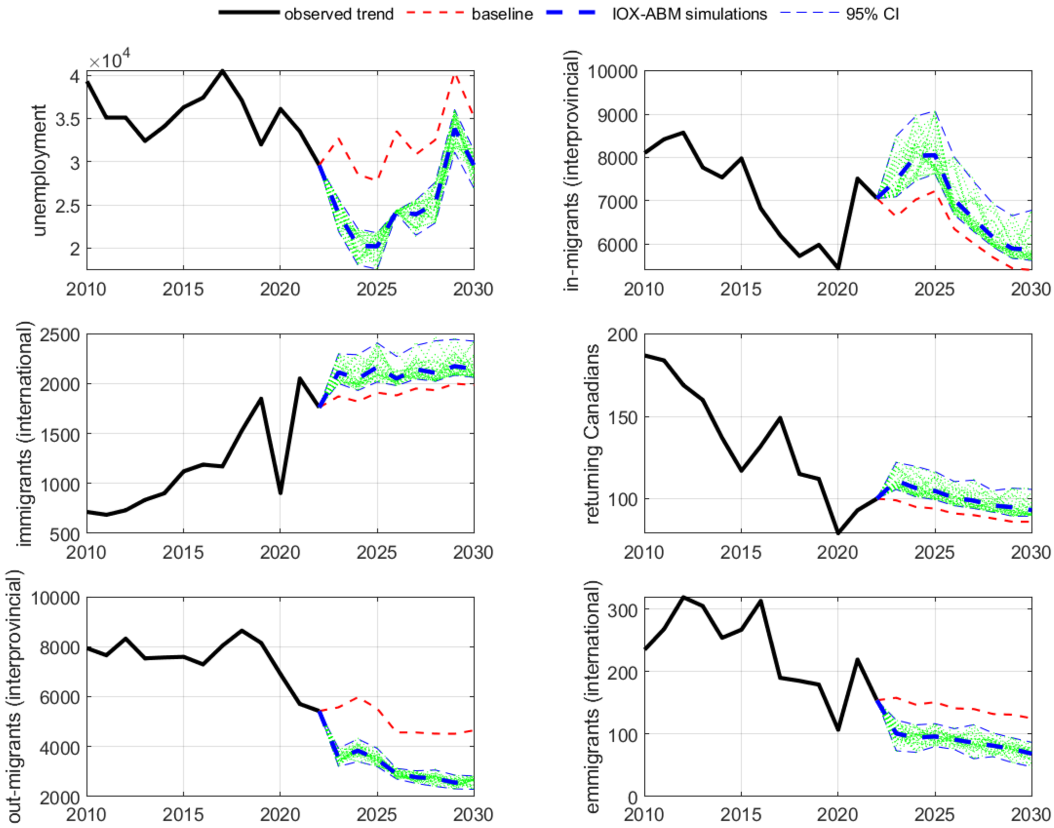


Figure 50a: Scenario 17 (Oil price = 147.27 USD/barrel, change in production = -18%)

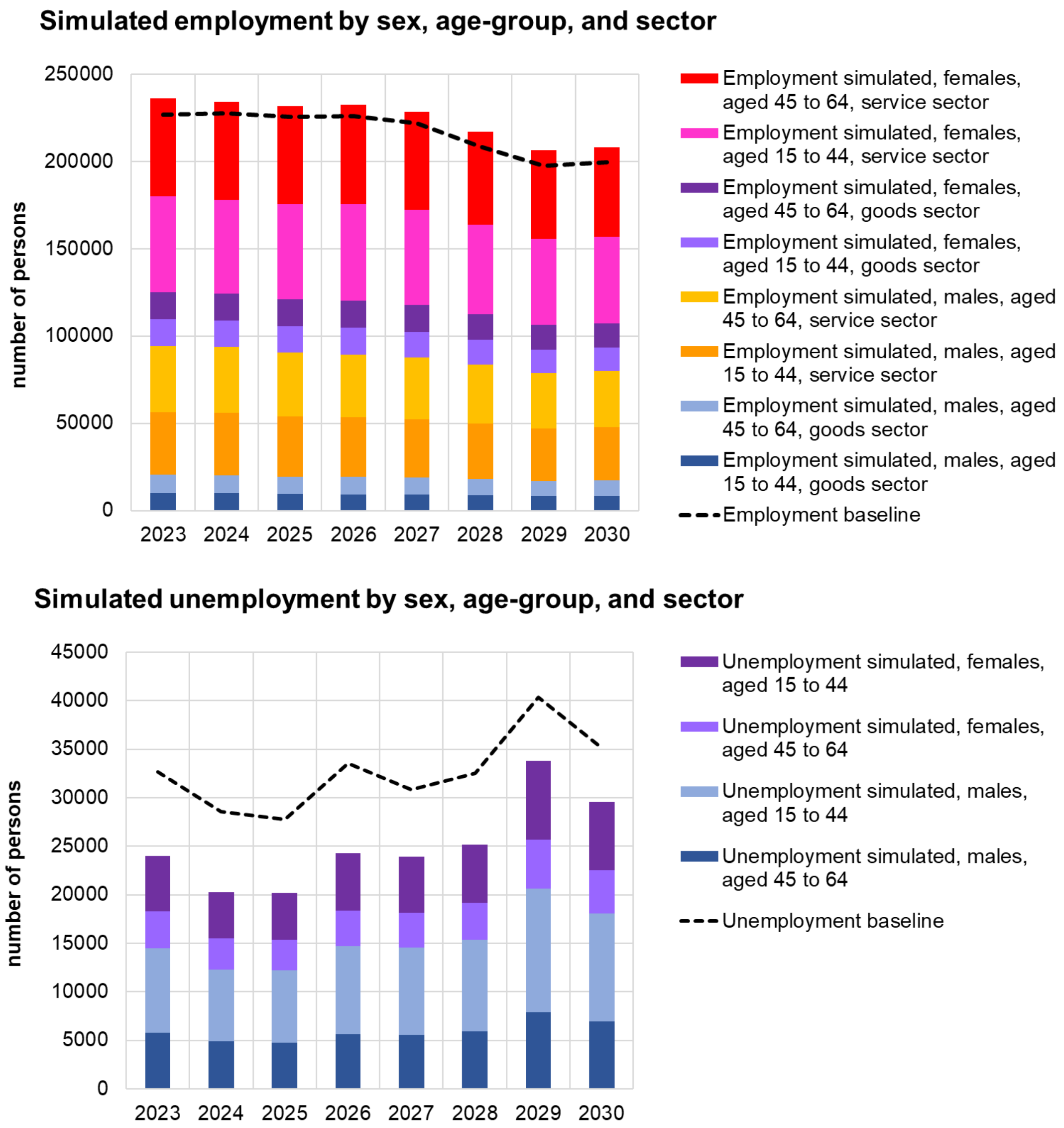


Figure 50b: Scenario 17 (Oil price = 147.27 USD/barrel, change in production = -18%)

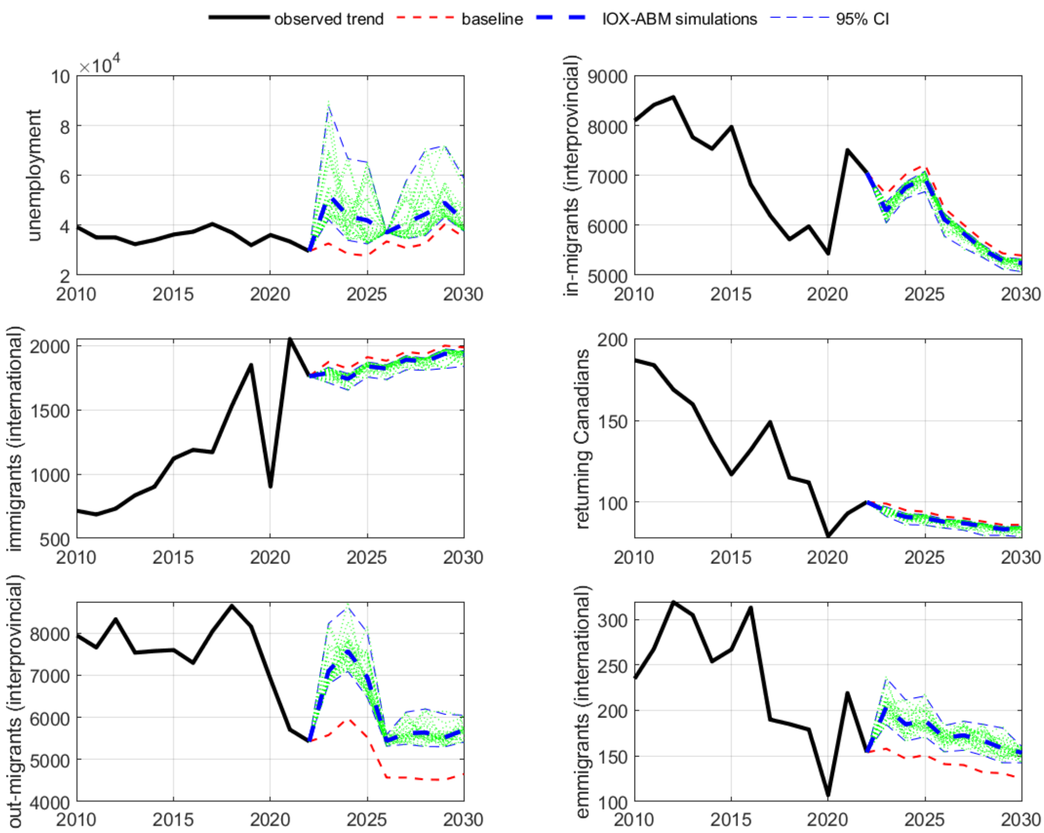


Figure 51a: Scenario 18 (Oil price = 40.32. USD/barrel, change in production = -18%)

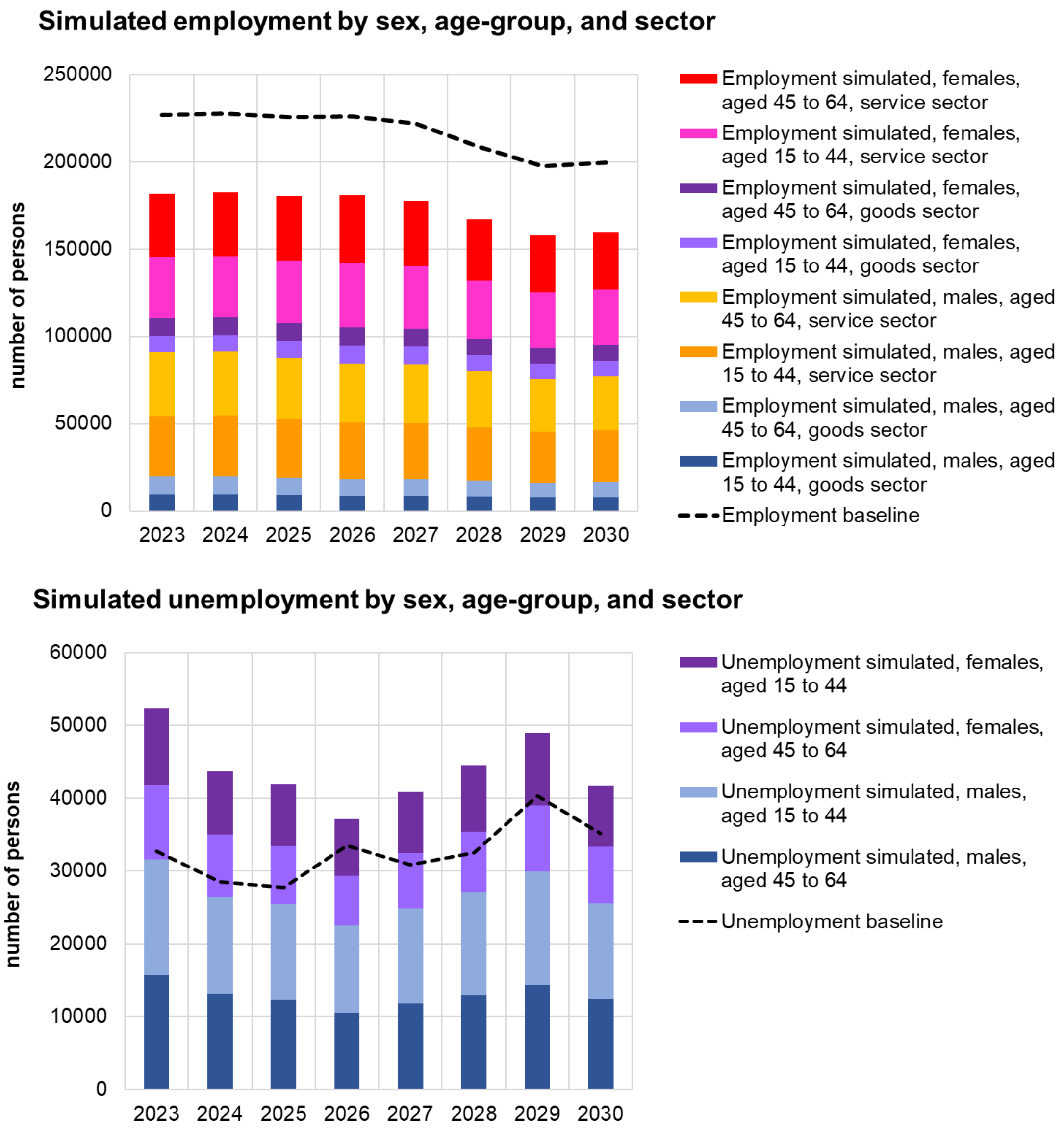


Figure 51b: Scenario 18 (Oil price = 40.32 USD/barrel, change in production = -18%)

Policy 6 is to reduce the production of oil and gas by 24%, depending on the energy market situation to replace that shortage. The prices vary, therefore scenarios 19 ,20, and 21 are presented below.

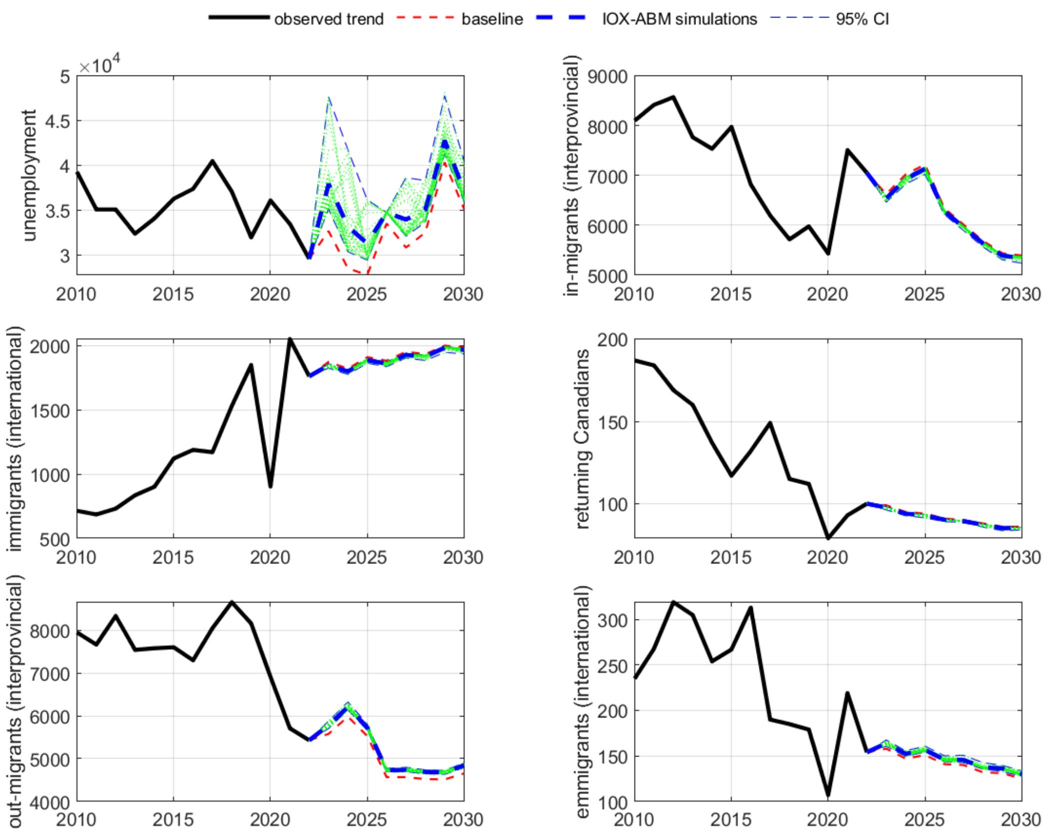
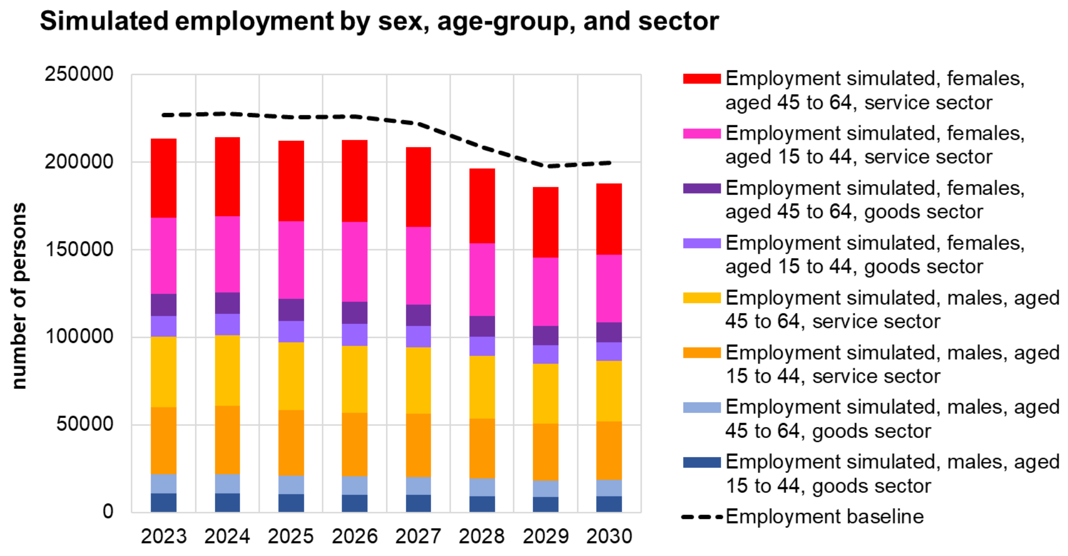


Figure 52a: Scenario 19 (Oil price = 65.83 USD/barrel, change in production = -24%)



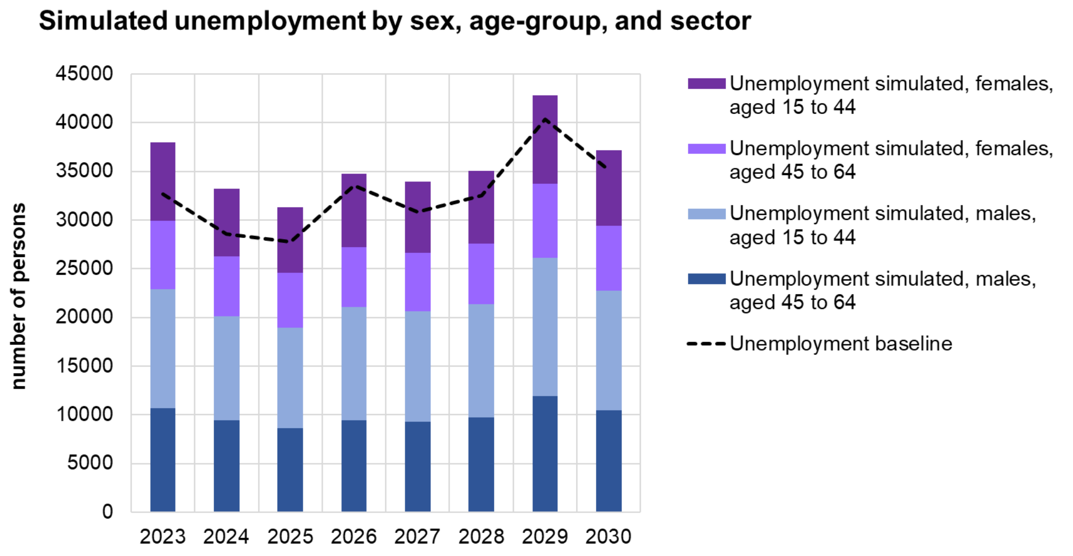


Figure 52b: Scenario 19 (Oil price = 65.83 USD/barrel, change in production = -24%)

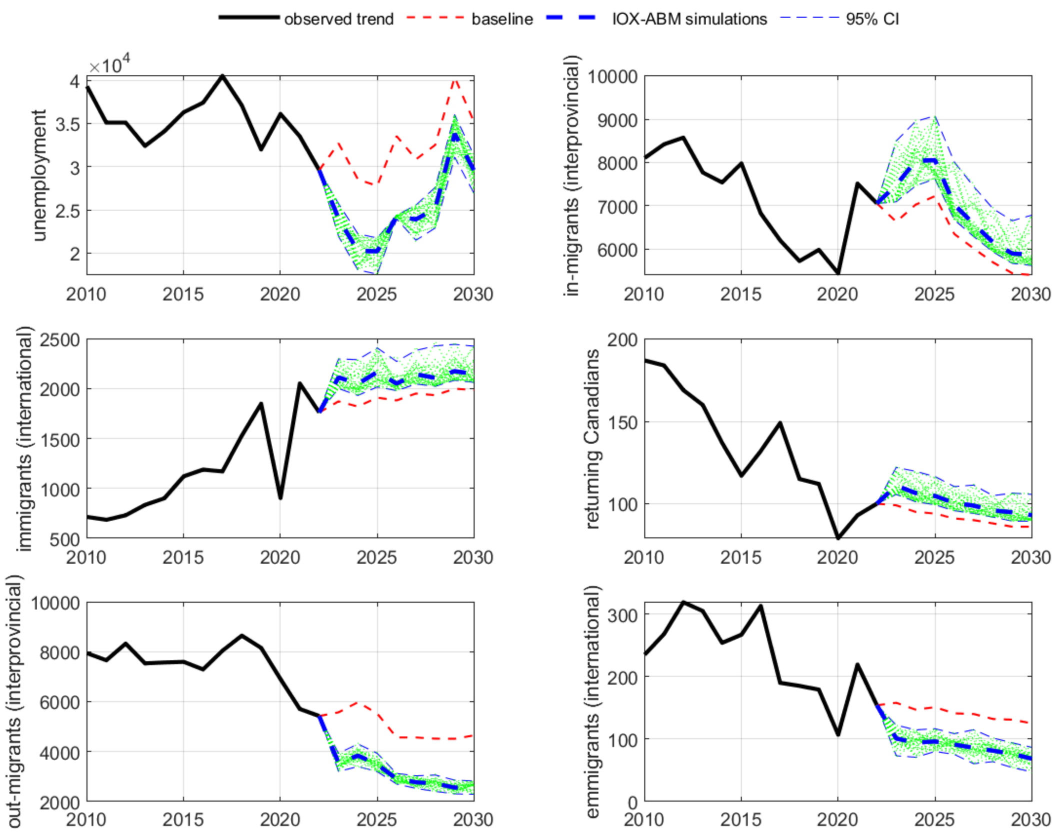
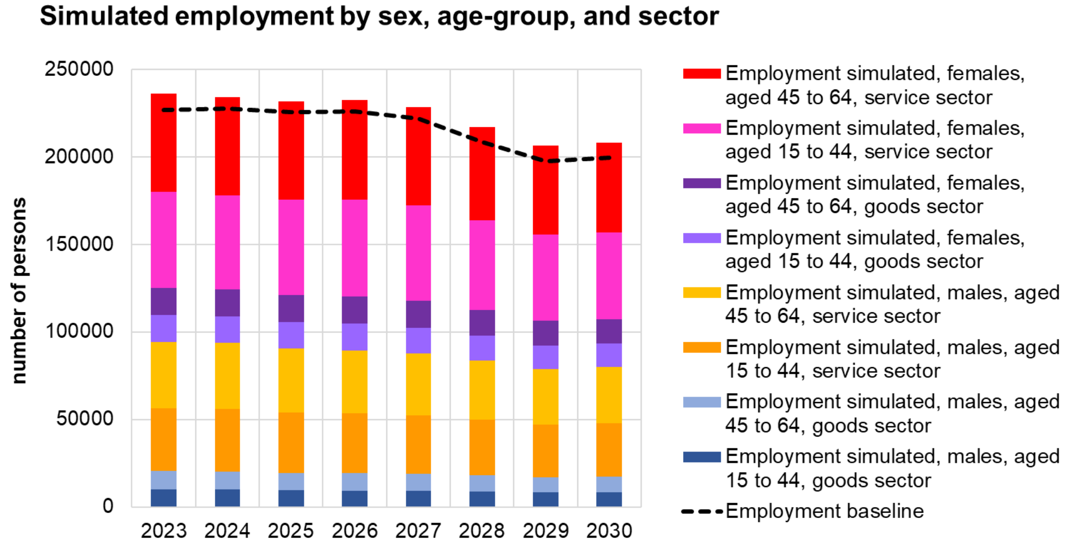


Figure 53a: Scenario 20 (Oil price = 147.27 USD/barrel, change in production = -24%)



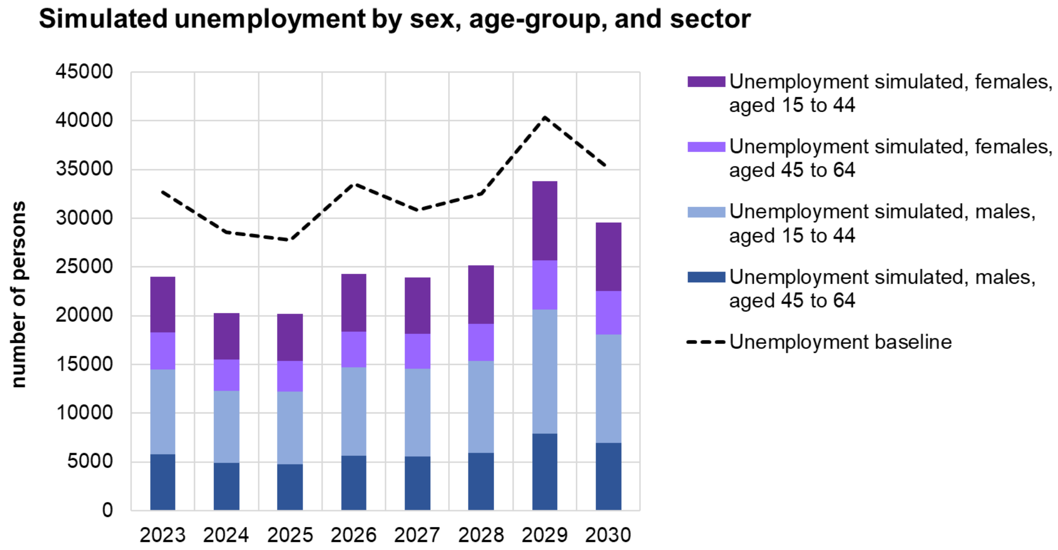


Figure 53b: Scenario 20 (Oil price = 147.27 USD/barrel, change in production = -24%)

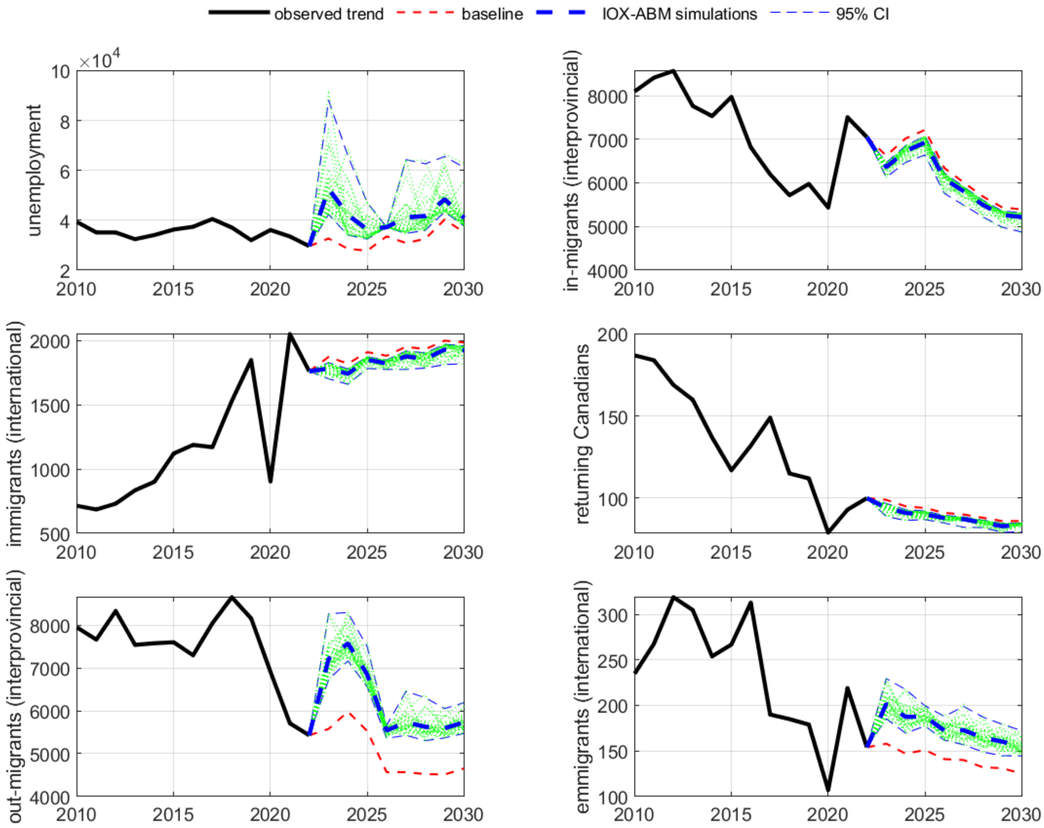


Figure 54a: Scenario 21 (Oil price = 40.32. USD/barrel, change in production = -24%)

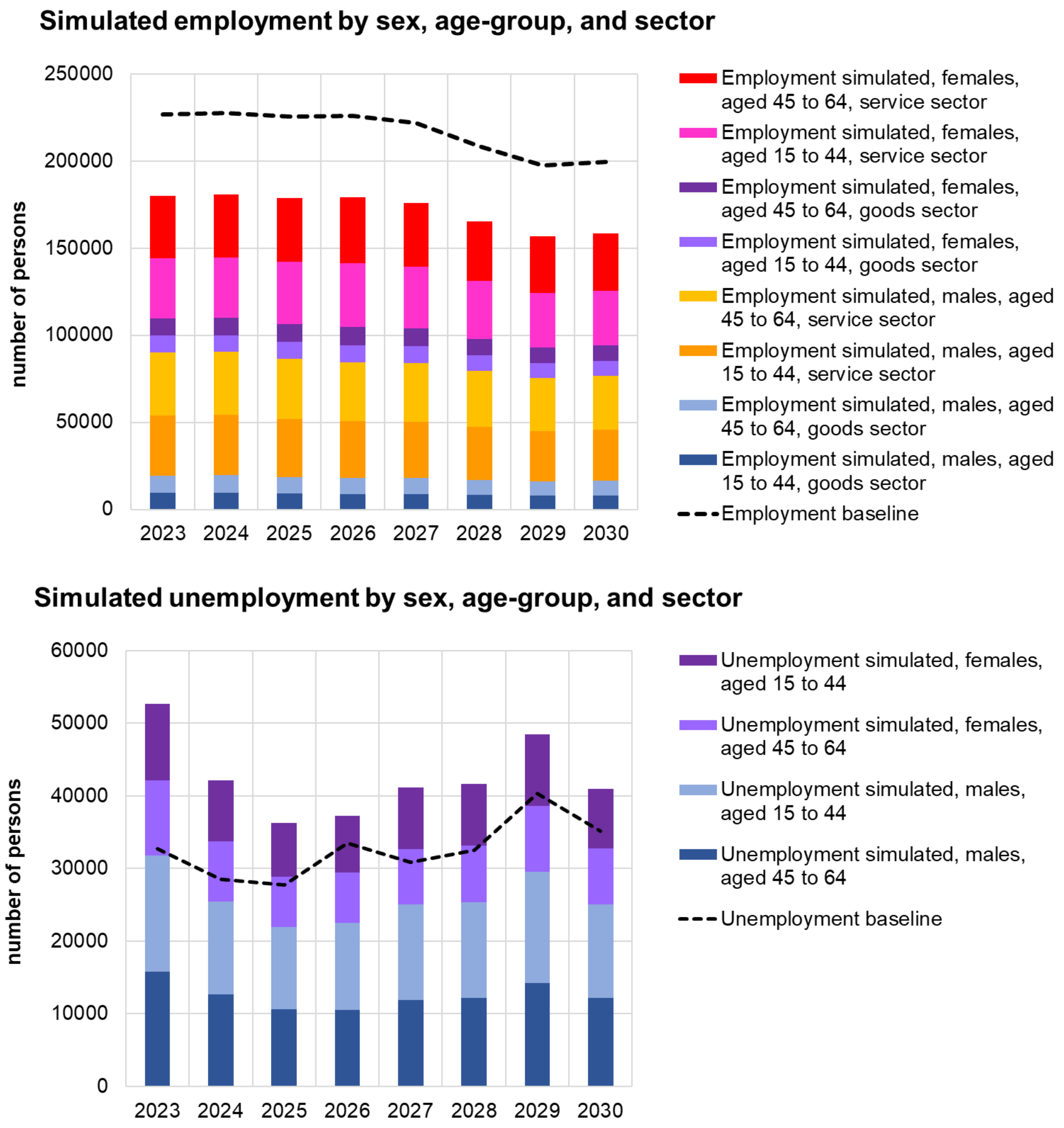


Figure 54b: Scenario 21 (Oil price = 40.32 USD/barrel, change in production = -24%)

4.5 Discussion:

An Input-Output model was extended with econometric models and agent-based simulations with the aim of simulating the impact that changes in oil prices and oil production have on both employment and the value added by industry. The data represents the province of Newfoundland and Labrador (NL) from the year 2018 up to the year 2030. The results of the IOX model indicated that value added, and employment are mainly affected by international oil prices, as compared to reductions in the production of natural resources. At industry level, the primary sectors affected by changes in oil prices and changes in production, besides mining and oil and gas production, are manufacturing and transports. This finding aligns with the fact that construction and manufacturing industries in NL are highly associated with natural resources industries' projects. At the sectoral level, the reduction in prices and production reduces overall employment, but a migration effect between sectors is exists in the labor market, as some sectors like mining and oil and gas production reduce their employment levels. Yet, other sectors absorb the changes and increase their employment, such as the retail and trade and the public sectors.

The ABM simulations were modeled based on the Harris-Todaro theory of migration, however, the model considers the social environment —besides expected changes in wages— of reference groups sorted by age and the various economic sectors. As in modern ABM implementations, the decision rules of the agents are expressed in probabilistic form, to reflect subjective expected utility theory. The learning rules are dynamic and adaptative, based on information of previous years, and are compared to the ABM simulations made with VAR baseline results.

The results of the ABM extension (IOX-ABM) indicate that negative shocks (reduction in prices and production) have a larger impact on migration compared to positive shocks. Positive shocks reduce unemployment and increase migration to NL (as expected), but the effects are mainly on inter-provincial in-migrants, as compared to international immigrants and returning Canadians. The main effect of a positive shock is the reduction of out-migration and emigrants, due to the increase in wages and more labour opportunities both in the goods sector and the service sector. In contrast, a negative shock in NL increases unemployment and reduces migration to NL from other provinces and other countries to NL, but the effects on migration to NL are not significant when compared to the effects on migration to other countries (emigration) and migration to other provinces of NL (out-migration). Migration to other provinces of Canada is the primary migration effect arising from a reduction in oil prices and a reduction in the production of natural resources in Newfoundland and Labrador (NL). Net migration—the number of migrants that enter NL compared to the number of agents that leave NL to go other provinces of Canada or to other countries— is higher with stable oil prices. However, a degrowth scenario increases the number of migrants that move from NL to other provinces of Canada, making net migration negative.

4.6 Summary:

This chapter demonstrated the empirical results for the model with discussion. In the next chapter, thesis conclusion, limitations and possible future work are covered.

Chapter 5: Thesis Research Summary and Conclusion, Limitations, and Future Work

This chapter summarizes and concludes the research, discusses the limitations and possible future work.

5.1 Summary and Conclusion:

The scope of this research focused on the impact analysis of transitioning from depleted resources' intensive and dependent economies to green-growth or de-growth economies on employment and migration. Alternatives require designing a set of policies that would ensure a viable transition is possible and it depends on case-specific for each economy and social structure. The oil and gas are the main engines for our case study, Newfoundland and Labrador (NL)'s economy to function. One of the common denominators between green growth and degrowth is setting production threshold for the extraction of depleted natural resources. For the impact analysis, econometric model, I-O model, and ABM are linked to simulate 21 scenarios of oil price and production reduction rates (as exogenous variables) and analyze its impact over time on employment and migration. The three econometric regression models are to estimate elasticities of oil production with respect to oil prices, exports with respect to oil production, and employment with respect to changes in the GDP (as proxy for value-added). The result of exports estimated with the second econometric regression is included in the vector of exports in I-O model to simulate the impact on value-added and labor income. The simulated results are compared to the observed data in the year 2018, as this is the year for which there is I-O information for NL. The output of IOX and ABM model linked through GDP and employment income; along with result from third econometric model (employment in number). Using Harris-Todaro theory of migration and considers the social environment — expected changes in wages and of reference groups sorted by age, the ABM implementations, the decision rules of the agents are expressed in probabilistic form, to reflect subjective expected utility theory. The learning rules are dynamic and adaptative, based on information of previous years. The model calibration is done through choosing initial parameters that makes the model output matches the historical data, while the model validation is done through comparing its output with output of another model VAR results.

The result of the model shows that current economic policy of NL to double the production and export of oil by 2030 is not sustainable. The NL oil dependent economy is highly sensitive to the oil price fluctuation, which impacted other industries. The construction projects and manufacturing are highly related to oil industry, when oil price drops, the NL income declines, and these industries suffer. Even though service sector employed almost 80% of economically active population and contributed to 35% of NL GDP, it relies on the spending power of employees from natural resources industries and its associated industries including oil and gas. The induced effect of oil industry on other industries has greater impact on employment and migration. Moving from oil dependent economy, green growth and degrowth economic models should be considered. The green growth assumes the economy continue to grow with less environmental negative externalities, hence decoupling the economic growth from natural resources usage. It covers wide areas from natural resources conservation, alternative renewable energy sources, energy efficiency, clean technologies dissemination, to research and development, and education. While degrowth is centered around stopping the economic growth and setting the threshold on natural resources capitals. Both concepts share idea reducing the natural resources assets, therefore, the alternative policy suggested and examined in this research is reduction in NL oil production with different rates, lower for green growth and higher for degrowth. The model shows that even with higher percentage reduction of oil, the negative impact on overall economy and employment are less. For NL to be less dependent on oil and gas, a policy mix need to be designed to ensure the economy is less vulnerable to external factors and align with Canadian and international efforts for sustainability. Government of NL could implement a policy to reduce the production of oil and gas and redirect its investments into new industries that the province lacks. Research and development, education and vocational trainings, green manufacturing, and innovations might absorb the impact from reduction natural resources industries. Further analysis should be done to study the impact of new industries on employments and selective migrations.

5.2 Research Limitations:

The current limitations of the IOX-ABM implementation are the lack of spatial neighborhood effects, which could capture the geographical influence that migrants living close to each other may exert on each other's decisions to migrate. Currently, the model captures indirectly this social network effects by calculating separately those decision rules for groups that belong to the same reference social groups. Neighborhood effects related to geographical or social proximity are approximated by the age and the economic factors of the agents, as people tend to socialize better with people of similar age range and working in a similar activity. Therefore, they are influenced by their social networks in these reference groups. Both age and economic factors are used as a proxy of neighboring social connections in the ABM simulations.

5.3 Future Work:

Future studies can expand the current ABM simulations to include spatial neighborhood effects based on the geographical information at subregional level in NL, as for example, information of migration of agents according to their geographical proximity at municipality level. This information can be used to expand the ABM model in a discrete-time, discrete-space mathematical model of computation based on a grid of sub-regional cells that influence each other. The availability of household information in NL will also be extremely useful to expand the ABM simulations with additional demographic characteristics that may influence employment and migrations, as for example, ethnicity or household size. The model can be used to examine other provinces such as Alberta, or other impact of relying on different natural resources such as uranium ore in Niger.

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Appendix A: Data

Box 1. Employment structure by industry
in Newfoundland and Labrador in the year 2018*

	GDP		Employment	
	2017e		2018	
	$ Millions	% of Total	Person Years, 000s	% of Total
Goods-Producing Sector	13,129.0	43.3	46.3	20.6
Agriculture, Forestry & Logging	186.4	0.6	2.5	1.1
Fishing, Hunting & Trapping	435.3	1.4	3.5	1.6
Mining	1,904.8	6.3	2.7	1.2
Oil Extraction	4,359.1	14.4	2.7	1.2
Support Activities for Oil and Mining	365.8	1.2	2.5	1.1
Manufacturing	1,389.0	4.6	9.0	4.0
Fish Products	339.2	1.1	3.2	1.4
Other	1,049.8	3.5	5.8	2.6
Construction	3,894.1	12.8	20.1	8.9
Utilities	594.4	2.0	3.1	1.4
Services-Producing Sector	17,199.0	56.7	179.0	79.4
Wholesale Trade	649.0	2.1	5.7	2.5
Retail Trade	1,619.5	5.3	31.7	14.1
Transportation & Warehousing	1,049.3	3.5	11.9	5.3
Finance, Insurance, Real Estate & Business Support Services	4,455.2	14.7	13.8	6.1
Professional, Scientific & Technical Services	943.2	3.1	10.0	4.4
Educational Services	1,722.6	5.7	15.9	7.1
Health Care & Social Assistance	2,556.7	8.4	39.6	17.6
Information, Culture & Recreation	806.7	2.7	7.2	3.2
Accommodation & Food Services	588.4	1.9	16.0	7.1
Public Administration	2,277.6	7.5	16.8	7.5
Other Services	530.7	1.8	10.4	4.6
Total, All Industries	30,328.0	100.0	225.3	100.0

e: estimate

Note: Gross Domestic Product (GDP) is expressed at basic prices, measuring payments made to the owners of factor inputs in production. This differs from GDP at market prices. The difference is attributable to taxes less subsidies on products and imports. Industry components may not sum to total due to independent rounding.

Source: Statistics Canada; Department of Finance

Source: The Economy 2019, Department of Finance of the Government of Newfoundland and Labrador.
Available at:https://www.gov.nl.ca/fin/files/e2019-theeconomy2019.pdf

Box 2. GDP structure of the goods-producing sector by industry
in Newfoundland and Labrador in the year 2018*

	GDP	
	2018e	
	$ Millions	% of Total
Goods-Producing Sector	13,352.5	43.8
Agriculture, Forestry & Logging	166.1	0.5
Fishing, Hunting & Trapping	395.4	1.3
Mining	1,675.6	5.5
Oil Extraction	5,539.7	18.2
Support Activities for Oil and Mining	393.4	1.3
Manufacturing	1,437.5	4.7
Fish Products	425.2	1.4
Other	1,012.3	3.3
Construction	3,033.7	9.9
Utilities	711.1	2.3

Source: The Economy 2020, Department of Finance of the Government of Newfoundland and Labrador.
Available at: https://www.gov.nl.ca/budget/2020/wp-content/uploads/sites/3/2020/09/The-Economy-2020.pdf

Appendix B: IOX-ABM Parameters

Parameter	Value	Justification
Employed persons	224300 persons	Total persons employed in the starting year (2018, base year of the I-O model, 2018)
Unemployed Agents		
Disposition to work of unemployed agents in the goods sector (learning and adaptation rule)	$k_{goods\ sector} = 7$	The decision to work of unemployed agents depends on the changes of labor income (salaries) obtained from the IOX model. Agents in the goods sector have a different tendency to learn and adapt to changes in salaries compared to agents in the service sector. The value of tendency to learn and adapt to changes in salaries equal to $k_{goods\ sector} = 7$ was calibrated to replicate the historical patterns (baseline) of unemployment in the goods sector of NL
Disposition to work of unemployed agents in the service sector (learning and adaptation rule)	$k_{service\ sector} = 9$	The decision to work of unemployed agents depends on the changes of labor income (salaries) obtained from the IOX model, and agents in the goods sector have a different tendency to learn and adapt to changes in salaries compared to agents in the service sector. The value of the tendency to learn and adapt to changes in salaries $k_{service\ sector} = 9$ was calibrated to replicate the historical patterns (baseline) of unemployment in the service sector of NL
Disposition to migrate into NL (learning and adaptation rule) of people aged 15 to 44 years	$k_{in,15\ to\ 44} = 1$	The agent's decision to migrate to NL depends on the expected salaries that change every year depending on the economic situation (GDP) of NL; agents aged 15 to 44 years learn and adapt to these changes and have a higher tendency to migrate compared to agents aged 45 to 64 years old. The value of $k_{in,15\ to\ 44} = 1$ was calibrated to replicate the historical patterns (baseline) of migration into NL
Disposition to migrate into NL (learning and adaptation rule) of people aged 45 to 64 years	$k_{in,45\ to\ 64} = 3$	The agent's decision to migrate to NL depends on the expected salaries that change every year depending on the economic situation (GDP) of NL; agents aged 15 to 44 years learn and adapt to these changes and have a higher tendency to migrate compared to agents aged 45 to 64 years old. The value of $k_{in,45\ to\ 64} = 1$ was calibrated to replicate the historical patterns (baseline) of migration into NL
Disposition to migrate out of NL (learning and adaptation rule) of people aged 15 to 44 years	$k_{out,15\ to\ 44} = 3$	The agent's decision to migrate to NL depends on the expected economic situation inside of NL; agents aged 15 to 44 years learn and adapt to these changes and have a higher tendency to migrate compared to agents aged 45 to 64 years old. The value of $k_{out,15\ to\ 44} = 3$ was calibrated to replicate the historical patterns (baseline) of migration out of NL
Disposition to migrate out of NL (learning and adaptation rule) of people aged 45 to 64 years	$k_{out,45\ to\ 64} = 5$	The agent's decision to migrate to NL depends on the expected economic situation inside of NL; agents aged 15 to 44 years learn and adapt to these changes and have a higher tendency to migrate compared to agents aged 45 to 64 years old. The value of $k_{out,15\ to\ 44} = 5$ was calibrated to replicate the historical patterns (baseline) of migration out of NL
Number of simulations	50 for each year	A total of 600 simulations since 50 simulations are run for each year

Parameter	Value	Justification
Number of agents: Interprovincial Migration (2018)	In = 5717 Out = 8659	The number of agents changes after the year 2018 based on the simulated shocks
Number of agents: International migration (2018)	Immigrants = 1531 Emigrants = 185 Returning Canadians = 115	The number of agents changes after the year 2018 based on the simulated shocks
Unemployment rate (2018)	14%	The number of unemployed changes from year to year due to the simulation shocks.
Uncertainty in GDP growth	$\breve{g}_t = g_t u_t^{-1}$	GDP growth of the year 2018 is calculated as ((simulates_value_added_2018 - 32087.461)/32087.461)*100, where 32087.461 is the observed value added in the year 2018. The uncertainty u_t is a random shock (a stochastic process) that follows an integer random distribution, $u_t \sim \mathcal{U}\left(l + (t * U)\right)$, where $l = 9000$, $U = 10000$.
Proportion of population aged 15 to 44	52%	This parameter is constant over the years in the current version of the model, but it will be dynamic in the next version
Proportion of population aged 45 to 64	48%	This parameter is constant over the years in the current version of the model, but it will be dynamic in the next version
Distribution of employment in the goods sector (2018)	20.6%	This parameter is updated over the years based on the results of the simulated shocks
Distribution of employment in the service sector (2018)	79.4%	This parameter is updated over the years based on the results of the simulated shocks
Distribution of unemployment by sex (2018)	60% females	This parameter changes after the year 2018
Distribution of employment by sex (2018)	51% males	This parameter changes after the year 2018

Appendix C: Pseudocode

Econometric Model
1. Import Data from Consolidated Database for Performing Analysis 2. Divide Data as per the following (a) Model 1 Data including Oil Production, Oil Prices, GDP of USA and Exchange rate of USA (b) Model 2 Data including Oil Exports, Oil Production and GDP of USA (c) Model 3 Data including Employment and GDP of Newfoundland & Labrador 3. Perform Analysis for Econometric Model 1 (Quantity of Oil Production as a function of Oil Prices, GDP of USA, and Exchange rate of USA) (a) Pre-Processing of Data:Take log of Data related to Quantity of Oil Production, Oil Prices, GDP of USA, and Exchange rate of USA and Combine it in the order of Oil Prices, GDP of USA, Exchange rate of USA, and Quantity of Oil Production (b) Fit linear regression model using Quantity of Oil Production as the response variable and the others i.e. (Oil Prices, GDP of USA, and Exchange rate of USA) as the predictor variables. (c) Perform the augmented Dickey-Fuller test for a unit root in order to assesses the null hypothesis for Quantity of Oil Production, Oil Prices, GDP of USA and Exchange rate of USA (d) Perform Engle-Granger Cointegration test in order to assesses the null hypothesis using Quantity of Oil Production as the response variable and the others i.e. (Oil Prices, GDP of USA, and Exchange rate of USA) as the predictor variables with Cointegrating regression form specified as constant and the linear time trend. (e) Perform Ljung-Box Q-test for residual autocorrelation on the Residuals obtained from linear regression model and Number of lags equal to 1,3 and 5. (f) Perform Engle test for residual heteroscedasticity on the Residuals obtained from linear regression model 4. Perform Analysis for Econometric Model 2 (Quantity of Oil Exports as a function of Oil Production, and the GDP of USA) (a) Pre-Processing of Data:Take log of Data related to Quantity of Oil Exports, Oil Production, and the GDP of USA and Combine it in the order of Oil Production, the GDP of USA, and Quantity of Oil Exports (b) Fit linear regression model using Quantity of Oil Exports as the response variable and the others i.e. (Oil Production, and the GDP of USA) as the predictor variables. (c) Perform the augmented Dickey-Fuller test for a unit root in order to assesses the null hypothesis for Quantity of Oil Exports, Oil Production and GDP of USA (d) Perform Engle-Granger Cointegration test in order to assesses the null hypothesis using Quantity of Oil Exports as the response variable and the others i.e. (Oil Production, and the GDP of USA) as the predictor variables. (e) Perform Ljung-Box Q-test for residual autocorrelation on the Residuals obtained from linear regression model and Number of lags equal to 1,3 and 5. (f) Perform Engle test for residual heteroscedasticity on the Residuals obtained from linear regression model 5. Perform Analysis for Econometric Model 3 (Employment as a function of GDP of Newfoundland & Labrador) (a) Pre-Processing of Data: Take log of Data related to Employment and GDP of Newfoundland & Labrador and Combine it in the order of GDP of Newfoundland & Labrador and Employment (b) Fit linear regression model using Employment as the response variable and the GDP of Newfoundland & Labrador as the predictor variables. (c) Perform the augmented Dickey-Fuller test for a unit root in order to assesses the null hypothesis for Employment and GDP of Newfoundland & Labrador

(d) Perform Engle-Granger Cointegration test in order to assesses the null hypothesis using Employment as the response variable and the GDP of Newfoundland & Labrador as the predictor variables without Cointegrating regression.

(e) Perform Ljung-Box Q-test for residual autocorrelation on the Residuals obtained from linear regression model and Number of lags equal to 1.

(f) Perform Engle test for residual heteroscedasticity on the Residuals obtained from linear regression model

Function Name loading_data

Inputs

- Path of the Source File

Outputs

- Consolidated Database

1. Configure Import Options (i.e. Number of Variables etc.)
2. Select the Required Spreadsheet
3. Define the Range of Data to be Imported from Required Spreadsheet
4. Define Double Data Type and Name of Columns as follows
   - Year
   - Oil Prices
   - Oil Exports
   - GDP NL
   - GDP Quebec
   - XrateUSD
   - XrateNLD
   - EmpTOT
   - EmpGoods
   - Revenues
   - GDP Canada
   - GDP USA
   - GDP NLD
   - GDP CHN
   - GDP DEU
   - GDP JPN
   - Oil Production
5. Import the Data from Excel Spreadsheet and save it in the Consolidated Database

IOX Model

1. Configure Directory Paths for using helper functions in order to Perform Simulations and save Results
2. Perform Simulations using IOX (I-O model Extended with Econometric Models) for Testing

(a) Perform Simulation using IOX (I-O model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = X US dollars/barrel
- Reduction in Natural Resources Production = -Y%

IOX Function outputs

- Total Impact on value added by Industry
- Total Impact on Employment by Sector
- Impact on value added by Industry
- Impact on Employment by Sector
- Industries and Impact value added by Industry in Percentage
- Sectors and Impact Employment by Sector in Percentage
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(b) Save Results (Impact on value added by Industry and Impact on Employment by Sector) from Previous Step (a) in Excel file - simulation_results.xlsx
Function Name - IOX Inputs - Oil_price - Natural_resources_production_reduction Outputs - total_impact_value_added - total_impact_employment - impact_value_added_by_industry - impact_employment_by_sector - Tv - Te - changes_wages_goodsec - changes_wages_servsec Variables: x gross output d domestic final demand (c + g + s) c private consumption g public (government) consumption e exports v value added w labor income (not available in this version) h value added coefficients u labor income coefficients (not available in this version) p employment participation coefficients Assumptions Domestic demand is constant (no changes in d), hence c, g, s are constant. 1. Estimated Elasticities with the econometric models from a01_econometric_models file are mentioned below (a) alpha elasticities intercept = alpha1_oilproduction elasticity for oil prices = alpha2_oilproduction elasticity for GDP USA = alpha3_oilproduction - elasticity for exchange rate CAD-USD = alpha4_oilproduction Combine above elasticities into a single matrix alpha (b) beta elasticities intercept = beta1_oilexports elasticity for oil production = beta2_oilexports elasticity for GDP USA = beta3_oilexports Combine above elasticities into a single matrix beta (c) theta elasticities intercept = theta1_employment GDP NL = theta2_employment Combine above elasticities into a single matrix theta 2. Perform Calibration for the year 2018 (baseline) using following values GDP_NL = NL GDP value GDP_USA = GDP USA value XrateUSD = USD and Canadian Dollar Exchange Rate

```
        simulation_oilpr = Oil_price
        if simulation_oilpr is less than 0 display "Error: oil prices should be higher than zero"
        calibration_oilva = value added from oil
        calibration_empto = employment value
3. Generate Input-Output Model without extensions using IOprovince_Update_NL Function with following arguments
        Inputs
                - None
        Outputs
                - x    Output
                - A Matrix of Technical Coefficients
                - enat Exports National
                - eint Exports International
                - v v alue-added / GDP
                - w    Labor Income
4. Generate Econometric Model 1 using following formula
        lnoil_production = alpha(1) + alpha(2)*log(simulation_oilpr) + alpha(3)*log(GDP_USA) + alpha(4)*log(XrateUSD)
        nr_production    = exp(lnoil_production)
        simulation_nrpro = max(((Natural_resources_production_reduction/100)*nr_production + nr_production),0)
5. Generate Econometric Model 2 using following formulas
        if simulation_nrpro is equal to 0 than oil_exports are 0 (Oil exports equal to zero in case there is no oil production)
        otherwise
                lnoil_exports = beta(1) + beta(2)*log(simulation_nrpro) + beta(3)*log(GDP_USA);
                oil_exports = exp(lnoil_exports);
        e_sim = calibration_oilva * oil_exports;
6. Add Extensions to the Models from Steps 3 and 5
        I  = Identity matrix eqal to the length of x (Output) from Step 3
        d  = enat (Exports National) from Step 3
        ep = eint (Exports International) / Sum of eint (Exports International) from Step 3
        e_sim = ep * e_sim (from Step 5)
7. Compute Coefficients using following
        h = diag(v)*inv(diag(x))
        u = diag(w)*inv(diag(x))
        delta = is the difference between the uncalibrated Model and the historical data (historical matching calibration)
8. Percentage of value added by sector (industry)
        ps = value added per industry / total value added
9. The employment information is based on Statistics Canada:
        employment_baseline = number of employee per industry
10. Impact on value added:
        vsim = h*inv(I - A)*d + e_sim
11. Percentage change in value added
        v0 = sum(v)
        v1 = sum(vsim)
        percentage_change_v = (v1 - v0)/v0
        value_added_by_industry_sim = max(vsim + delta,0)
```

12. Impact on value added by industry

ivap = ((value_added_by_industry_sim - v)./v)

13. Impact on good sector

igs = [(ivap(1)+ivap(4))/2 ivap(3) ivap(2) ivap(5:7)' ivap(12:18)' sum(ivap(8:11))/4 ivap(19) ivap(21:22)' ivap(24:25)' sum(ivap(27:32))/6]'

% distribution of people by sector

pp = 0.206*igs + 0.794*ps; pp = pp./sum(pp);

14. Impact on Employment (Econometric model 3)

lnEMP = theta(1) + theta(2)*log((percentage_change_v*GDP_NL + GDP_NL))

15. Impact on employment by sector

employment_sim = exp(lnEMP) + calibration_empto

sectorial_employment_effects_sim = employment_sim * pp

16. Impact on Labor Income

(a) Simulated Labor Income using Model

wsim = u*inv(I - A)*d + e_sim

(b) Calibrated Labor Income

wcal = wages forecast based on historical data using regression

(c) Simulated Labor Income using Step 16 (a) and Step 16 (b)

labor_income_sim = Sum of wsim and wcal from Step 16

(d) Percentage changes in labor income by industry

labor_income_pch = ((labor_income_sim - w')./w') (w - Labor Income from Step 3)

wages_goods_sector = Mean of first 12 elements of labor_income_pch

wages_service_sector = Mean of 13 to last elements of labor_income_pch

17. Results of the I-O Extended Model

(a) Impact on value added by industry
total_impact_value_added is equal to sum of value_added_by_industry_sim

(b) Impact on employment by sector -
total_impact_employment is equal to sum of sectorial_employment_effects_sim

(c) Impact on value added by industry -
impact_value_added_by_industry is equal to value_added_by_industry_sim

(d) Impact on employment by sector -
impact_employment_by_sector is equal to sectorial_employment_effects_sim

(e) Impact on value added by industry percentage -
impact_value_added_by_industry_percentage is equal to product of ivap and 100

(f) Impact on employment by sector percentage -
impact_employment_by_sector_percentage is equal to ((sectorial_employment_effects_sim - employment_baseline)./employment_baseline)*100

(g) Changes in wages of good sector -
changes_wages_goodsec is equal to wages_goods_sector

(h) Changes in wages of service sector
changes_wages_servsec is equal to wages_service_sector

18. List of Industries for NL is as follows

- Crop and animal production
- Forestry and logging
- Fishing, hunting and trapping
- Support activities for agriculture and forestry
- Mining, quarrying, and oil and gas extraction
- Utilities
- Residential building construction

- Non-residential building construction
- Engineering construction
- Repair construction
- Other activities of the construction industry
- Manufacturing
- Wholesale trade
- Retail trade
- Transportation and warehousing
- Information and cultural industries
- Finance, insurance, real estate, rental and leasing and holding companies
- Owner occupied dwellings
- Professional, scientific and technical services
- Administrative and support, waste management and remediation services
- Educational services
- Health care and social assistance
- Arts, entertainment and recreation
- Accommodation and food services
- Other services (except public administration)
- Non-profit institutions serving households
- Government education services
- Government health services
- Other federal government services
- Other provincial and territorial government services
- Other municipal government services
- Other aboriginal government services

19. List of Sectors is as follows
- Agriculture
- Fishing, hunting and trapping
- Forestry and logging and support activities for forestry
- Mining, quarrying, and oil and gas extraction
- Utilities
- Construction
- Manufacturing
- Wholesale trade
- Retail trade
- Transportation and warehousing
- Information, culture and recreation
- Finance and insurance
- Real estate and rental and leasing
- Business, building and other support services
- Professional, scientific and technical services
- Educational services
- Health care and social assistance
- Accommodation and food services
- Other services (except public administration)
- Public administration

20. Make a Table Tv having List of industries from Step 5 and impact_value_added_by_industry_percentage from Step 4 (e) sorted in ascending order based on values in impact_value_added_by_industry_percentage column with headings as "industry" and "percentage change"

21. Make a Table Te having List of sectors from Step 6 and impact_employment_by_sector_percentage from Step 4 (f) sorted in ascending order based on values in impact_employment_by_sector_percentage column with headings as "sector" and "percentage change"
Function Name - IOprovince Update NL Inputs - None Outputs - Output - Matrix of Technical Coefficients - Intermediate Consumption - Household & Government Consumption - Gross Capital Formation - Change Inventories - Exports National - Exports International - Imports - Value-added / GDP - Labor Income 1. Select the Required Excel File (supply and use table for NL) 2. Import Data for Supply and Use Matrices (a) Import Data from Spreadsheet - Supply within the Range 'C7:BC82' (b) Import Data from Spreadsheet - Use_Basic within the Range 'C7:BV82' 3. Perform Pre-Processing by removing any NaN (Not a Number) Value and replacing it with 0 in the imported data from Step 2 4. Extract Labor Income from the Data imported in Step 2 (b) Note: Do not extract empty columns (having no information) in Spreadsheet - Use_Basic which are as follows - Repair, maintenance and operating and office supplies - Advertising, promotion, meals, entertainment, and travel - Transportation margins 5. Remove Rows from the Data imported in Step 2 (a) Remove Rows from the Data imported in Step 2 (a) having Products Code F1000 - Fictive materials F2000 - Fictive services F3000 - Transportation margins and Columns Codes FC100 - Repair, maintenance and operating and office supplies FC200 - Advertising, promotion, meals, entertainment, and travel FC300 - Transportation margins (b) Remove Rows from the Data imported in Step 2 (b) having Products Code F1000, F2000 and F3000 and Columns Code FC100, FC200 and FC3006. Remove last 10 Gross Value added Rows from the Data in Step 5 (a) Remove last 10 Gross Value added Rows from the Data in Step 5(a) (b) Remove last 10 Gross Value added Rows from the Data in Step 5(b) 7. Extracting Final Demands and Imports from the Data from Step 6 (a) Extract Total Household & Government Consumption (Columns 34 to 42) By Adding them as per the Products from Data in Step 6(b) (b) Extract Gross Capital Formation (Columns 41 to 50) By Adding them as per the Products from Data in Step 6(b) (c) Extract Change inventories (Columns 51) from Data in Step 6(b) (d) Extract Exports national (Columns 54 to 67) By Adding them as per the Products from Data in Step 6(b) (e) Extract Exports international (Columns 52 to 53) By Adding them as per the Products from Data in Step 6(b) (f) Extract Imports (Columns 34 to 48) By Adding them as per the Products from Data in Step 6(a)

(g) Combine the Data from Previous Steps (a), (b), (c), (d) and (e) to form Final Demand

8. Extract Provincial Supply and Use Data (only inter-industry) From Step 6

(a) Extract Provincial Supply Data (only inter-industry) (Columns 1 to 32) From Step 6 (a)

(b) Extract Provincial Use Data (only inter-industry) (Columns 1 to 32) From Step 6 (b)

9. Calculate National totals

(a) Sum the Columns from the Data in Step 8 (a) and transform it into a column vector

(b) Combine Data from Step 8 (a) and Step 7 (f) and add them as per the Products to form a column vector

10. Check consistency in Data by using the following formula

Checksum = sum(abs(Sum of the Data after combining Data from Step 8 (b) and Step 7 (g) as per the Products - Data from Step 9 (b)));

if Checksum > 1E-4 than give error "Supply and use tables not consistent."

11. Total Supply and Use Matrices

(a) Combine Data from Step 8 (a) and Step 7 (f) into Total Supply and Transpose it

(b) Combine Data from Step 8 (b) and Step 7 (g) into Total Use

12. Obtain Use Matrix by dividing each element of Matrix from Step 11 (b) by the corresponding element of Matrix from Step 9 (b)

13. Perform Data Processing by replacing any NaN (Not a Number) and Infinity Values by 0 in the Data from Step 12

14. Obtain Matrix M by multiplying Total Supply Matrix from Step 11 (a) and Total Use Matrix from Step 13

15. Form a Demand model with following Parameters

(a) Intermediate Consumption is equal to Matrix M (1:32 Rows, 1:32 Columns) from Step 14

(b) Matrix of Technical Coefficients is equal to Matrix M (1:32 Rows, 1:32 Columns) from Step 14 multiplied by inv(diag(Matrix from Step 9 (a)))

(c) Household & Government Consumption is equal to Matrix M (1:32 Rows, 33 Column) from Step 14

(d) Gross Capital Formation is equal to Matrix M (1:32 Rows, 34 Column) from Step 14

(e) Change Inventories is equal to Matrix M (1:32 Rows, 35 Column) from Step 14

(f) Exports National is equal to Matrix M (1:32 Rows, 36 Column) from Step 14

(g) Exports International is equal to Matrix M (1:32 Rows, 37 Column) from Step 14

(h) Imports is equal to Transpose of Matrix M (Last Row, 1:32 Columns) from Step 14

(j) Output using following formula

inv(eye(size(Step 15 (b),1)) - Step 15 (b)) * (Step 15 (c) + Step 15 (d) + Step 15 (e) + Step 15 (f) + Step 15 (g))

(k) Value-Added / GDP is equal to Step 15 (j) - Transpose of Sum of first 32 Columns of Matrix M Row wise

16. Check Consistency using Following

if sum(abs(Output Matrix from Step 15 (j) - Matrix from Step 9 (a))) > 1E-6 give error "A matrix not consistent."

if abs(sum of Matrix M (Last Row, All Columns) from Step 14 - sum of Matrix from Step 7 (f)) > 1E-5 give error "Imports not consistent"

if abs(sum of Matrix M (Last Row, 33 Column) from Step 14 - sum of Matrix (All Rows, 1 Column) from Step 7 (g)) > 1E-5 give error "Final demand not consistent"

if abs(sum of Matrix M (Last Row, 34 Column) from Step 14 - sum of Matrix (All Rows, 2 Column) from Step 7 (g)) > 1E-5 give error "Exports not consistent"

if abs(sum of Matrix M (Last Row, 35 Column) from Step 14 - sum of Matrix (All Rows, 3 Column) from Step 7 (g)) > 1E-5 give error "Exports not consistent"

IOXABM Model
1. Configure Directory Paths for using helper functions in order to Perform Simulations and save Results 2. Perform Simulations using IOX-ABM (I-O Model Extended with Econometric Models and Agent-Based Modelling) for Base Scenario (As of 2018) (a) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = 65.23 US dollars/barrel
- Reduction in Natural Resources Production = 0%

IOX Function outputs

- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(b) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (a) and save the results in required directory

IOXABM Function inputs

- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name = Base

3. Perform Simulations using IOX-ABM (I-O Model Extended with Econometric Models and Agent-Based Modelling) for Scenario related to increase in prices and production (in comparison with 2018)

(a) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = 150 US dollars/barrel
- Reduction in Natural Resources Production = 10%

IOX Function outputs

- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(b) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (a) and save the results in required directory

IOXABM Function inputs

- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name = Positive Shock

4. Perform Simulations using IOX-ABM (I-O Model Extended with Econometric Models and Agent-Based Modelling) for Scenario related to decrease in prices and production (in comparison with 2018)

(a) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = 50 US dollars/barrel
- Reduction in Natural Resources Production = -10%

IOX Function outputs

- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(b) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (a) and save the results in required directory

IOXABM Function inputs

- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name = Negative Shock

5. Perform Simulations using IOX-ABM (I-O Model Extended with Econometric Models and Agent-Based Modelling) for following Scenarios

(a) IOX-ABM Simulations for Baseline Growth Scenario vs each Oil Price 65.83, 142.27 and 40.32 individually

(i) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = 65.83, 142.27 and 40.32 US dollars/barrel individually
- Reduction in Natural Resources Production = 0% (Baseline Growth)

IOX Function outputs

- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(ii) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (i) and save the results in required directory

IOXABM Function inputs

- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name = strcat('bg_p', str(price),'n'))

IOXABM Function outputs

- Results of Baseline Growth Average Employment between 2018 and 2030
- Results of Baseline Growth Average Unemployment between 2018 and 2030
- Results of Baseline Growth Average Interprovincial Out-Migrants between 2018 and 2030
- Results of Baseline Growth Average International Emmigrants between 2018 and 2030
- Results of Baseline Growth Average Returning Canadians between 2018 and 2030
- Results of Baseline Growth Average International Immigrants between 2018 and 2030
- Results of Baseline Growth Average Interprovincial In-Migrants between 2018 and 2030
- Unemployment and Employment Aggregated for Baseline Growth
- Employment by Industry for Baseline Growth

(iii) Save Detailed Results in Excel file - simulation_results.xlsx in following separate spreadsheets

- Spreadsheet with name strcat('bgsima', str(price)) and Unemployment and Employment Aggregated for Baseline Growth output from previous Step (ii)
- Spreadsheet with name strcat('bgsimd', str(price)) and Employment by Industry for Baseline Growth output from previous Step (ii)

(b) IOX-ABM Simulations using -2, -4 and -6 values for Green Growth Scenarios vs each Oil Price as 65.83, 142.27 and 40.32 individually.

Note: Total No of Simulations will be 9

(i) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs

- Oil Price = 65.83, 142.27 and 40.32 US dollars/barrel individually
- Reduction in Natural Resources Production = -2%, -4% and -6% (Green Growth) individually

IOX Function outputs

- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(ii) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (i) and save the results in required directory

IOXABM Function inputs

- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name= strcat('gg_p', str(price), 'n', str(nr_changes))

IOXABM Function outputs
- Results of Green Growth Average Employment between 2018 and 2030
- Results of Green Growth Average Unemployment between 2018 and 2030
- Results of Green Growth Average Interprovincial Out-Migrants between 2018 and 2030
- Results of Green Growth Average International Emmigrants between 2018 and 2030
- Results of Green Growth Average Returning Canadians between 2018 and 2030
- Results of Green Growth Average International Immigrants between 2018 and 2030
- Results of Green Growth Average Interprovincial In-Migrants between 2018 and 2030
- Unemployment and Employment Aggregated for Green Growth
- Employment by Industry for Green Growth

(iii) Save Detailed Results in Excel file - simulation_results.xlsx in following separate spreadsheets
- Spreadsheet with name strcat('ggsima', str(price), str(nr_changes)) and Unemployment and Employment Aggregated for Green Growth output from previous Step (ii)
- Spreadsheet with name strcat('ggsimd', str(price), str(nr_changes)) and Employment by Industry for Green Growth output from previous Step (ii)

(c) IOX-ABM Simlation using -12, -18 and -24 values for Degrowth Scenarios vs each Oil Price as 65.83, 142.27 and 40.32 individually.

Note: Total No of Simulations will be 9

(i) Perform Simulation using IOX (I-O Model Extended with Econometric Models) Function with following arguments

IOX Function inputs
- Oil Price = 65.83, 142.27 and 40.32 US dollars/barrel individually
- Reduction in Natural Resources Production = -12%, -18% and -24% (Degrowth) individually

IOX Function outputs
- Total Impact on value added by Industry
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector

(ii) Perform IOX-ABM: ABM Simulations 50 times using IOXABM Function with following arguments based on the output of previous step (i) and save the results in required directory

IOXABM Function inputs
- Impact on Employment by Sector
- Change in Wages of Goods Sector
- Change in Wages of Services Sector
- Total Impact on value added by Industry
- Number of Simulations = 50
- Make Figure or Not = Yes
- Directory for Saving Results = Path
- Simulation Name = strcat('dg_p', str(price),'n', str(nr_changes))

IOXABM Function outputs - Results of Degrowth Average Employment between 2018 and 2030 - Results of Degrowth Average Unemployment between 2018 and 2030 - Results of Degrowth Average Interprovincial Out-Migrants between 2018 and 2030 - Results of Degrowth Average International Emmigrants between 2018 and 2030 - Results of Degrowth Average Returning Canadians between 2018 and 2030 - Results of Degrowth Average International Immigrants between 2018 and 2030 - Results of Degrowth Average Interprovincial In-Migrants between 2018 and 2030 - Unemployment and Employment Aggregated for Degrowth - Employment by Industry for Degrowth (iii) Save Detailed Results in Excel file - simulation_results.xlsx in following separate spreadsheets - Spreadsheet with name strcat('dgsima', str(price), str(nr_changes)) and Unemployment and Employment Aggregated for Degrowth output from previous Step (ii) - Spreadsheet with name strcat('dgsimd', str(price), str(nr_changes)) and Employment by Industry for Degrowth output from previous Step (ii) 6. Make Tables for the following T_emi (Size 3 x 6) = Round of to positive infinity combine matrix of ggavg_iemigrants and dgavg_iemigrants T_out (Size 3 x 6) = Round of to positive infinity combine matrix of ggavg_outmigrant and dgavg_outmigrant T_rec (Size 3 x 6) = Round of to positive infinity combine matrix of ggavg_iretcanads and dgavg_iretcanads T_imi (Size 3 x 6) = Round of to positive infinity combine matrix of ggavg_immigrants and dgavg_immigrants T_inm (Size 3 x 6) = Round of to positive infinity combine matrix of ggavg_inmigrants and dgavg_inmigrants 7. Combine Tables from Step 6 to form a Single Table T (Size 15 x 6) (a) Combine T_emi, T_out, T_rec, T_imi and T_inm to form a Table T (b) Name Columns of Table T as - Green growth (low) - Green growth (medium) - Green growth (high) - Degrowth (low) - Degrowth (medium) - Degrowth (high) (c) Repeat Matrix {'middle';'high';'low'} 5 times and add as a 7 Column to Table T (d) Repeat each element of Matrix {'emigrants','outmigrants','retcanadians','immigrants','inmigrants'} 3 times and add as a 8 Column to Table T 7. Save Table from Step 6 in Excel file - simulation_results.xlsx in separate sheet - MatLab_results_IOXABM
Function Name - IOXABM Inputs - impact_employment_by_sector_2018 - changes_labor_income_goodssector_2018

- changes_labor_income_servssector_2018
- total_impact_value_added_2018
- simulations
- makefigures
- results_folder
- sim_name

Outputs
- avg_employment
- avg_unemploymt
- avg_iemigrants
- avg_outmigrant
- avg_iretcanads
- avg_immigrants
- avg_inmigrants
- results_aggregated
- results_employment

1. Initializing Variables
- dynamic_employement = Matrix of zeros with Size (simulations x 13)
- dynamic_unemploymen = Matrix of zeros with Size (simulations x 13)
- dynamic_inpmigrants = Matrix of zeros with Size (simulations x 13)
- dynamic_intimmigran = Matrix of zeros with Size (simulations x 13)
- dynamic_intretcanad = Matrix of zeros with Size (simulations x 13)
- dynamic_outmigrants = Matrix of zeros with Size (simulations x 13)
- dynamic_ouemigrants = Matrix of zeros with Size (simulations x 13)
- initialize Wait Bar (0,'Setting up...')

2. Compute shock_employment = sum(impact_employment_by_sector_2018) – observed value and call appropriate functions based on its value

if shock_employment is greater than 0
for i = 1 to number of simulations
Call funABM_dynamicsp Function with following arguments
Inputs
- impact_employment_by_sector_2018
- changes_labor_income_goodssector_2018
- changes_labor_income_servssector_2018
- total_impact_value_added_2018

Outputs
- dynamic_employement(i,:)
- dynamic_unemploymen(i,:)
- dynamic_inpmigrants(i,:)
- dynamic_intimmigran(i,:)
- dynamic_intretcanad(i,:)
- dynamic_outmigrants(i,:)
- dynamic_ouemigrants(i,:)

Update Wait Bar with progress (i/simulations,h,'Running IOX-ABM simulations')

otherwise
for i = 1 to number of simulations
Call funABM_dynamicsn Function with following arguments
Inputs
- impact_employment_by_sector_2018

- changes_labor_income_goodssector_2018
- changes_labor_income_servssector_2018
- total_impact_value_added_2018

Outputs

- dynamic_employement(i,:)
- dynamic_unemploymen(i,:)
- dynamic_inpmigrants(i,:)
- dynamic_intimmigran(i,:)
- dynamic_intretcanad(i,:)
- dynamic_outmigrants(i,:)
- dynamic_ouemigrants(i,:)

Update Wait Bar with progress (i/simulations,h,'Running IOX-ABM simulations')

3. IOX-ABM results per sex, age-group, industry impacts, then aggregated to overall

(a) Employment (baseline), 2018 – 2030 = emp_baseline = forecasted from historical data using regression

(b) Unemployment (baseline), 2018 – 2030 = une_baseline = forecasted from historical data using regression

(c) Unemployment by sex, baseline

Unemployed Male = male ratio changes over time from regression

Unemployed Female = 1 - Unemployed Male

(d) Unemployment by sex, simulated with IOX-ABM

for i = 1 to number of simulations

unem_male(i,:) = dynamic_unemploymen(i Row, 6 to last Columns).*Unemployed Male

unem_fema(i,:) = dynamic_unemploymen(i Row, 6 to last Columns).*Unemployed Female

(i) Summarizing results by year

unem_male = Round toward positive infinity mean of unem_male

unem_fema = Round toward positive infinity mean of unem_fema

(e) Employment by sex, baseline

Employed Male = male ratio changes over time from regression

Employed Female = 1 - Employed Male

(f) Employment by sex, simulated with IOX-ABM

for i = 1 to number of simulations

emps_male(i,:) = dynamic_employement(i Row, 6 to last Columns).*Employed Male

emps_fema(i,:) = dynamic_employement(i Row, 6 to last Columns).*Employed Female

(i) Summarizing results by year

emps_male_avg_by_year = mean of emps_male

emps_fema_avg_by_year = mean of emps_fema

(g) Employment by sex and sector:

sectorp = distribution of employment per sector

sectorp_gs = distribution of employment in good sector

(i) Results of employment by sector and sex

for i = 1 to 8

emp_sector_male(:,i) = Round toward negative infinity product of emps_male_avg_by_year(i) and sectorp(all rows, i column) emp_sector_fema(:,i) = Round toward negative infinity product of emps_fema_avg_by_year(i) and sectorp(all rows, i column)

(ii) Adding results by sex and type of sector

emp_male_goods = Round toward negative infinity sum of emp_sector_male(1 to 8 Rows, all columns)

emp_male_servs = Round toward positive infinity sum of emp_sector_male(9 to last Row, all columns)

emp_fema_goods = Round toward negative infinity sum of emp_sector_fema(1 to 8 Rows, all columns)

emp_fema_servs = Round toward positive infinity sum of emp_sector_fema(9 to last Row, all columns)

4. Migration Results

(a) In-Migrants

inm = Sum of mean of dynamic_inpmigrants(all rows,6 to last Columns), mean of dynamic_intimmigran(all rows,6 to last Columns) and mean of dynamic_intretcanad(all rows, 6 to last Columns)

(b) Out-Migrants

out = Sum of mean of dynamic_outmigrants(all rows,6 to last Columns) and mean of dynamic_ouemigrants(all rows,6 to last Columns)

5. Simulated unemployment by age group, considering migration patterns

(a) unemployed male by age group

une_male_aged_15to44 = Round toward positive infinity((((inm./(inm + out))+0.48)/2).*unem_male)

une_male_aged_45to64 = Round toward negative infinity((((out./(inm + out))+0.52)/2).*unem_male)

(b) unemployed female by age group

une_fema_aged_15to44 = Round toward positive infinity((((inm./(inm + out))+0.48)/2).*unem_fema)

une_fema_aged_45to64 = Round toward negative infinity((((out./(inm + out))+0.52)/2).*unem_fema)

6. Simulated employment by age group, sex, and sector, considering migration patterns

(a) employmed male by age group 15 to 44 in goods and services sectors

emp_male_aged_15to44_goods = Round toward positive infinity((((out./(inm + out))+0.48)/2).*emp_male_goods)

emp_male_aged_15to44_servs = Round toward positive infinity((((out./(inm + out))+0.48)/2).*emp_male_servs)

(b) employmed male by age group 45 to 64 in goods and services sectors

emp_male_aged_45to64_goods = Round toward positive infinity((((out./(inm + out))+0.52)/2).*emp_male_goods)

emp_male_aged_45to64_servs = Round toward positive infinity((((out./(inm + out))+0.52)/2).*emp_male_servs)

(c) employmed female by age group 15 to 44 in goods and services sectors

emp_fema_aged_15to44_goods = Round toward positive infinity((((inm./(inm + out))+0.48)/2).*emp_fema_goods)

emp_fema_aged_15to44_servs = Round toward positive infinity((((inm./(inm + out))+0.48)/2).*emp_fema_servs)

(d) employmed female by age group 45 to 64 in goods and services sectors emp_fema_aged_45to64_goods = Round toward positive infinity((((inm./(inm + out))+0.52)/2).*emp_fema_goods)

emp_fema_aged_45to64_servs = Round toward positive infinity((((inm./(inm + out))+0.52)/2).*emp_fema_servs)

(e) Results of employment by sector

for i = 1 to 8

(i) By sex, sector and age group 15 to 44

emp_male_aged_15to44_goods_sec(all rows, i column) = emp_male_aged_15to44_goods(i)*sectorp_gs(1 to 8 Rows,i column)

emp_male_aged_15to44_servs_sec(all rows, i column) = emp_male_aged_15to44_servs(i)*sectorp_gs(9 to last Row,i column)

emp_fema_aged_15to44_goods_sec(all rows, i column) = emp_fema_aged_15to44_goods(i)*sectorp_gs(1 to 8 Rows,i column)

emp_fema_aged_15to44_servs_sec(all rows, i column) = emp_fema_aged_15to44_servs(i)*sectorp_gs(9 to last Row,i column)

(ii) By sex, sector and age group 45 to 64

emp_male_aged_45to64_goods_sec(all rows, i column) = emp_male_aged_45to64_goods(year)*sectorp_gs(1 to 8 Rows,i column)

emp_male_aged_45to64_servs_sec(all rows, i column) = emp_male_aged_45to64_servs(year)*sectorp_gs(9 to last Row,i column)

emp_fema_aged_45to64_goods_sec(all rows, i column) = emp_fema_aged_45to64_goods(year)*sectorp_gs(1 to 8 Rows,i column)

emp_fema_aged_45to64_servs_sec(all rows, i column) = emp_fema_aged_45to64_servs(year)*sectorp_gs(9 to last Row,i column)

7. Total simulated employment

empt_simulated = emp_male_aged_15to44_goods + emp_male_aged_15to44_servs + emp_male_aged_45to64_goods + emp_male_aged_45to64_servs + emp_fema_aged_15to44_goods + emp_fema_aged_15to44_servs + emp_fema_aged_45to64_goods + emp_fema_aged_45to64_servs

8. Total simulated unemployment

unem_simulated = une_male_aged_15to44 + une_male_aged_45to64 + une_fema_aged_15to44 + une_fema_aged_45to64

9. List of Industries is as follows

- Agriculture
- Forestry, Fishing, Quarrying
- Oil and Gas Extraction
- Mining (except Oil and Gas) and Mix Mining
- Support Activities for Mining and Oil and Gas Extraction
- Utilities
- Construction
- Manufacturing
- Trade
- Transportation and Warehousing
- Finance, Insurance, Real Estate and Leasing
- Professional, Scientific and Technical Services
- Business, Building and Other Support Services
- Educational Services
- Health Care and Social Assistance
- Information, culture and recreation

- Accommodation and food services
- Other services
- Public administration

10. Make a industries Matrix by repeating 4 time List of industries from Step 9
11. Make an employment_by_industry Matrix by combining following
    - Round to nearest integer emp_male_aged_15to44_goods_sec
    - Round to nearest integer emp_male_aged_15to44_servs_sec
    - Round to nearest integer emp_fema_aged_15to44_goods_sec
    - Round to nearest integer emp_fema_aged_15to44_servs_sec
    - Round to nearest integer emp_male_aged_45to64_goods_sec
    - Round to nearest integer emp_male_aged_45to64_servs_sec
    - Round to nearest integer emp_fema_aged_45to64_goods_sec
    - Round to nearest integer emp_fema_aged_45to64_servs_sec
12. Total simulated employment for males and females is calculated as follows

(a) Employed Male by age group 15 to 44 in goods and services sectors

emp_male_aged_15to44_goods = sum of Round to nearest integer emp_male_aged_15to44_goods_sec

emp_male_aged_15to44_servs = sum of Round to nearest integer emp_male_aged_15to44_servs_sec

emp_male_aged_15to44 = emp_male_aged_15to44_goods + emp_male_aged_15to44_servs

(b) Employed Male by age group 45 to 64 in goods and services sectors

emp_male_aged_45to64_goods = sum of Round to nearest integer emp_male_aged_45to64_goods_sec

emp_male_aged_45to64_servs = sum of Round to nearest integer emp_male_aged_45to64_servs_sec

emp_male_aged_45to64 = emp_male_aged_45to64_goods + emp_male_aged_45to64_servs

(c) Total Employed Males

emp_male = emp_male_aged_15to44 + emp_male_aged_45to64

(d) Employed Female by age group 15 to 44 in goods and services sectors

emp_fema_aged_15to44_goods = sum of Round to nearest integer emp_fema_aged_15to44_goods_sec

emp_fema_aged_15to44_servs = sum of Round to nearest integer emp_fema_aged_15to44_servs_sec

emp_fema_aged_15to44 = emp_fema_aged_15to44_goods + emp_fema_aged_15to44_servs;

(e) Employed Female by age group 45 to 64 in goods and services sectors

emp_fema_aged_45to64_goods = sum of Round to nearest integer emp_fema_aged_45to64_goods_sec

emp_fema_aged_45to64_servs = sum of Round to nearest integer emp_fema_aged_45to64_servs_sec

emp_fema_aged_45to64 = emp_fema_aged_45to64_goods + emp_fema_aged_45to64_servs

(f) Total Employed Females

emp_fema = emp_fema_aged_15to44 + emp_fema_aged_45to64

(g) Total Simulated Employment

empt_simulated = emp_male + emp_fema

13. List of Labels for different data is as follows

- Unemployment baseline
- Unemployment simulated
- Unemployment simulated, males, aged 15 to 44
- Unemployment simulated, males, aged 45 to 64
- Unemployment simulated, females, aged 15 to 44
- Unemployment simulated, females, aged 45 to 64
- Employment baseline
- Employment simulated
- Employment simulated, males
- Employment simulated, females
- Employment simulated, males, aged 15 to 44
- Employment simulated, males, aged 45 to 64
- Employment simulated, females, aged 15 to 44
- Employment simulated, females, aged 45 to 64
- Employment simulated, males, aged 15 to 44, goods sector
- Employment simulated, males, aged 45 to 64, goods sector
- Employment simulated, males, aged 15 to 44, service sector
- Employment simulated, males, aged 45 to 64, service sector
- Employment simulated, females, aged 15 to 44, goods sector
- Employment simulated, females, aged 45 to 64, goods sector
- Employment simulated, females, aged 15 to 44, service sector
- Employment simulated, females, aged 45 to 64, service sector

14. Make a unemp_emp_aggregated (Unemployment and Employment Aggregated) Matrix by combining following

- une_baseline
- unem_simulated
- une_male_aged_15to44
- une_male_aged_45to64
- une_fema_aged_15to44
- une_fema_aged_45to64
- emp_baseline
- empt_simulated
- emp_male
- emp_fema
- emp_male_aged_15to44
- emp_male_aged_45to64
- emp_fema_aged_15to44
- emp_fema_aged_45to64
- emp_male_aged_15to44_goods
- emp_male_aged_45to64_goods
- emp_male_aged_15to44_servs
- emp_male_aged_45to64_servs
- emp_fema_aged_15to44_goods
- emp_fema_aged_45to64_goods
- emp_fema_aged_15to44_servs
- emp_fema_aged_45to64_servs

15. Make Final tables

(a) Make a results_aggregated table by combining Label from Step 13 and unemp_emp_aggregated matrix from Step 14

(b) Make a results_employment table by combining industries from Step 10 and employment_by_industry from Step 11

16. Closing waitbar

17. Plot Figures

if makefigures is equal to 1

(a) Define the different parameters of Figure)

(b) Plot figures by Calling appropriate functions

- Call fig_ABMunemployem function with dynamic_unemploymen as input
- Call fig_ABMinmigrants function with dynamic_inpmigrants as input
- Call fig_ABMimmigrants function with dynamic_intimmigran as input
- Call fig_ABMimretcanad function with dynamic_intretcanad as input
- Call fig_ABMoutmigrant function with dynamic_outmigrants as input
- Call fig_ABMemmigrants function with dynamic_ouemigrants as input

(c) Make following legends for the figure

- observed trend
- baseline
- IOX-ABM simulations
- 95% CI

(d) Saving figures strcat('IOXABM_',sim_name,'.png')) in the results_folder

otherwise display "No figures were produced, change makefigures to 1 to produce figures"

18. Average results between 2023 and 2030

(a) Results of employment

avg_employment = mean(mean of dynamic_employement(all rows,6 to last columns))

avg_unemploymt = mean(mean of dynamic_unemploymen(all rows,6 to last columns))

(b) Results of Migration

- Out:

avg_iemigrants = mean(mean of dynamic_ouemigrants(all rows,6 to last columns))

avg_outmigrant = mean(mean of dynamic_outmigrants(all rows,6 to last columns))

- In:

avg_iretcanads = mean(mean of dynamic_intretcanad(all rows,6 to last columns))

avg_immigrants = mean(mean of dynamic_intimmigran(all rows,6 to last columns))

avg_inmigrants = mean(mean of dynamic_inpmigrants(all rows,6 to last columns))

19. Display the Reslts of Simulation from Step 18 in the following format on screen

```
==========================================================================
                                                   average 2023-2030
--------------------------------------------------------------------------
Employment          , Round toward positive infinity avg_employment
Unemployment        , Round toward positive infinity avg_unemploymt
Emigrants           , Round toward positive infinity avg_iemigrants
Immigrants          , Round toward positive infinity avg_immigrants
Returning canadians , Round toward positive infinity avg_iretcanads
Out-migrants        , Round toward positive infinity avg_outmigrant
In-migrants         , Round toward positive infinity avg_inmigrants
==========================================================================
```

Function Name funABM_unemp_agents
Inputs
- num_unemployed
- w_gs
- w_ss
- empcomp_gs
- empcomp_ss
Outputs
- simulated_agents_gs
- simulated_agents_ss
1. Initialize Following Parameters
(a) Number of Unemployed in Good Sector = num_unemployed * empcomp_gs
(b) Number of Unemployed in Service Sector = num_unemployed * empcomp_ss
(c) Less chances of working in the Good Sector kappa_gs = 7
(d) More chances of working in the Service Sector kappa_ss = 9
2. Keeping of the condition kappa_ss > kappa_gs (more chances of working in the Service Sector compared to the Good Sector)
(a) Unemployed Agents Good Sector
for i = 1 to Number of Unemployed in Good Sector from Step 1 (a)
disposition_to_work_goods_sector = Beta Random Numbers using w_gs and kappa_gs
utility_threshold_gs = Uniformly distributed random number
uagent_gs(i) = disposition_to_work_goods_sector > utility_threshold_gs;
(b) Unemployed Agents Service Sector
for i = 1 to Number of Unemployed in Service Sector from Step 1 (b)
disposition_to_work_serv_sector = Beta Random Numbers using w_ss and kappa_ss
utility_threshold_ss = Uniformly distributed random number
uagent_ss(i) = disposition_to_work_serv_sector > utility_threshold_ss;
3. Computing Agregated results for following
(a) simulated_agents_gs = Round toward positive infinity the sum of uagent_gs from Step 2 (a)
(b) simulated_agents_ss = Round toward positive infinity the sum of uagent_ss from Step 2 (b)

Function Name - funABM_dynamicsn
Inputs
- impact_employment_by_sector_2018
- ~
- ~
- total_impact_value_added_2018
Outputs
- dynamic_employement
- dynamic_unemployment
- dynamic_inmigrants
- dynamic_immigrants
- dynamic_imretcanads
- dynamic_outmigrants
- dynamic_emmigrants
1. Baselines obtained from historical data in NL
(a) Changes in Economic Environment (i.e. Growth in GDP, GDP Low Shock and GDP High Shock) are as follows
GDPgrowth = ((total_impact_value_added_2018 – base value added)/ base value added) * -120
Economic uncertainty - GDPlowsh = 9e3
Economic uncertainty - GDPhighs = 1e4
(b) Baseline Vectors used for computing the aggregated dynamic behavior of unemployed agents and migration are as follows
Baseline fraction of 15-64+ over the total population (2018-2030)
bfP = ratio forecast from historical data based on regression
Baseline reduction in EAP (2018-2030)
brEAP = ratio forecast from historical data based on regression

Baseline unemployment
bU = ratio forecast from historical data based on regression
Baseline unemployment rate (2018-2030)
bUrate = ratio forecast from historical data based on regression
Baseline employment
bE = ratio forecast from historical data based on regression
Baseline changes in salaries (2018-2030)
wage = forecast from historical data based on regression
gWai = ratio forecast from historical data based on regression
Interprovincial in-migrants
pIPi = ratio forecast from historical data based on regression
ipib = forecast from historical data based on regression
International immigrants
pImi = ratio forecast from historical data based on regression
inib = forecast from historical data based on regression
Returning Canadians (pIrc)
pIrc = ratio forecast from historical data based on regression
ircb = forecast from historical data based on regression
Interprovincial out-migrants
pIPo = ratio forecast from historical data based on regression
ipom = forecast from historical data based on regression
International emmigrants
pIem = ratio forecast from historical data based on regression
inem = forecast from historical data based on regression

2. Dynamic behavior of agents over the period of 2018 to 2030 is computed as follows

(a) 2018

(i) Dynamic behavior of agents for Year 2018
t = 1;

(ii) Compute Shock Employment and Shock Unemployment
shock_employment = sum of impact_employment_by_sector_2018 – observed data
shock = sign of shock_employment
shock_unemployment = observed data - sum of impact_employment_by_sector_2018

(iii) Compute Unemployed and Employed for the base year 2018 as follows
unemployed_2018 = Round towards negative infinity (bU(t) + shock_unemployment * shock * GDPgrowth);
num_employed_2018 = Round towards negative infinity (bE(t) + bE(t) * GDPgrowth/100);

(iv) Compute Migration patterns for in-migrants and immigrants
In order to compute interprov_inmigrants_2018 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs
- num_employed_2018
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs
- interprov_inmigrants_2018

In order to compute internati_immigrants_2018 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs

- num_employed_2018
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2018

In order to compute internati_imretcanad_2018 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs

- num_employed_2018
- pIrc(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2018

(v) Compute Migration patterns for out-migrants and emmigrants

In order to compute interprov_outmigrant_2018 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 1

Inputs

- unemployed_2018
- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)
- t

Outputs

- interprov_outmigrant_2018

In order to compute internatl_emmigrants_2018 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 1

Inputs

- unemployed_2018
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2018

(vi) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2018, internati_immigrants_2018 and internati_imretcanad_2018 from Step 2 (a) (iv)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vii) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2018 = Round towards positive infinity (unemployed_2018 - unemployed_2018 * brEAP(t))

num_employed_2018 = Round towards positive infinity (num_employed_2018 - num_employed_2018 * brEAP(t))

(viii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2018

unemployed_2018 = Sum of unemployed_2018 from Step 2 (a) (vii) and inimret_unemp from Step 2 (a) (vi)

num_employed_2018 = Sum of num_employed_2018 from Step 2 (a) (vii) and inimret_emp from Step 2 (a) (vi)

(b) 2019

(i) Dynamic behavior of agents for Year 2019

t = 2

(ii) Compute Unemployed and Employed for the year 2019 as follows

unemployed_2019 = Round towards positive infinity(bU(t) - num_employed_2018*shock*GDPgrowth/(randi([GDPlowsh(t*GDPhighs)],1,1)))

num_employed_2019 = bE(t) + bE(t)*GDPgrowth/100

(iii) Compute Migration patterns for in-migrants and immigrants

In order to compute interprov_inmigrants_2019 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs

- interprov_inmigrants_2019

In order to compute internati_immigrants_2019 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2019

In order to compute internati_imretcanad_2019 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pIrc(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2019

(iv) Compute Migration patterns for out-migrants and emmigrants

In order to compute interprov_outmigrant_2019 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 2

Inputs

- unemployed_2019
- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)
- t

Outputs

- interprov_outmigrant_2019

In order to compute internatl_emmigrants_2019 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 2

Inputs

- unemployed_2019
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2019

(v) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2019, internati_immigrants_2019 and internati_imretcanad_2019 from Step 2 (b) (iii)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vi) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2019 = Round towards positive infinity (unemployed_2019 - unemployed_2019 * brEAP(t))

num_employed_2019 = Round towards positive infinity (num_employed_2019 - num_employed_2019 * brEAP(t))

(vii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2019 unemployed_2019 = Sum of unemployed_2019 from Step 2 (b) (vi) and inimret_unemp from Step 2 (b) (v)

num_employed_2019 = Sum of num_employed_2019 from Step 2 (b) (vi) and inimret_emp from Step 2 (b) (v)

Repeat the same process for t = 3-12.

(n) 2030

(i) Dynamic behavior of agents for Year 2030

t = 13

(ii) Compute Unemployed and Employed for the year 2030 as follows

unemployed_2030 = bU(t) - num_employed_2029*shock*GDPgrowth/(randi([GDPlowsh (t*GDPhighs)],1,1))

num_employed_2030 = bE(t) - bE(t)*GDPgrowth/100

(iii) Compute Migration patterns for in-migrants and immigrantsIn order to compute interprov_inmigrants_2030 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs

- interprov_inmigrants_2030

In order to compute internati_immigrants_2030 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2030

In order to compute internati_imretcanad_2030 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pIrc(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2030

(iv) Compute Migration patterns for out-migrants and emmigrants

In order to compute interprov_outmigrant_2030 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 13

Inputs

- unemployed_2030

- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)
- t

Outputs

- interprov_outmigrant_2030

In order to compute internatl_emmigrants_2030 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 13

Inputs

- unemployed_2030
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2030

(v) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2030, internati_immigrants_2030 and internati_imretcanad_2030 from Step 2 (n) (iii)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vi) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2030 = Round towards positive infinity (unemployed_2030 - unemployed_2030 * brEAP(t))

num_employed_2030 = Round towards positive infinity (num_employed_2030 - num_employed_2030 * brEAP(t))

(vii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2030

unemployed_2030 = Sum of unemployed_2030 from Step 2 (n) (vi) and inimret_unemp from Step 2 (n) (v)

num_employed_2030 = Sum of num_employed_2030 from Step 2 (n) (vi) and inimret_emp from Step 2 (n) (v)

3. Aggregate all results from the Step 2 to form the outputs of the funABM_dynamicsn function

(a) Create a dynamic_employement matrix by combining following

- num_employed_2018 from Step 2 (a) (viii)
- num_employed_2019 from Step 2 (b) (vii)
- num_employed_2020 from Step 2 (c) (vii)
- num_employed_2021 from Step 2 (d) (vii)
- num_employed_2022 from Step 2 (e) (vii)
- num_employed_2023 from Step 2 (f) (vii)
- num_employed_2024 from Step 2 (g) (vii)
- num_employed_2025 from Step 2 (h) (vii)
- num_employed_2026 from Step 2 (j) (vii)
- num_employed_2027 from Step 2 (k) (vii)
- num_employed_2028 from Step 2 (l) (vii)

- num_employed_2029 from Step 2 (m) (vii)
- num_employed_2030 from Step 2 (n) (vii)

(b) Create a dynamic_inmigrants matrix by combining following

- interprov_inmigrants_2018 from Step 2 (a) (iv)
- interprov_inmigrants_2019 from Step 2 (b) (iii)
- interprov_inmigrants_2020 from Step 2 (c) (iii)
- interprov_inmigrants_2021 from Step 2 (d) (iii)
- interprov_inmigrants_2022 from Step 2 (e) (iii)
- interprov_inmigrants_2023 from Step 2 (f) (iii)
- interprov_inmigrants_2024 from Step 2 (g) (iii)
- interprov_inmigrants_2025 from Step 2 (h) (iii)
- interprov_inmigrants_2026 from Step 2 (j) (iii)
- interprov_inmigrants_2027 from Step 2 (k) (iii)
- interprov_inmigrants_2028 from Step 2 (l) (iii)
- interprov_inmigrants_2029 from Step 2 (m) (iii)
- interprov_inmigrants_2030 from Step 2 (n) (iii)

(c) Create a dynamic_immigrants matrix by combining following

- internati_immigrants_2018 from Step 2 (a) (iv)
- internati_immigrants_2019 from Step 2 (b) (iii)
- internati_immigrants_2020 from Step 2 (c) (iii)
- internati_immigrants_2021 from Step 2 (d) (iii)
- internati_immigrants_2022 from Step 2 (e) (iii)
- internati_immigrants_2023 from Step 2 (f) (iii)
- internati_immigrants_2024 from Step 2 (g) (iii)
- internati_immigrants_2025 from Step 2 (h) (iii)
- internati_immigrants_2026 from Step 2 (j) (iii)
- internati_immigrants_2027 from Step 2 (k) (iii)
- internati_immigrants_2028 from Step 2 (l) (iii)
- internati_immigrants_2029 from Step 2 (m) (iii)
- internati_immigrants_2030 from Step 2 (n) (iii)

(d) Create a dynamic_imretcanads matrix by combining following

- internati_imretcanad_2018 from Step 2 (a) (iv)
- internati_imretcanad_2019 from Step 2 (b) (iii)
- internati_imretcanad_2020 from Step 2 (c) (iii)
- internati_imretcanad_2021 from Step 2 (d) (iii)
- internati_imretcanad_2022 from Step 2 (e) (iii)
- internati_imretcanad_2023 from Step 2 (f) (iii)
- internati_imretcanad_2024 from Step 2 (g) (iii)
- internati_imretcanad_2025 from Step 2 (h) (iii)
- internati_imretcanad_2026 from Step 2 (j) (iii)
- internati_imretcanad_2027 from Step 2 (k) (iii)
- internati_imretcanad_2028 from Step 2 (l) (iii)
- internati_imretcanad_2029 from Step 2 (m) (iii)
- internati_imretcanad_2030 from Step 2 (n) (iii)

(e) Create a dynamic_unemployment matrix by combining following

- unemployed_2018 from Step 2 (a) (viii)
- unemployed_2019 from Step 2 (b) (vii)
- unemployed_2020 from Step 2 (c) (vii)
- unemployed_2021 from Step 2 (d) (vii)
- unemployed_2022 from Step 2 (e) (vii)
- unemployed_2023 from Step 2 (f) (vii)
- unemployed_2024 from Step 2 (g) (vii)
- unemployed_2025 from Step 2 (h) (vii)
- unemployed_2026 from Step 2 (j) (vii)
- unemployed_2027 from Step 2 (k) (vii)
- unemployed_2028 from Step 2 (l) (vii)
- unemployed_2029 from Step 2 (m) (vii)

- unemployed_2030 from Step 2 (n) (vii)

(f) Create a dynamic_outmigrants matrix by combining following

- interprov_outmigrant_2018 from Step 2 (a) (v)
- interprov_outmigrant_2019 from Step 2 (b) (iv)
- interprov_outmigrant_2020 from Step 2 (c) (iv)
- interprov_outmigrant_2021 from Step 2 (d) (iv)
- interprov_outmigrant_2022 from Step 2 (e) (iv)
- interprov_outmigrant_2023 from Step 2 (f) (iv)
- interprov_outmigrant_2024 from Step 2 (g) (iv)
- interprov_outmigrant_2025 from Step 2 (h) (iv)
- interprov_outmigrant_2026 from Step 2 (j) (iv)
- interprov_outmigrant_2027 from Step 2 (k) (iv)
- interprov_outmigrant_2028 from Step 2 (l) (iv)
- interprov_outmigrant_2029 from Step 2 (m) (iv)
- interprov_outmigrant_2030 from Step 2 (n) (iv)

(g) Create a dynamic_emmigrants matrix by combining following

- internatl_emmigrants_2018 from Step 2 (a) (v)
- internatl_emmigrants_2019 from Step 2 (b) (iv)
- internatl_emmigrants_2020 from Step 2 (c) (iv)
- internatl_emmigrants_2021 from Step 2 (d) (iv)
- internatl_emmigrants_2022 from Step 2 (e) (iv)
- internatl_emmigrants_2023 from Step 2 (f) (iv)
- internatl_emmigrants_2024 from Step 2 (g) (iv)
- internatl_emmigrants_2025 from Step 2 (h) (iv)
- internatl_emmigrants_2026 from Step 2 (j) (iv)
- internatl_emmigrants_2027 from Step 2 (k) (iv)
- internatl_emmigrants_2028 from Step 2 (l) (iv)
- internatl_emmigrants_2029 from Step 2 (m) (iv)
- internatl_emmigrants_2030 from Step 2 (n) (iv)

Function Name - funABM_dynamicsp

Inputs

- impact_employment_by_sector_2018
- changes_labor_income_goodssector_2018
- changes_labor_income_servssector_2018
- total_impact_value_added_2018

Outputs

- dynamic_employement
- dynamic_unemployment
- dynamic_inmigrants
- dynamic_immigrants
- dynamic_imretcanads
- dynamic_outmigrants
- dynamic_emmigrants

1. Baselines obtained from historical data in NL&L

(a) Changes in Employment's Composition in Goods and Services Sectors are as follows

empcomp_gs_2018 = sum(impact_employment_by_sector_2018(1:7))/sum(impact_employment_by_sector_2018)

empcomp_ss_2018 = sum(impact_employment_by_sector_2018(8:end))/sum(impact_employment_by_sector_2018)

(b) Changes in Economic Environment (i.e. Growth in GDP, GDP Low Shock and GDP High Shock) are as follows

GDPgrowth = ((total_impact_value_added_2018 – observed data)/observed data) * 100

Economic uncertainty - GDPlowsh = 9e3

Economic uncertainty - GDPhighs = 1e4

(c) Baseline Vectors used for computing the aggregated dynamic behavior of unemployed agents and migration are as follows

Baseline fraction of 15-64+ over the total population (2018-2030)
bfP = ratio forecast from historical data based on regression
Baseline reduction in EAP (2018-2030)
brEAP = ratio forecast from historical data based on regression
Baseline unemployment:
bU = forecast from historical data based on regression
Baseline unemployment rate (2018-2030)
bUrate = ratio forecast from historical data based on regression
Baseline employment
bE = ratio forecast from historical data based on regression
Composition of the goods sector in the labor market
cG = ratio forecast from historical data based on regression
Baseline changes in salaries (2018-2030)
wage = forecast from historical data based on regression
gWgs = ratio forecast from historical data based on regression
gWss = ratio forecast from historical data based on regression
gWai = ratio forecast from historical data based on regression
Interprovincial in-migrants
pIPi = ratio forecast from historical data based on regression
ipib = forecast from historical data based on regression
International immigrants
pImi = ratio forecast from historical data based on regression
inib = forecast from historical data based on regression
Returning Canadians (pIrc)
pIrc = ratio forecast from historical data based on regression
ircb = forecast from historical data based on regression
Interprovincial out-migrants
pIPo = ratio forecast from historical data based on regression
ipom = forecast from historical data based on regression
International emmigrants
pIem = ratio forecast from historical data based on regression
inem = forecast from historical data based on regression

2. Dynamic behavior of agents over the period of 2018 to 2030 is computed as follows
(a) 2018
(i) Dynamic behavior of agents for Year 2018
t = 1
(ii) Compute Shock Employment and Shock Unemployment
shock_employment = sum of impact_employment_by_sector_2018 – observed data
shock = sign of shock_employment
shock_unemployment = observed data - sum of impact_employment_by_sector_2018
(iii) Compute Unemployed and Employed for the base year 2018 as follows
Unemployed for the year 2018
unemployed_2018 = Round towards positive infinity (bU(t) + shock_unemployment * shock * GDPgrowth)

In order to compute unemployed simulated_agents_gs and simulated_agents_ss Call funABM_unemp_agents Function with following arguments
Inputs
- unemployed_2018
- changes_labor_income_goodssector_2018
- changes_labor_income_servssector_2018
- empcomp_gs_2018
- empcomp_ss_2018
Outputs
- simulated_agents_gs

- simulated_agents_ss

Employed for the year 2018

num_employed_2018 = Round towards positive infinity((simulated_agents_gs + simulated_agents_ss)*GDPgrowth/(randi([1 (t*2)],1,1)) + bE(t))

Employment Composition Goods Sector

empcomp_gs = Mean of ([simulated_agents_gs/(simulated_agents_gs+simulated_agents_ss),cG(t)]) ignoring NaN values

(iv) Compute Migration patterns for in-migrants and immigrants

In order to compute interprov_inmigrants_2018 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs

- num_employed_2018
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs

- interprov_inmigrants_2018

In order to compute internati_immigrants_2018 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs

- num_employed_2018
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2018

In order to compute internati_imretcanad_2018 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 1

Inputs

- num_employed_2018
- pIrc(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2018

(v) Compute Migration patterns for out-migrants and emmigrants

In order to compute interprov_outmigrant_2018 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 1

Inputs

- unemployed_2018
- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)

- t

Outputs

- interprov_outmigrant_2018

In order to compute internatl_emmigrants_2018 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 1

Inputs

- unemployed_2018
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2018

(vi) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2018, internati_immigrants_2018 and internati_imretcanad_2018 from Step 2 (a) (iv)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vii) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2018 = Round towards positive infinity (unemployed_2018 - unemployed_2018 * brEAP(t))

num_employed_2018 = Round towards positive infinity (num_employed_2018 - num_employed_2018 * brEAP(t))

(viii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2018

unemployed_2018 = Sum of unemployed_2018 from Step 2 (a) (vii) and inimret_unemp from Step 2 (a) (vi)

num_employed_2018 = Sum of num_employed_2018 from Step 2 (a) (vii) and inimret_emp from Step 2 (a) (vi)

(b) 2019

(i) Dynamic behavior of agents for Year 2019

t = 2

(ii) Compute Unemployed and Employed for the year 2019 as follows

Unemployed for the year 2019

unemployed_2019 = Round towards positive infinity (bU(t) - num_employed_2018*shock*GDPgrowth/(randi([GDPlowsh (t*GDPhighs)],1,1)))

Employment Composition Goods Sector 2019

empcomp_gs_2019 = (empcomp_gs + cG(t))/2

Changes in Labor Income Goods Sector 2019

w_gs_2019 = changes_labor_income_goodssector_2018 + gWgs(2)*changes_labor_income_goodssector_2018

Changes in Labor Income Services Sector 2019

w_ss_2019 = changes_labor_income_servssector_2018 + gWss(2)*changes_labor_income_goodssector_2018

In order to compute unemployed simulated_agents_gs and simulated_agents_ss Call funABM_unemp_agents Function with following arguments

Inputs

- unemployed_2019
- w_gs_2019
- w_ss_2019
- empcomp_gs_2019
- (1-empcomp_gs_2019)

Outputs

- simulated_agents_gs
- simulated_agents_ss

Employed for the year 2019

num_employed_2019 = (simulated_agents_gs + simulated_agents_ss)*GDPgrowth/(randi([1 (t*2)],1,1)) + bE(t)

Employment Composition Goods Sector

empcomp_gs = Mean of ([simulated_agents_gs/(simulated_agents_gs+simulated_agents_ss),cG(t)]) ignoring NaN values

(iii) Compute Migration patterns for in-migrants and immigrants

In order to compute interprov_inmigrants_2019 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs

- interprov_inmigrants_2019

In order to compute internati_immigrants_2019 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2019

In order to compute internati_imretcanad_2019 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 2

Inputs

- num_employed_2019
- pIrc(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2019

(iv) Compute Migration patterns for out-migrants and emmigrants
In order to compute interprov_outmigrant_2019 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 2

Inputs

- unemployed_2019
- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)
- t

Outputs

- interprov_outmigrant_2019

In order to compute internatl_emmigrants_2019 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 2

Inputs

- unemployed_2019
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2019

(v) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2019, internati_immigrants_2019 and internati_imretcanad_2019 from Step 2 (b) (iii)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vi) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2019 = Round towards positive infinity (unemployed_2019 - unemployed_2019 * brEAP(t))

num_employed_2019 = Round towards positive infinity (num_employed_2019 - num_employed_2019 * brEAP(t))

(vii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2019

unemployed_2019 = Sum of unemployed_2019 from Step 2 (b) (vi) and inimret_unemp from Step 2 (b) (v)

num_employed_2019 = Sum of num_employed_2019 from Step 2 (b) (vi) and inimret_emp from Step 2 (b) (v)

Repeat the same process from t = 3- 12

(n) 2030

(i) Dynamic behavior of agents for Year 2030

t = 13

(ii) Compute Unemployed and Employed for the year 2030 as follows

Unemployed for the year 2030

unemployed_2030 = bU(t) - num_employed_2029*shock*GDPgrowth/(randi([GDPlowsh (t*GDPhighs)],1,1))

Employment Composition Goods Sector 2030

empcomp_gs_2030 = (empcomp_gs + cG(t))/2

Changes in Labor Income Goods Sector 2030

w_gs_2030 = w_gs_2029 + gWgs(t)*w_gs_2029

Changes in Labor Income Services Sector 2030

w_ss_2030 = w_ss_2029 + gWss(t)*w_ss_2029

In order to compute unemployed simulated_agents_gs and simulated_agents_ss Call funABM_unemp_agents Function with following arguments

Inputs

- unemployed_2030
- w_gs_2030
- w_ss_2022
- empcomp_gs_2030
- (1-empcomp_gs_2030)

Outputs

- simulated_agents_gs
- simulated_agents_ss

Employed for the year 2030

num_employed_2030 = (simulated_agents_gs + simulated_agents_ss)*GDPgrowth/(randi([t-8 (t*2)],1,1)) + bE(t)

Employment Composition Goods Sector

empcomp_gs = Mean of ([simulated_agents_gs/(simulated_agents_gs+simulated_agents_ss),cG(t)]) ignoring NaN values

(iii) Compute Migration patterns for in-migrants and immigrants

In order to compute interprov_inmigrants_2030 (Interprovincial In-Migrants) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pIPi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ipib(t)
- t

Outputs

- interprov_inmigrants_2030

In order to compute internati_immigrants_2030 (International Immigrants) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pImi(t)
- wage(t)
- gWai(t)
- GDPgrowth
- shock
- inib(t)
- t

Outputs

- internati_immigrants_2030

In order to compute internati_imretcanad_2030 (International Immigrants returning to Cananda) Call funABM_migrant_agents_in Function with following arguments where t = 13

Inputs

- num_employed_2030
- pIrc(t)

- wage(t)
- gWai(t)
- GDPgrowth
- shock
- ircb(t)
- t

Outputs

- internati_imretcanad_2030

(iv) Compute Migration patterns for out-migrants and emmigrants

In order to compute interprov_outmigrant_2030 (Interprovincial Out-Migrants) Call funABM_migrant_agents_out Function with following arguments where t = 13

Inputs

- unemployed_2030
- pIPo(t)
- GDPgrowth
- shock_unemployment
- ipom(t)
- t

Outputs

- interprov_outmigrant_2030

In order to compute internatl_emmigrants_2030 (International Emmigrants) Call funABM_migrant_agents_out Function with following arguments where t = 13

Inputs

- unemployed_2030
- pIem(t)
- GDPgrowth
- shock_unemployment
- inem(t)
- t

Outputs

- internatl_emmigrants_2030

(v) Compute Connection of migration with labour market

Total Number of inmigrants, immigrants and returning canadians

inimretpop_tot = Sum of interprov_inmigrants_2030, internati_immigrants_2030 and internati_imretcanad_2030 from Step 2 (n) (iii)

Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+

inimretpop_15to64p = Round towards positive infinity (bfP(t)*inimretpop_tot)

Divide Total Nummber of inmigrants, immigrants and returning canadians in the Age group of 15-64+ into employed and unemployed

inimret_unemp = Round towards positive infinity (bUrate(t)*inimretpop_15to64p)

inimret_emp = Round towards positive infinity ((1 - bUrate(t))*inimretpop_15to64p)

(vi) Considering changes in economic active population (EAP) because a fraction of the population retires also every year

unemployed_2030 = Round towards positive infinity (unemployed_2030 - unemployed_2030 * brEAP(t))

num_employed_2030 = Round towards positive infinity (num_employed_2030 - num_employed_2030 * brEAP(t))

(vii) Finally Adding effect of migration on the labour market and computing Unemployed and Employed for the year 2030

unemployed_2030 = Sum of unemployed_2030 from Step 2 (n) (vi) and inimret_unemp from Step 2 (n) (v)

num_employed_2030 = Sum of num_employed_2030 from Step 2 (n) (vi) and inimret_emp from Step 2 (n) (v)

3. Aggregate all results from the Step 2 to form the outputs of the funABM_dynamicsp function

(a) Create a dynamic_employement matrix by combining following

- num_employed_2018 from Step 2 (a) (viii)
- num_employed_2019 from Step 2 (b) (vii)
- num_employed_2020 from Step 2 (c) (vii)
- num_employed_2021 from Step 2 (d) (vii)
- num_employed_2022 from Step 2 (e) (vii)
- num_employed_2023 from Step 2 (f) (vii)
- num_employed_2024 from Step 2 (g) (vii)
- num_employed_2025 from Step 2 (h) (vii)
- num_employed_2026 from Step 2 (j) (vii)
- num_employed_2027 from Step 2 (k) (vii)
- num_employed_2028 from Step 2 (l) (vii)
- num_employed_2029 from Step 2 (m) (vii)
- num_employed_2030 from Step 2 (n) (vii)

(b) Create a dynamic_inmigrants matrix by combining following

- interprov_inmigrants_2018 from Step 2 (a) (iv)
- interprov_inmigrants_2019 from Step 2 (b) (iii)
- interprov_inmigrants_2020 from Step 2 (c) (iii)
- interprov_inmigrants_2021 from Step 2 (d) (iii)
- interprov_inmigrants_2022 from Step 2 (e) (iii)
- interprov_inmigrants_2023 from Step 2 (f) (iii)
- interprov_inmigrants_2024 from Step 2 (g) (iii)
- interprov_inmigrants_2025 from Step 2 (h) (iii)
- interprov_inmigrants_2026 from Step 2 (j) (iii)
- interprov_inmigrants_2027 from Step 2 (k) (iii)
- interprov_inmigrants_2028 from Step 2 (l) (iii)
- interprov_inmigrants_2029 from Step 2 (m) (iii)
- interprov_inmigrants_2030 from Step 2 (n) (iii)

(c) Create a dynamic_immigrants matrix by combining following

- internati_immigrants_2018 from Step 2 (a) (iv)
- internati_immigrants_2019 from Step 2 (b) (iii)
- internati_immigrants_2020 from Step 2 (c) (iii)
- internati_immigrants_2021 from Step 2 (d) (iii)
- internati_immigrants_2022 from Step 2 (e) (iii)
- internati_immigrants_2023 from Step 2 (f) (iii)
- internati_immigrants_2024 from Step 2 (g) (iii)
- internati_immigrants_2025 from Step 2 (h) (iii)
- internati_immigrants_2026 from Step 2 (j) (iii)
- internati_immigrants_2027 from Step 2 (k) (iii)
- internati_immigrants_2028 from Step 2 (l) (iii)
- internati_immigrants_2029 from Step 2 (m) (iii)
- internati_immigrants_2030 from Step 2 (n) (iii)

(d) Create a dynamic_imretcanads matrix by combining following

- internati_imretcanad_2018 from Step 2 (a) (iv)
- internati_imretcanad_2019 from Step 2 (b) (iii)
- internati_imretcanad_2020 from Step 2 (c) (iii)
- internati_imretcanad_2021 from Step 2 (d) (iii)
- internati_imretcanad_2022 from Step 2 (e) (iii)
- internati_imretcanad_2023 from Step 2 (f) (iii)
- internati_imretcanad_2024 from Step 2 (g) (iii)
- internati_imretcanad_2025 from Step 2 (h) (iii)
- internati_imretcanad_2026 from Step 2 (j) (iii)
- internati_imretcanad_2027 from Step 2 (k) (iii)
- internati_imretcanad_2028 from Step 2 (l) (iii)
- internati_imretcanad_2029 from Step 2 (m) (iii)
- internati_imretcanad_2030 from Step 2 (n) (iii)

(e) Create a dynamic_unemployment matrix by combining following
- unemployed_2018 from Step 2 (a) (viii)
- unemployed_2019 from Step 2 (b) (vii)
- unemployed_2020 from Step 2 (c) (vii)
- unemployed_2021 from Step 2 (d) (vii)
- unemployed_2022 from Step 2 (e) (vii)
- unemployed_2023 from Step 2 (f) (vii)
- unemployed_2024 from Step 2 (g) (vii)
- unemployed_2025 from Step 2 (h) (vii)
- unemployed_2026 from Step 2 (j) (vii)
- unemployed_2027 from Step 2 (k) (vii)
- unemployed_2028 from Step 2 (l) (vii)
- unemployed_2029 from Step 2 (m) (vii)
- unemployed_2030 from Step 2 (n) (vii)

(f) Create a dynamic_outmigrants matrix by combining following
- interprov_outmigrant_2018 from Step 2 (a) (v)
- interprov_outmigrant_2019 from Step 2 (b) (iv)
- interprov_outmigrant_2020 from Step 2 (c) (iv)
- interprov_outmigrant_2021 from Step 2 (d) (iv)
- interprov_outmigrant_2022 from Step 2 (e) (iv)
- interprov_outmigrant_2023 from Step 2 (f) (iv)
- interprov_outmigrant_2024 from Step 2 (g) (iv)
- interprov_outmigrant_2025 from Step 2 (h) (iv)
- interprov_outmigrant_2026 from Step 2 (j) (iv)
- interprov_outmigrant_2027 from Step 2 (k) (iv)
- interprov_outmigrant_2028 from Step 2 (l) (iv)
- interprov_outmigrant_2029 from Step 2 (m) (iv)
- interprov_outmigrant_2030 from Step 2 (n) (iv)

(g) Create a dynamic_emmigrants matrix by combining following
- internatl_emmigrants_2018 from Step 2 (a) (v)
- internatl_emmigrants_2019 from Step 2 (b) (iv)
- internatl_emmigrants_2020 from Step 2 (c) (iv)
- internatl_emmigrants_2021 from Step 2 (d) (iv)
- internatl_emmigrants_2022 from Step 2 (e) (iv)
- internatl_emmigrants_2023 from Step 2 (f) (iv)
- internatl_emmigrants_2024 from Step 2 (g) (iv)
- internatl_emmigrants_2025 from Step 2 (h) (iv)
- internatl_emmigrants_2026 from Step 2 (j) (iv)
- internatl_emmigrants_2027 from Step 2 (k) (iv)
- internatl_emmigrants_2028 from Step 2 (l) (iv)
- internatl_emmigrants_2029 from Step 2 (m) (iv)
- internatl_emmigrants_2030 from Step 2 (n) (iv)

Function Name funABM_migrant_agents_in

Inputs
- employment_situation
- baseline
- wages
- gWai
- GDPgrowth
- shock
- iib
- t

Outputs
- number_of_migrants

1. Initialize Following Parameters

(a) expected_salary = (wages + wages*gWai)/100

(b) lowgrowth = 0.05 + (t/2/100);

(c) highgrowth = 0.15 + (t/100);
(d) expected_economic_situation = (GDPgrowth/100) + (lowgrowth + (highgrowth-lowgrowth) *rand(1,1));

2. Proportion of Agents based on age structure
(a) Proportion of agents aged 45 to 64 years = 0.48
(b) Proportion of agents aged 15 to 44 years = 0.52

3. Number of Potential Agents that could decide to migrate = Round toward positive infinity (product of employment_situation and baseline + product of employment_situation, baseline and expected_economic_situation)

4. Compute Number of Migrants using following method
if Number of Potential Agents from Step 3 are less than 3
Number of Migrants are 1 (In the case of low counts as e.g. returning Canadians)
Otherwise
Compute Number of Migrants aged 15 to 44 years
Number of Potential Agents aged 15 to 44 years are equal to Number of Potential Agents * Proportion of agents aged 15 to 44 years
for i = 1 to Number of Potential Agents aged 15 to 44 years
utility_to_migrate = Beta Random Numbers using expected_salary and 1
utility_threshold = Uniformly distributed random number
migrants_aged_15to44(i) = utility_to_migrate > utility_threshold
Compute Number of Migrants aged 45 to 64 years
Number of Potential Agents aged 45 to 64 years are equal to Number of Potential Agents * Proportion of agents aged 45 to 64 years
for i = 1 to Number of Potential Agents aged 45 to 64 years
utility_to_migrate = Beta Random Numbers using expected_salary and 3
utility_threshold = Uniformly distributed random number
migrants_aged_45to64(i) = utility_to_migrate > utility_threshold
simulated_agents_aged_45_to_64 = Round toward positive infinity sum of migrants_aged_15to44
simulated_agents_aged_15_to_44 = Round toward positive infinity sum of migrants_aged_45to64
Number of Migrants = iib + (simulated_agents_aged_45_to_64 + simulated_agents_aged_15_to_44) * shock * abs(GDPgrowth/randi([200 (t*100 + 200)],1,1))

Function Name funABM_migrant_agents_out
Inputs
- employment_situation
- baseline
- GDPgrowth
- shock_employment
- base
- t
Outputs
- number_of_migrants

1. Initialize Following Parameters
(a) shock = sign(shock_employment) * -1
(b) lowgrowth = 0.05 + (t/2/100)
(c) highgrowth = 0.15 + (t/100)
(d) expected_economic_situation = (GDPgrowth/100) + (lowgrowth + (highgrowth-lowgrowth) *rand(1,1))

2. Proportion of Agents based on age structure
(a) Proportion of agents aged 45 to 64 years = 0.48
(b) Proportion of agents aged 15 to 44 years = 0.52

3. Number of Potential Agents that could decide to migrate = Round toward positive infinity product of employment_situation and baseline

4. Compute Number of Migrants using following method
if Number of Potential Agents from Step 3 are less than 3
Number of Migrants are 1 (In the case of low counts as e.g. returning Canadians)

```
            Otherwise
                        Compute Number of Migrants aged 15 to 44 years
                                    Number of Potential Agents aged 15 to 44 years are equal to Number of Potential
Agents * Proportion of agents aged 15 to 44 years
                                    for i = 1 to Number of Potential Agents aged 15 to 44 years
                                                utility_to_migrate = Beta Random Numbers using
2*expected_economic_situation and 3
                                                utility_threshold = Uniformly distributed random number
                                                migrants_aged_15to44(i) = utility_to_migrate > utility_threshold
                        Compute Number of Migrants aged 45 to 64 years
                                    Number of Potential Agents aged 45 to 64 years are equal to Number of Potential
Agents * Proportion of agents aged 45 to 64 years
                                    for i = 1 to Number of Potential Agents aged 45 to 64 years
                                                utility_to_migrate = Beta Random Numbers using
expected_economic_situation and 5
                                                utility_threshold = Uniformly distributed random number
                                                migrants_aged_45to64(i) = utility_to_migrate > utility_threshold
                        simulated_agents_aged_45_to_64 = Round toward positive infinity sum of
migrants_aged_15to44
                        simulated_agents_aged_15_to_44 = Round toward positive infinity sum of
migrants_aged_45to64
                        Number of Migrants = max(0, base - (simulated_agents_aged_45_to_64 +
simulated_agents_aged_15_to_44) * abs(GDPgrowth/15) * shock)
```