Carbon Emissions in India: A Computable General Equilibrium Analysis

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in Engineering and Policy Analysis

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Executive Summary

As the world's third-largest emitter of greenhouse gases, India stands at a crucial juncture in the global fight against climate change. Recognising the delicate balance India must strike between rapid economic growth and sustainable development, this research employs a Computable General Equilibrium (CGE) model tailored specifically for the nation. By incorporating Greenhouse Gas (GHG) emissions, the model delivers an in-depth analysis of the potential economic impacts of climate mitigation strategies, especially carbon taxation, within the intricate fabric of India's diverse economy. This endeavour fills a significant knowledge gap, offering a tool that policy analysts can use to harmonise India's developmental aspirations with its global climate commitments.

Tapping into the power of quantitative methodologies, the study leverages CGE models known for their proficiency in capturing a country's economic interconnections. For India, this model weaves in GHG emissions to holistically assess the economic ramifications of carbon taxation. Core to this research is data sourced from India's Social Accounting Matrix (SAM) (Pal et al., 2020), complemented by inputs from national databases capturing carbon intensities, labour productivity, and capital stock depreciation.

The application of the CGE model to India's context yielded pivotal insights. A deep dive into sectors revealed that five of them, led prominently by the coal-intensive energy sector, are responsible for over 95% of India's emissions. Notwithstanding the nation's push towards renewables, emissions are dauntingly high. While a modest carbon tax has limited impact, a more aggressive tax rate, although effective, disrupts income distribution, disproportionately affecting India's marginalised populations. The research thus underscores a synergistic approach, merging targeted reinvestments with a robust carbon tax as the linchpin for sustainable decarbonisation in India. While potent in emission reduction, such strategies necessitate protective measures, like subsidies, to prevent deepening India's socio-economic divides.

The study recognises intrinsic limitations that need addressing. The current model's architecture possesses constraints, particularly in its representation of export levels and wage growth. An endogenous presentation in these areas would provide a richer systemic view. While the research touched upon two primary tax rates, a broader exploration of tax rates is warranted to align more accurately with Key Performance Indicators (KPIs). The present pricing mechanism, which leans heavily on consumers bearing the entirety of the carbon tax, hints at a potential imbalance in economic impact and needs reevaluation. Additionally, using placeholder coefficients for decarbonisation offers a limited perspective, potentially glossing over the nuances of carbon reduction dynamics. Notably, the model's exclusion of simulations for extreme weather events is a critical oversight, which could affect its forecasting abilities, especially in climate change.

This research presents actionable policy recommendations, chiefly underscoring the role of targeted reinvestment coupled with a high carbon tax rate. With India's energy sector at the forefront, targeted reinvestments promise to bolster GDP and reduce emissions, providing a roadmap that aligns economic growth with climate mitigation. However, given India's socio-economic fabric, implementing such strategies mandates careful consideration of potential impacts, especially on vulnerable sectors like agriculture and the vast populace of lower-income households.

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PART 1: THESIS DEFINITION

1. Introduction

This chapter presents a comprehensive analysis of the problem under investigation, focusing on its significance in the societal context and highlighting the existing research gaps. Furthermore, it delves into the relevance of the identified problem and outlines the specific research questions that this thesis aims to address.

1.1 Societal Relevance and Context

Climate change is a global phenomenon precipitated by human activities that contribute to altering the atmosphere. It leads to the depletion of natural resources, environmental damage, and increased global temperatures (Manuel et al., 2021). In order to mitigate the escalating consequences of global warming, policymakers are endeavouring to reduce and eventually phase out greenhouse gas emissions (Babatunde et al., 2017).

The Intergovernmental Panel on Climate Change, in its Sixth Assessment Report (AR6), highlights this concern by noting that the concentration of carbon dioxide in the atmosphere has reached unprecedented levels in the last 800,000 years, making it a perilous time for life on Earth. The report further emphasises the urgency of immediate action to address the issue of GHG emissions. It underscores and critically identifies anthropogenic GHG emissions as the primary driver of several severe climate impacts observed worldwide (AR6 Synthesis Report: Climate Change, 2023, 2023). This finding has led to a growing consensus regarding the urgency of tackling global emissions. Notably, fossil fuel combustion accounts for approximately three-quarters of all anthropogenic GHG emissions (Goodman, 2016), underscoring the critical need for economy-wide decarbonisation.

In 2023, the top three emitters of GHGs are USA, China, and India. While India is still a developing nation, it is quickly becoming one of the world's largest polluters. Nevertheless, as of 2021, India's per capita greenhouse gas emissions remained relatively nominal, registering approximately 2.77 tonnes. This figure is considerably lower when juxtaposed with China's emissions, which averaged 9.62 tonnes per capita, and the United States, which were markedly higher at 17.58 tonnes per individual (Per capita greenhouse gas emissions, 2023). The two key challenges for developing countries such as India are tackling poverty and mitigating climate change simultaneously (Stern, 2016). In India, both challenges are formidable and urgent. India's per capita emissions are amongst the world's lowest and are expected to rise drastically in the coming decades (Weitzel et al., 2014). Further, the country has over 200 million people living in poverty and over 40 million without electricity, further exacerbating the issue (World Bank Group, 2021; Gupta et al., 2019).

The myriad problems that plague the country are urgent since India is also expected to face among the most drastic impacts of climate change due to loss of arable land, increased temperatures, reduced food security, and water scarcity leading to a tangible loss of life (CSTEP, 2022). Given the issue's complexity, effective policies that tackle climate change without relegating its economic or social issues are pivotal. A comprehensive policy analysis assessing the impact of such changes in the broader economy is pivotal to effectively addressing climate change (Burfisher, 2021). Some effective tools for assessing these policies come from macroeconomic modelling paradigms.

Computable General Equilibrium (CGE) modelling has been a common choice to assess the effectiveness and impacts of various economic policies on the broader economy (Hossain et al., 2022; Ochuodho et al., 2012). CGE models provide the ability to analyse both direct and indirect effects of policy changes across all sectors of the economy, capturing the interlinkages and ripple effects (Bezabih, 2010). The advantage of the Computable General Equilibrium (CGE) modelling methodology lies in its reliance on national accounting identities and a harmonious Social Accounting Matrix (SAM). This approach safeguards the consistency of the output and precludes the occurrence of 'black holes', which are undefined or non-closed relationships that are not otherwise acknowledged.

Furthermore, a CGE model accommodates economic structure changes over different periods. This allows for long-term analysis and scenario comparisons, which are crucial for understanding the sustained impacts of policy decisions (Taylor, 2016). By providing quantitative results, CGE models equip policymakers with specific data points to make informed decisions and create resilient, future-proof policies. Moreover, they illuminate the synergies and trade-offs between different policy goals, aiding in developing balanced and efficient strategies that cater to environmental and economic considerations (Burfisher, 2021).

1.2 Research Gaps

India's government develops macroeconomic policy and channels public investment to lift people out of poverty and boost economic growth, often at odds with climate mitigation goals (Goodman, 2016). However, despite difficulties, the country has committed to decreasing its emission intensity and developing enough capacity to obtain 50% of its power production from non-fossil sources by 2030 (Gupta et al., 2019). This would require extensive planning and insight into how effective policy can tackle this challenge without hampering the country's longer-term development strategy.

CGE models are a valuable tool for policymaking because they capture intersectoral linkages and simulate the economy-wide effects of policy interventions (Böhringer & Rutherford, 2009). They allow for a holistic evaluation of policy measures, considering direct and indirect effects. Despite the significance of such models, literature on development economics addressing climate change policies using CGE models incorporating emissions is relatively sparse (Kiuila & Rutherford, 2013).

This is a significant research gap as climate policies have far-reaching implications across the entire economy and its sectors. Analysing these policies in isolation or without consideration of their emissions impacts risks overlooking necessary interconnections and potential trade-offs (Böhringer & Löschel, 2006). Furthermore, developing countries such as India, where both growth and sustainability are imperative, present a unique challenge that is underrepresented in the existing body of research (Babiker & Eckaus, 2006).

In the prevailing context, this research offers pivotal contributions to policy discussions. Central to the study is developing a Computable General Equilibrium (CGE) model for India that integrates Greenhouse Gas (GHG) emissions. This model quantifies carbon emissions as a function of the production output levels of various economic sectors. Such an integration facilitates a more comprehensive evaluation of climate mitigation strategies. Notably, many extant CGE models predominantly focus on economic variables adversely affected by mitigation efforts, often overlooking emissions. This exclusion can inadvertently present such policies in an unduly negative light. Among mitigation strategies, carbon taxation stands out as a widely adopted measure. Its essence lies in regulating emissions by escalating production costs or imposing output limits. The model presented in this research is instrumental in dissecting both the overt and subtle implications of climate change mitigation measures, with an emphasis on carbon taxation. This analytical tool deepens our grasp of climate interventions' potential economic repercussions and efficacy. This comprehension assists in sculpting policies harmonising economic growth with climate mitigation objectives. Reinforcing the urgency of such analyses is India's robust commitment to a greener energy trajectory, demanding meticulous evaluation of policy ramifications, as highlighted by Gupta et al. (2019).

Integrating emissions into CGE models thus forms a crucial bridge between economic planning and environmental stewardship. This bridge is crucial in navigating sustainable development challenges in the face of climate change (Wing, 2004). This research attempts to fortify this bridge, filling an essential gap in the literature and providing policymakers with a valuable tool to inform their decision-making processes.

1.3 Relevance

As delineated in the previous sections, climate change is a grand challenge calling for coordinated global action. In particular, the goal of decarbonisation is vital for mitigating disasters precipitated by climate change. Specific countries like India are vital to unlocking the decarbonised future, which is pivotal for mitigating climate disasters (Den Elzen et al., 2012). The complexity of climate change is further magnified by the intergenerational effects and the effects of climate change that transcend temporal and geographical boundaries (Hulme, 2009). If used well, modelling and simulation tools are invaluable to address this complexity. Since CGE models capture the interactions between different economic sectors, it allows for simulating the impacts of various policy scenarios. By incorporating GHG emissions, carbon taxation and public investment in renewable energy technology, CGE models can offer a platform for comparing policy packages that align economic growth and climate mitigation goals (Wing, 2004). This research, connected to the Engineering and

Policy Analysis (EPA) MSc program, focuses on the current climate crisis and the actions needed to address it by the Indian government during the next decade. It addresses a major societal issue that demands robust policy analysis.

1.4 Research Questions

Against the background of the earlier sections, the main **research question is as follows:**

How can a CGE model incorporate the impact of GHG emissions on the Indian economy?

The following are the sub-research questions:

SRQ - 1: What main sectors must be included in the CGE model?

SRQ - 2: What are different sectors' carbon emission levels and corresponding carbon intensity)? How to incorporate them into the CGE model?

SRQ - 3: What are the macroeconomic effects of introducing a carbon tax in India in the short and long run?

SRQ - 4: What role can carbon pricing play in aligning India's economic growth with its climate mitigation goals?

1.5 Structure of the Thesis

The ultimate objective of this thesis is to address the research questions mentioned above. The thesis is structured into distinct phases, each playing a distinct role in the research process. These include the phases of definition, construction, and analysis. Each of these phases is further subdivided into specific chapters that delve into detailed aspects of the research. The progression of the thesis follows a logical narrative, as depicted in Table 1.1, which presents an illustrative roadmap of the thesis storyline.

Part	Part Title	Chapter	Chapter Title
I	Thesis Definition	1	Introduction
		2	Literature Review
II	CGE Model	3	Model Design
		4	Experimental Setup
III	Results and Conclusions	5	Analysis
		6	Conclusion

Table 1.1 Structure of the Thesis

The following portions of this section, chapter 2, will discuss the literature and methodologies that will help answer the research questions. Part II discusses CGE model development. Chapter 3 focuses on the model design, overarching assumptions, and model specifications. Further, the experimental setup for the thesis is discussed in Chapter 4. Part III discusses the results of the simulations and policy implications that can be drawn from the work.

2. Literature Review

This section discusses the research problem in more detail. It reviews the existing body of literature in the field to provide further context to the challenge of climate change and the urgency of climate mitigation in India. It further discusses using models to tackle climate change and dives deeper into using CGE models. The last section of this chapter discusses the structure of the Indian economy using the SAM data, which will further be used to construct the CGE model.

2.1 India and Climate Change

India has the world's largest population, with over 10% of its people living in poverty, i.e., living on less than $2.15 per day in 2020 (World Bank Group, 2021). The country's per capita emission is 1.8 Mt CO_2, around one-third of the global average. Simultaneously, India is one of the countries most likely to experience significant economic loss from extreme weather events like heat waves and heavy downpours due to the effects of climate change (CSTEP, 2022). While the policy discourse is mostly aligned on dealing with the country's seemingly most potent socio-economic challenges, India has made several steps also to address climate change and reduce greenhouse gas emissions.

In 2008, the government of India released the National Action Plan on Climate Change, which set the country's strategy for mitigating and adapting to the impacts of climate change (Gupta et al., 2019). This plan prioritised measures that promote both economic development and climate action. The government set ambitious targets for the growth of its renewable energy sector and aims to produce 40% of its electricity from renewable sources by 2030. The government also introduced a framework for a voluntary cap and trade system in the country in 2022 (Ministry of Power & GOI, 2022). This blueprint lays the foundation for a three-step approach to tackle this challenge. The final system is imagined to be very similar to the Emissions Trading System of the European Union (EU ETS) design. While this is still in the early preliminary stages, it is a promising first step. As with most targets concerning carbon emission abatement, these are not legally binding and are voluntary. Mitigation efforts are costly and have been a significant point of contention since they are often at the 'cost' of development. While environmentally necessary, mitigation efforts increase the operational expenses of carbon-intensive industries such as energy production. This cost escalation can adversely impact profit margins, constraining investment capabilities and impeding economic growth. Simultaneously, the imposition of carbon pricing or taxation mechanisms can cause an inflationary effect on the costs of crucial commodities, including energy and food. This economic repercussion disproportionately affects individuals within lower income brackets, exacerbating issues of socioeconomic disparity. Hence, it becomes essential to assess the macroeconomic impact of such policies.

2.2 Climate Change and Models

Climate change is a complex global phenomenon with regional impacts not commensurate with the cumulative historical 'regional contribution’. Historical data indicates that the global distribution of carbon emissions is significantly skewed. For instance, the economies of the Northern Hemisphere, specifically the United States and the European Union (EU-28), have been responsible for 25% and 22% of historical carbon emissions, respectively (Who has contributed most to global CO2 emissions? 2019). In contrast, populous nations that underwent industrialisation at a later stage, such as China and India, account for merely 17.3% and 4% of these emissions, respectively.

This is a unique challenge since international and regional policies are crucial in effectively addressing the crisis. Hitherto, most global models tend to consolidate individual countries and, often, groups of countries into larger regional entities. While this is useful in deriving insights on an aggregate level, it can hide the distributional impacts of climate policy within nations. Most global models and policy proposals have included special measures to partly compensate for mitigation costs in India (Gupta et al., 2019). Several of these underscore that depending on the constitution of a "global climate regime", India would neither profoundly benefit nor lose in the mitigation and abatement effort (Weitzel et al., 2014). However, one major limitation of these models, as already mentioned before, is that the impact and, subsequently, abatement cost is minimised to a few metrics like the impact on gross domestic product (GDP) or unemployment rate. This can lead to spurious policy insights since these metrics do not offer an in-depth analysis of how the economy is impacted on a disaggregated level, i.e., at the level of specific industries and specific income classes.

On the other hand, regional (country-specific) models offer more profound insight into the economy-wide repercussions of climate policies. While this is an adequate method, climate damages are a function of global emissions. This is a significant limitation of regional modelling since they often only capture regional emissions. Consequently, CGE models are powerful tools for capturing any policy's economy-wide, income-distributional and sector-specific impacts. In India's case, this insight becomes invaluable when assessing the efficacy of climate policy on a broader level due to the multi-faceted nature of India's challenges. CGE models have historically been used to assess the impact of shocks on the economy or of significant policy decisions. However, there are fewer studies on developing, industrialising economies. This is mainly due to the complex nature of developing economies and the relatively simplified approach of the CGE modelling paradigm. However, in recent years, CGE models are emerging as the prevalent method in climate economic modelling and assessing the impacts of climate policies. So far, these models have widely been used as an analysis tool for studying the impacts of carbon tax policies (van Van Ruijven et al., 2012).

Some notable works include a study on Tanzania by Solomon et al. 2021. It captures the impact of climate change on food security and identifies mitigation strategies to unlock low-carbon pathways for the country going forward without impacting its food security. Similarly, studies focusing on Bangladesh, India and Mozambique use CGE models to capture the impact of climate change on food security and extract policy insights based on its distributional impact (Hossain et al., 2022; Manuel et al., 2021; Pradhan & Ghosh, 2019). These studies have been carried out by introducing exogenous shocks to agricultural yields or precipitation levels to mimic extreme weather events.

Climate policies such as carbon taxation and cap and trade systems have also been assessed with CGE models (Boccanfuso & Savard, 2011). Studies by Johansson et al. 2014 assess the impact of carbon taxation on India and China. These studies highlight how the impact of carbon pricing depends on the design of revenue recycling within the economy. They do this by calculating the carbon intensities associated with the consumption of different households. Each household's carbon intensity is then used to determine its relative contribution to a calculated equivalent carbon tax. In this way, the aggregated carbon tax is derived directly from the collective consumption patterns of these households. This is a meaningful way to analyse and represent a nation's carbon footprint. However, another way to capture emissions and compute carbon tax can be from the production point of view. This approach provides a holistic and different representation of the country's carbon footprint. Computing emissions from the production point of view instead of the consumption point of view allows for a more transparent analysis when implementing carbon taxes which are predominantly imposed at the 'source' of emission. One noteworthy study that approximates climate damage from the production point of view is the analysis by Kolsuz & Yeldan, 2017. They use "pollutant data" to capture climate damage as a function of industrial output in Turkey and derive interesting and valuable policy insight. While such research has been conducted in several countries, such as Sweden, China, and Germany, this approach is relatively scarce when applied to India (Goodman, 2016; Johansson et al., 2014; Matti et al., 2021). Therefore, this research attempts to create a CGE model that accounts for carbon emissions and computes carbon tax from the production side. The following section reviews notable CGE models for India.

2.3 CGE Models for India

A few fields in which CGE models have been used extensively for the Indian economy are energy security, agriculture, industry, forestry and transport (Babatunde et al., 2017). Several models have also been made for the Indian economy for market-based development analysis or for analysing the impact of agricultural policy (Pradhan & Ghosh, 2019; Storm, 1994).

Pradhan & Ghosh, 2021 use a dynamic CGE model of India to assess the compatibility of the Paris Agreement target with pursuing post-COVID economic recovery. They identify that effective carbon pricing could allow for achieving both of these goals. Similar studies analyse the impact of climate change on India's agricultural output. They identify the energy sector as a significant area that can generate revenue for mitigation by using carbon tax and emission allowance (Kolsuz & Yeldan, 2017; Jacoby et al., 2006). Several other works identify the complexity of the challenge of mitigation efforts in emerging economies, including India, and underscore the role of international policies and foreign investments (Choumert et al., 2015; Jaeger & Michaelowa, 2015).

For most studies mentioned, climate damages are captured using pollution indices. Since energy production is a predominant polluter, few other models are coupled or linked with energy system models representing the emissions (Pradhan & Ghosh, 2019). This approach provides a satisfactory approximation; however, it only partially accounts for the distribution of emissions across all sectors. Particularly in countries like India, where the manufacturing sector comprises a significant part of the economy, emissions are not confined solely to the energy sector. Despite the energy sector being a considerable contributor, it cannot be treated as a proxy for the entire economy. Moreover, the proposed carbon tax and cap-and-trade systems, being discussed for application in developing economies, are set to influence a broad range of industries. Therefore it is paramount to capture these broader impacts to ensure a comprehensive understanding and effective policy-making.

A study by Pradhan et al., 2017 identifies that due to the economy's structure, which is represented using a CGE model, the effectiveness of the country's climate mitigation strategies will depend significantly on the design of the policy. Consequently, for any policy, the main drivers of the corresponding model results are the model's underlying assumptions (Jacoby et al., 2006). Hence in the subsequent sections, I delve into the fundamentals of CGE models and discuss the underlying mechanism of this modelling paradigm.

2.4 Fundamentals of CGE Modelling

CGE models provide the ability to analyse both direct and indirect effects of policy changes across all sectors of the economy, capturing the interlinkages and ripple effects (Bezabih, 2010). Furthermore, they allow for short-term and long-term analysis and scenario comparisons, which are crucial for understanding the sustained impacts of policy decisions (Taylor, 2016). By providing quantitative results, CGE models equip policymakers with specific data points to make informed decisions and create resilient, future-proof policies. Moreover, they illuminate the synergies and trade-offs between different policy goals, aiding in developing balanced and efficient strategies that cater to environmental and economic considerations (Burfisher, 2021). Computable General Equilibrium or CGE modelling simulates the economies of entire nations or a group of countries. The simplified portrayal of an economy is illustrated in Figure 2.1.

A CGE model is a set of mathematical equations that depict the inputs, outputs and interconnections of different sectors (Storm & Isaacs, 2016). Each country's model is rooted in country-specific data representing individual sectors and their relations (Babatunde et al., 2017). These data are usually in the form of a **Social Accounting Matrix (SAM)** that comprehensively captures all economic transactions during a particular period. The model is calibrated with these data, the 'computing' aspect, and the 'equilibrium' is achieved (Taylor, 2016).

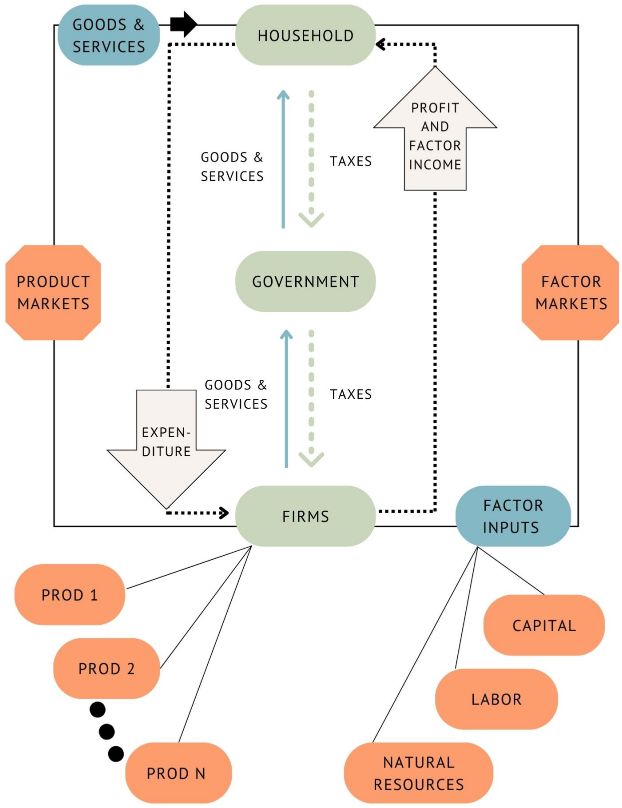


Figure 2.1: Structure of an economy

'Equilibrium' signifies a vital characteristic of this modelling paradigm. Building from the basics of microeconomics, a sector achieves equilibrium when supply meets demand. CGE modelling aggregates this equilibrium condition for all sectors to achieve an equilibrium state for the country under macroeconomic constraints (Babatunde et al., 2017; Manuel et al., 2021). Policy analysts use these models to analyse the impact of policies on entire economies. They introduce the policy as a 'shock' and then observe how the model responds and the new 'equilibrium condition' (Taylor, 2016). This allows policymakers to assess policy effectiveness and potential externalities. Figure 2.2 is a representation of a CGE model.

CGE modelling has certain limitations due to its fundamental assumptions. One major caveat of the method is that CGE models are often rooted in neoclassical assumptions of rational choice, profit, and full employment (Storm & Isaacs, 2016). Instead of representing the economy 'as it is', it represents the economy assuming that the neoclassical theory holds. This is primarily a way to simplify the analysis but leads to significant limitations regarding insights about the policy impact, arguably especially so in the context of an industrialising developing economy. The classical modelling paradigm is lacking in an economy like India with a large unstructured sector and protective pricing for critical sectors like agriculture. CGE models built in the structuralist tradition try to incorporate key structural features and constraints of the developing economy under consideration (Taylor, 2016). These models can be used as a valuable tool for macroeconomic policy analysis by focusing on the patterns of macroeconomic causality between sectors, international trade and fiscal linkages (Taylor, 2016).

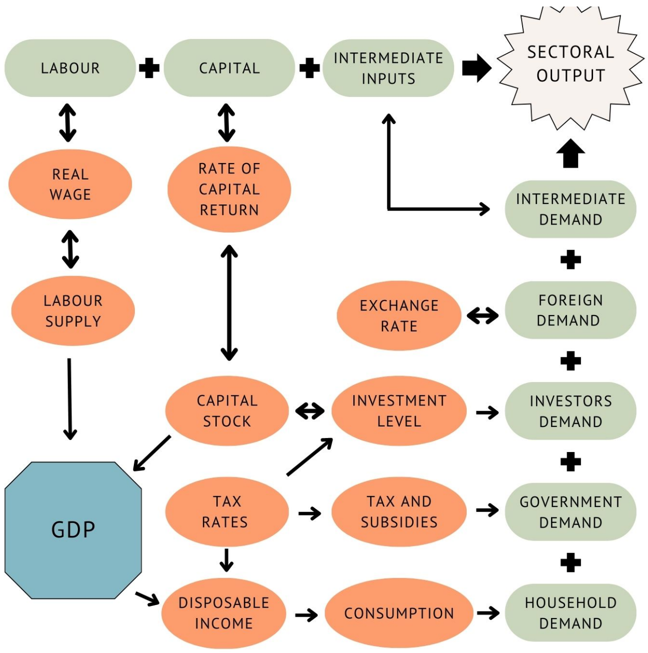


Figure 2.2: Simple CGE Model

In this research, I will create a CGE model informed by the model created by Dr Servaas Storm for a previous study (Storm, 1994). The model will be updated for the current sector dynamics, and the latest social accounting matrix will be used to calibrate the model in accordance with data from the year 2017-18. Further, the model will be updated to incorporate carbon intensities for different sectors.

The following section discusses the structure of the Indian economy using a Social Accounting Matrix (SAM) for 2017-18. This data has been aggregated for this work and subsequently used in the modelling process.

2.5 Structure of the Economy Using the SAM

A Social Accounting Matrix (SAM) is a comprehensive and economy-wide data framework representing a snapshot of the economy at a specific time. The SAM provides a systematic depiction of the economic transactions within an economy in a particular year, detailing the flow of all economic exchanges and interdependencies among different sectors. Aspects pertaining to production, income generation, income distribution, consumption, government expenditure, and savings are among several economic flows captured in a SAM.

The defining characteristic of a Social Accounting Matrix (SAM) lies in its square matrix form that provides a disaggregated and consistent portrayal of an economy. The configuration of each row and column within the matrix aligns with a different account. These accounts encompass various economic agents such as households, government entities, diverse commodities and productive factors. Interpretation of the matrix involves discerning payments made by an account, indicated by the entries in the respective rows, and the receipts accruing to that account, represented by the corresponding column entries.

The SAM is an invaluable tool for economic analysis because of its capability to capture the interconnectedness of different economic agents. Moreover, it provides a comprehensive framework for a simultaneous, consistent, and integrated analysis of production, income distribution, consumption, and capital accumulation. This feature of a SAM makes it a suitable tool for economy-wide impact analysis, policy evaluation, and complex economic modelling, including providing the accounting framework for Computable General Equilibrium (CGE) models.

TYPE OF SECTOR	NUMBER
Agricultural Sectors	39
Agricultural based processing activities	18
Mining sectors	4
Manufacturing sector other than agricultural processing	24
Utilities	3
Construction	1
Service sector (including transport and trade)	23

Table 2.1: Sectors of the SAM

In this research, I use the 2017-18 Social Accounting Matrix for India created by the International Food and Policy Research Institute (Pal et al., 2020). This SAM has 112 sectors of the Indian economy, and Table 2.1 summarises the different sectors. A detailed overview of all the sectors can be found in Appendix A. The SAM further identifies 15 income classes or households—five of each rural farm household, rural non-farm household and urban household. The values corresponding to these households represent consumption, remittances and public interest payments.

Next, primary factor inputs—also termed 'factors of production'—are the fundamental resources employed in producing goods and services. These inputs are the bedrock of any economic activity and comprise three core components. First, *labour* captures both physical and intellectual inputs of the workforce in an economy. Second, *capital* is a multi-faceted component that includes monetary capital, machinery and infrastructure. Lastly, *land* represents all natural resources used in production, including mineral resources and physical land. The SAM classifies primary factors into thirteen distinct categories. Table 2.2 represents this classification.

Primary Input	Category	Number
Rural uneducated	Labour	8
Rural primary educated		
Rural secondary educated		
Rural tertiary educated		
Urban uneducated		
Urban primary educated		
Urban secondary educated		
Urban tertiary educated		
Capital - crops	Capital	4
Capital - livestock		
Capital - mining		
Capital - other		
Land - agricultural crops	Land	1

Table 2.2: Primary factors of the SAM

Further, intermediate inputs refer to the goods and services utilised in the production process to produce other goods and services but do not form part of the final product. They are essentially consumed or transformed during production, providing a critical link in the production chain. Examples of intermediate inputs include raw materials, energy, and semi-finished goods. The value of these intermediate inputs, along with primary factors of production, can be effectively traced within a Social Accounting Matrix (SAM). In a SAM, transactions related to intermediate inputs are captured in the matrix's off-diagonal cells of the sector-by-sector section of the data frame, which trace the flow of goods and services from one economic sector (as a producer) to another (as a consumer). By identifying these intermediate inputs, the SAM provides a comprehensive and disaggregated depiction of the economic interlinkages and helps to understand the economy's multiplier effects and feedback mechanisms.

In a comprehensive analysis of the provided SAM, several salient points emerge that highlight the structure and dynamics of the Indian economy. The SAM for India presents an open and multi-faceted economy, generating a GDP exceeding 2.5 trillion USD (World Bank Group, 2021). The multiplicity of households within the SAM serves as a valuable tool in capturing the considerable income inequality within the nation, thus providing a more nuanced understanding of its socioeconomic fabric.

Observations indicate that factor income is the predominant source of revenue for households, especially those in the lower-income strata. This underscores the significance of employment opportunities and wages in economic mobility and alleviating poverty in the country. Investigation into the industrial composition of the economy reveals that the largest sectors by production include electrical manufacturing, construction, trade and transport, utilities, and mining. These industries are notably 'heavy' and typically associated with significant emissions, reflecting the challenges and trade-offs in balancing economic development with environmental sustainability. Figure 2.3 is a detailed overview of the specific financial flows captured in the SAM. It should be noted that this data offers insight only about the economic flows in the system and not about the carbon emission trends or intensities.

In the context of the present study, the commodities are consolidated into 16 distinct sectors. Furthermore, the study aggregates income classes into nine categories representative of different household groups. The methodological considerations and criteria guiding these classifications are discussed comprehensively in Chapter 3.

Before proceeding to the methods section of this thesis, it is vital to understand the political context in which the country operates. Hence, the next section will discuss the carbon tax debate in India.

	Activity/ Commodity (Sector)	Public interest payments	Factors	Surplus	Households	Government	Activity/ Commodity Tax	Direct Tax	Sales Tax/ Producers Subsidy	Investment (S-I)	Stock	Rest of World (ROW)	Total
Activity/ Commodity (Sector)	Intermediate Input a[i, j]				Household savings h_s[i, j]	Public Consumption cong[i]				Total Investment inv[i]	Commodity stock stk[i]	Exports level expo[i]	Total Demand
Public interest payments	Public Interest Payment vz[i]					Government Interest payments gint							
Factors	Value- added va[i]												Factor Income
Surplus	Surpluses per sector vg[i]												
Households			Wage transfers wtrans0	Factor income to households		Government transfer payments gtrans[i]						Remittances rem[i]	Household Income
Government							Tax revenues paid to the government						Government Income
Activity/ Commodity Tax	Tax for sectors t[i]												
Direct Tax					Tax value dtk[i]								Tax Income
Sales Tax/ Producers Subsidy	Sales tax for sectors s[i]												
Savings (S-I)					Savings value sk[i]	Government savings govsav0							Total Savings
Stock										Inventory accumulation or depletion			
Rest of World (ROW)	Imports imp[i]		Factor payments from abroad			Government payments from abroad							Foreign Exchange Outflow
Total	Production level x[i]		Factor Expenditure		Household Expenditure	Government Expenditure	Tax Payments			Investment total		Foreign Exchange Inflow	

Figure 2.3: SAM Overview

2.6 The Carbon Tax Debate in India

At present, India does not have an explicit carbon tax regime. Instead, it imposes an additional 'tax' on polluting commodities, predominantly fossil fuels. Though not designated as a carbon tax per se, its function is tantamount. Notably, exemptions cover sectors such as agriculture. This tax does not adhere to a uniform tax rate; it employs multiple brackets. The highest bracket affects only 20% of fuel usage (Qutubuddin, 2023). On average, when the tax is computed across all usage categories, it amounts to a low value. This value approximates \$1.6, which is meagre compared to the recommended rate of \$40, as advised by entities like the World Bank (Qutubuddin, 2023; World Bank Group, 2021).

Acknowledging India's sizeable pollution footprint, the global community anticipates its climate policy direction. India's net carbon emissions per capita trail the global mean and do not parallel the world's leading economies (Per capita greenhouse gas emissions, 2023). However, with its GDP poised to at least double by the end of 2030, in the base-as-usual scenario, carbon emissions are projected to surge by 50% (Mohan, 2021). Consequently, India grapples with escalating international pressure, notably after pledging to a net-zero economy by 2070—a commitment met with critiques for its perceived inadequacy (Bearak & Popovich, 2022).

India is making significant strides in renewable energy investments in its quest for energy security for its vast population while meeting its climate goals. As mentioned, India has committed to achieving a 50% non-fossil energy capacity by 2030 (Gupta et al., 2019). With its current investment trajectory and underway development projects, India is set to achieve a 60% non-fossil fuel capacity by 2030 (Mohan, 2021). While this progress is a positive sign for the climate mitigation journey, the practical impact of this decarbonisation effort is deemed 'insufficient' due to the country's extensively rising use of fossil fuels. India continues to lean heavily on fossil fuels, predominantly coal. While renewable investments, buoyed by supportive policies, have earned global commendation, the easing of conservation regulations to facilitate coal extraction has stirred considerable concern and demonstrations (Pradhan et al., 2017). This seemingly contradictory policy landscape could imply a less-than-desirable journey towards decarbonisation.

In the recent transformation of India's climate policy landscape, the introduction of voluntary cap-and-trade mechanisms stands out prominently. The Ministry of Power & GOI (2022) has delineated a framework for such a system, charting a three-tiered strategy to address environmental concerns. This proposed system parallels the European Union's Emissions Trading System (EU ETS) design. Notably, these carbon emission reduction targets operate voluntarily without legal binding. Complementing this, the paradigm shift includes synergies between public and private stakeholders in green technology advancement, fiscal incentives for sustainable practices, and initiatives to heighten climate change consciousness. Nonetheless, the efficacy of these measures largely rests on systematic enforcement and periodic reviews, particularly considering the dynamic nature of the international climate policy environment.

In a recent move, the European Union (EU) has outlined a Carbon Border Adjustment Mechanism (CBAM) as a part of its Green Deal, aiming to reduce greenhouse gas emissions by 55% from 1990 levels by 2030 (Briefing, 2023). This mechanism would levy carbon tariffs on energy-intensive products imported into the EU, targeting steel, aluminium, and electricity sectors. Set to take effect in January 2026 after a transition phase, the CBAM's implications for India, whose trade with the EU constituted €88 billion or 10.8% of its total in 2021, are crucial (Briefing, 2023; Anand, 2023). Although India's exports in the sectors initially covered by the CBAM to the EU make up a small portion of its total exports, the proposal might affect over 50% of India's European exports. Notably, the high carbon intensity of India's products, especially given its reliance on coal, poses challenges with potential tariffs. The CBAM also brings compliance costs and requires emission monitoring. India has reacted critically to the CBAM but must strategise for the changing global landscape, including possible negotiations for technology transfers and financial support from the EU, and consider establishing its carbon trading system or imposing a carbon tax.

In the face of the prevailing policy framework, the nation is confronted with an exigent and profound impetus to recalibrate its approach and potentially shoulder a greater mitigation responsibility than it might perceive as its equitable share (Singh, 2023). Historically, the country has been assertive in advocating for external support on its decarbonisation journey, grounding its arguments in its comparatively minimal contributions to historical emissions (Pradhan et al., 2017). Although numerous decarbonisation policies have emerged, emphasising renewable energy sources and promoting electric mobility, industrial emissions remain largely unchecked and unaccounted for (Anand, 2023). This backdrop often casts a dichotomy in the public discourse: a tug-of-war between the immediate urgency for socio-economic advancement and the overarching call for long-term ecological sustainability. As India endeavours to traverse this intricate terrain, striking a harmony between its developmental ambitions and global environmental pledges emerges as a critical crossroads. This sets the stage for the profound relevance and importance of carbon mitigation strategies, including carbon taxation and cap-and-trade policies, as pivotal domains for academic and policy research.

The subsequent section delves into the intricacies of the model's construction.

PART II: THE CGE MODEL

3. Model Design

This section deals with the construction of the CGE model. First, I discuss certain assumptions that drive the modelling process. The subsequent section discusses the data preparation of the SAM for the research at hand. This part also includes the key justifications for the data preparation choices made. After this, I dive into the model construction and discuss the different functions that make up the model.

3.1 Assumptions of the Model

General equilibrium in economics is a complex concept and can be understood from different perspectives. Notably, Frisch describes 'general equilibrium' as a condition where no variables are inclined to change. In this context, if the supply and demand quantities are not at equilibrium, (relative) price mechanisms would adjust to establish a state of balance. This perspective aligns with Walras' excess demand hypothesis, which posits that (relative) price changes are driven by an imbalance in supply and demand (Storm, 1994).

On the other hand, equilibrium can also be comprehended as a state where the price demanded by suppliers matches the price consumers are willing to pay. If this balance is disrupted, producers can regulate the quantity of goods or services provided to restore equilibrium. Marshall's excess price hypothesis asserts that quantity adjustments are made in response to price deviations (Taylor, 2016). In this model, agricultural sectors are assumed to operate under a price-clearing mechanism where price adjusts in response to changes in demand, reflecting a competitive market scenario. Non-agricultural sectors adhere to a quantity-clearing assumption, whereby production levels, rather than prices, flex to equate supply and demand, often indicating more rigid prices due to factors like market power or price regulations.

Aggregate demand has been modelled as the sum of intermediate demand, consumption demand, investment demand, demand for additional stocks and export demand.

$$x_{di} = \sum \alpha_{ij} x_{sj} + c_i + g_i + i_i + \Delta stk_i + e_i \qquad \text{i = 1,…,16}$$

Where x_{di} is the aggregate demand of commodity i, α_{ij} is the input-output coefficient corresponding to commodities i and j, c_i is the private consumption demand for commodity i, g_i is the private consumption demand for commodity i, i_i is the gross domestic investment demand, Δstk_i is the change in stock and e_i is the export demand.

The aggregate supply is equivalent to the domestic supply for a commodity plus the imports (m_i). Hence excess demand for $i = 1, \ldots, n$ industries can be defined as follows:

$$exdem_i = x_{di} - x_{si} - m_i$$

Hence general equilibrium can be defined as a vector of prices and quantities for all industries in the model for which the values of excess demand (exdem) equals zero. To elaborate further, the value of prices in the agricultural sector and the quantities of the non-agricultural sectors should be such that excess demand in all these industries equals zero.

This approach additionally has specific implications *ex-post*. Because the supply (of all sectors) for the economy as a whole is equal to its demand. GDP is equivalent to final demand, which includes the difference between exports and imports (all at current prices). Additionally, gross national savings (as a sum of domestic and foreign savings) equals the gross domestic investment.

3.1.2 Household specifications

In the Social Accounting Matrix (SAM), households are classified into three broad categories; rural farm, rural non-farm, and urban households. Each of these is further subdivided into quintiles. This study restructured these households into three groups within each broad category.

The criteria for this re-aggregation were derived from a comparison of consumption and wage levels across different household classes. Notably, the lowest quintile was kept separate due to its significantly lower wage and consumption values than the others. The second and third quintiles were combined owing to their similar consumption and wage patterns, and a similar approach was taken for the fourth and fifth quintiles.

This re-aggregation resulted in three categories within each rural farm, rural non-farm, and urban household division. The rationale behind this choice of stratification lies in its ability to provide a more nuanced understanding of the socioeconomic variations within these three crucial population segments. Considering the significant differences in consumption and wage levels, this approach allows for an accurate representation of these household groups' behaviour while making the model more efficient.

3.1.3 Sector Specifications

As delineated in the preceding section, the Social Accounting Matrix (SAM), used as the basis for the model analysis, incorporates 112 sectors. Given the scope and objectives of this research, these sectors have been consolidated into 16 more aggregated sectors. The process involved thoughtful categorisation of similar industries and economic activities, ensuring the retention of the salient features of the economy in the final sectoral representation. In the aggregation process, I paid particular attention to the carbon intensity of the different sectors and pricing mechanisms.

- **Agricultural Sectors**

The agricultural sectors have been aggregated according to the kind of crop that is cultivated and the pricing strategy. The Government of India (GOI) issues a Minimum Support Price (MSP) for certain crops deemed essential for the country's food security and hence, deserving of the government's support. MSP is the rate at which the GOI purchases these crops (Jacoby et al., 2014). These prices are decided yearly and serve as a 'minimum' for the market price. The crops that fall under this scheme have been aggregated, and a weighted average of the MSP of all the crops has been calculated to calibrate for the procurement price in the model. This is the first sector of the model. Additionally, it is vital to note that this is the only sector in which government procurement and food distribution have been modelled.

Apart from certain essential crops that receive MSP, the remainder of the sectors can be broadly categorised as 'crops' that use land as capital input and animal husbandry (which includes poultry and dairy). The model allocates land to different agricultural sectors, and it has been assumed that animal husbandry does not require land as capital input. As the next step, all the sectors related to animal husbandry have been aggregated together. The remainder of the crops have been divided into cash crops and agricultural crops.

It is worth highlighting that the variation in carbon intensities across diverse agricultural sectors is not pronounced. Consequently, the aggregation decisions' primary considerations were rooted in pricing mechanisms and land utilisation patterns. Cash crops and food crops (or agricultural crops) have been distinctly aggregated to account for their differential consumption patterns. Specifically, cash crops predominantly serve as an intermediate input for industries, while a substantial fraction of food crops directly satiates household consumption needs.

- **Agro - Based Processing Sectors**

The agro-based processing sectors have been aggregated to create three sectors. The three broad categories identified were food processing, milling and textiles. These manufacturing sectors have been aggregated accordingly.

- **Manufacturing Sectors:**

One distinct category of manufacturing sectors that can be identified is the chemical industry. The remainder of the sectors are categorised based on electrical/heavy machinery-based manufacturing or others. They were further compared based on their contribution towards capital stock input for other sectors. The sectors that contributed towards capital stock input for other sectors were aggregated in one sector as an 'electrical sector'. These include industries that produce machines, robots and capital goods. The remainder were put together as 'other manufacturing'.In this scenario, it was observed that the carbon intensities for all available sectors were notably high and exhibited similar magnitudes. Such uniformity in carbon intensities meant that these were not the primary criteria influencing the aggregation decisions for these sectors. One significant determinant retained as a separate entity was the capital stock input, given its pivotal role in the model's calibration. Additionally, the chemical industry was intentionally isolated from the aggregation due to its influence in setting the representative price of fertilisers—a crucial component in the agricultural sub-model.

- **Service Sectors:**

In the process of sectoral consolidation, an initial sector identified encompassed public administration, education, and health services. These sectors were collectively categorised under the label 'Public Sector'. It is worth noting that this consolidated sector is the sole receiver of public consumption allocation, aligning logically with its encompassing activities. Another major sector identified in this process is the composite of transportation and trade activities, which manifests as a considerably extensive sector due to the breadth of the activities it covers. The residual sectors, not part of any specialised clusters, were assembled under the 'other services' umbrella.

These aggregation decisions ensure that the nuances and specificities of these sectors are preserved in the broader sectoral overview. Figure 3.1 on the following page outlines the mapping employed to transition from 112 to 16 sectors for this analysis.

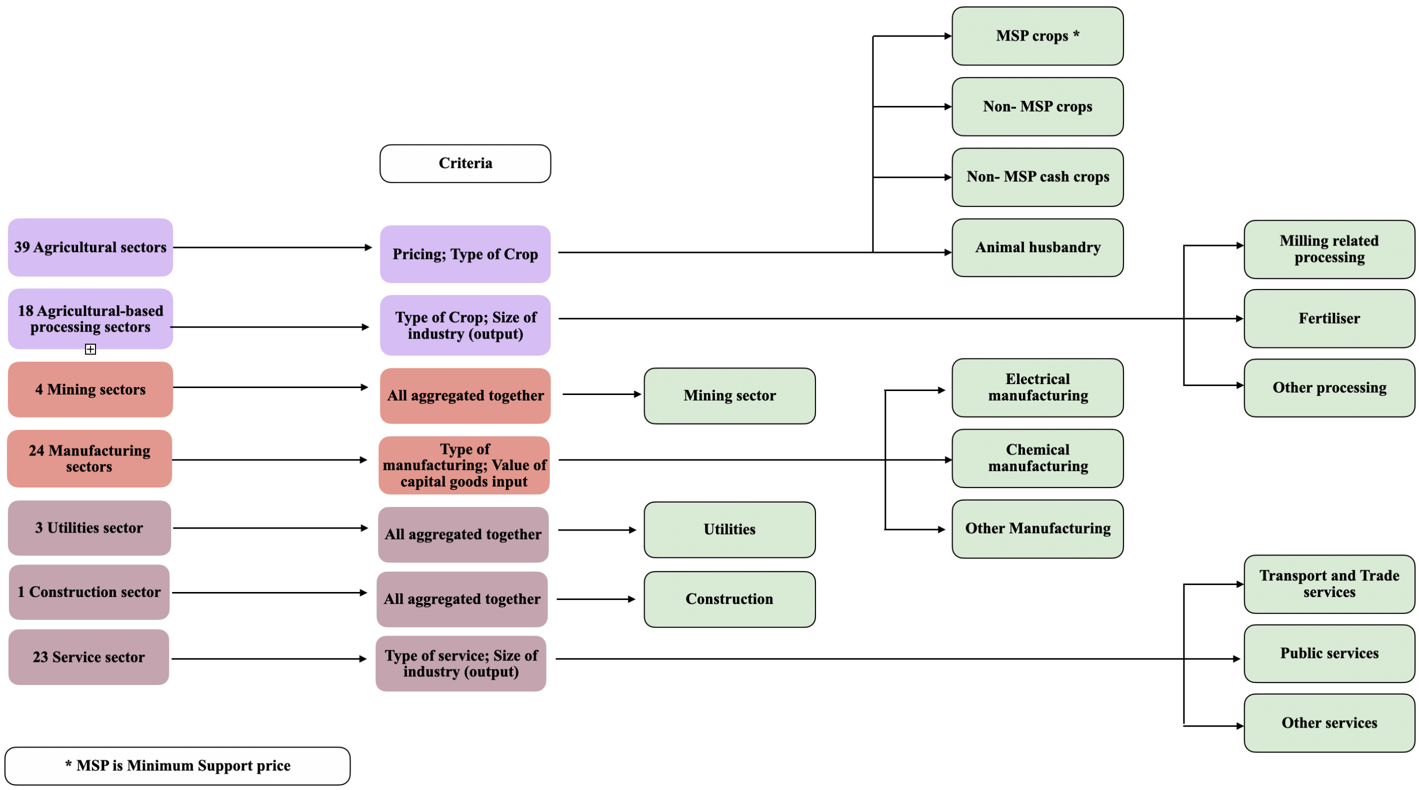


Figure 3.1: Aggregation of Sectors

3.1.4 Static Within-Period Model

The term "static within period model" refers to a model where the element of time is not considered to change within the examined period. It is a snapshot of the economy at a given point in time. In this type of model, all decisions are made simultaneously, and the repercussions of these decisions are realised instantly. For each period, the model calculates a general equilibrium outcome. This outcome does not account for any possible lag between decision-making and policy impact. Hence, the static within-period model helps examine a policy's or economic shock's impact within a specific timeframe. Notably, they do not account for the dynamic adjustment of the economy over time. One 'static period' can be understood as five years year.

- **Private investment** for a given sector is conceptualised as a function of two primary variables: the *terms of trade (TOT)* from the preceding year and the *private investment* value from the same prior period. In the model of Storm (1994), private investment also responds to the time-lagged markup income of a given sector. For this research, however, this component has been dropped. The TOT metric, characterised by the ratio of agricultural sectors' price index to non-agricultural sectors, elucidates the relationship between agricultural and non-agricultural commodities. It serves as a tool for gauging the comparative economic potency of the agricultural sector vis-à-vis the non-agricultural sector in a specific economy.

- **Prices for agricultural sectors** are adjusted to clear the market except for sector 1. As discussed earlier, sector 1 represents the crops for which the government issues a minimum support price (MSP). In scenarios where the prevailing market price plummets below the established MSP, the government increases its procurement quantities to elevate the market price to the level of the MSP. In other cases, the procurement of food grains is fixed.

- **Prices for non-agricultural sectors** have been determined following the *Kaleckian cost-plus pricing model*. It follows from this model that the price set by firms is obtained by adding a markup to their unit variable costs. The markup is not necessarily a constant and is altered if the sector's output exceeds its production capacity (Storm, 1994).

- **Consumption** patterns for all nine income classes (or households) are ascertained using the Average Propensity to Consume (APC) and the Marginal Propensity to Consume (MPC). The APC values are derived from the available Social Accounting Matrix (SAM) data. Notably, for simplification and to maintain model tractability, the MPC is assumed to be equivalent to the APC. Although this represents a departure from the more nuanced real-world scenario where APC and MPC may differ, this trade-off is deemed appropriate given the time available for this research endeavour.

- **Carbon emissions** have been modelled as a function of sectoral output. The associated carbon intensities are predetermined at the commencement of the respective period, facilitating the subsequent computation of emissions. These emissions are then used to calculate the carbon tax associated with a given sector for one discrete period. Notably, this data is not available in the SAM obtained. The carbon intensities have been obtained from the OECD database which has information about aggregated sectoral output levels and emission levels (OECD Stat 2016).

3.1.5 Between-periods adjustment

Exogenous and lagged variables can be adjusted between two periods to represent technological growth, introduce a policy shock, etc. The model has been run for three periods which can be interpreted as fifteen years from 2016-17. The following is an overview of the major between-period adjustments.

Variable	Description	Implication
$\omega_{ci,t+1}$	Weights of Consumer price Index	The contributions of individual commodities to the overall Consumer Price Index (CPI) are determined by their respective weights. Following each iteration of the code, these weights are updated to reflect any alterations in prices.
$K_{i,t+1}$	Capital stock per sector	The capital stock of a non-agricultural sector sets its peak production capacity. When demand surpasses this capacity, the profit markup diminishes. This parameter, which serves as an indicator of capacity expansion, varies across periods, influenced by the level of investment in the sector in the previous period.
$z^*_{gi,t+1}$	Level of Public Stock	This measurement is predominantly utilised for the agricultural sector, particularly for the Minimum Support Price (MSP) which the government procures to operate its public distribution system. In the initial period, this variable is derived from public procurement data, and this information is then carried forward to subsequent periods to ascertain the levels of public distribution.
c_t	Carbon Tax Rate	The carbon tax rate is designed to escalate by 10% across successive periods, reflecting a gradual approach to policy implementation. This increment is a deliberate policy decision and can be adjusted as a potential variable in future analyses.
$ci_{i,t}$	Carbon Intensities	Should there be a decision to reinvest into decarbonisation, there's an assumption that this will lead to a decrease in carbon intensity. The mechanisms driving this reduction are elaborately discussed in the section detailing the experimental setup.

Table 3.1: Between-period adjustments

3.2 Model Components

This section of the thesis discusses the components of the CGE model. The equations corresponding to the different components of the model can be found in Appendix B.

3.2.1 Prices

Non-agricultural prices are determined by the Kaleckian cost-plus model. This rule considers not only the production cost but also the producer's desired profit margin. Hence, the computed price equals the sum of the intermediate input cost, wage cost, a fixed markup, sales tax, and carbon tax. The wage and intermediate input costs encompass the expenses incurred in production, while the markup represents the profit margin. The taxes incorporate the fiscal aspects and environmental costs of production. Hence, the price can be obtained from equation 19. The sales tax rate is calculated for every sector from the SAM data and is assumed to be fixed for the entirety of the simulation. Figure 3.2 represents the logic of the price procedure.

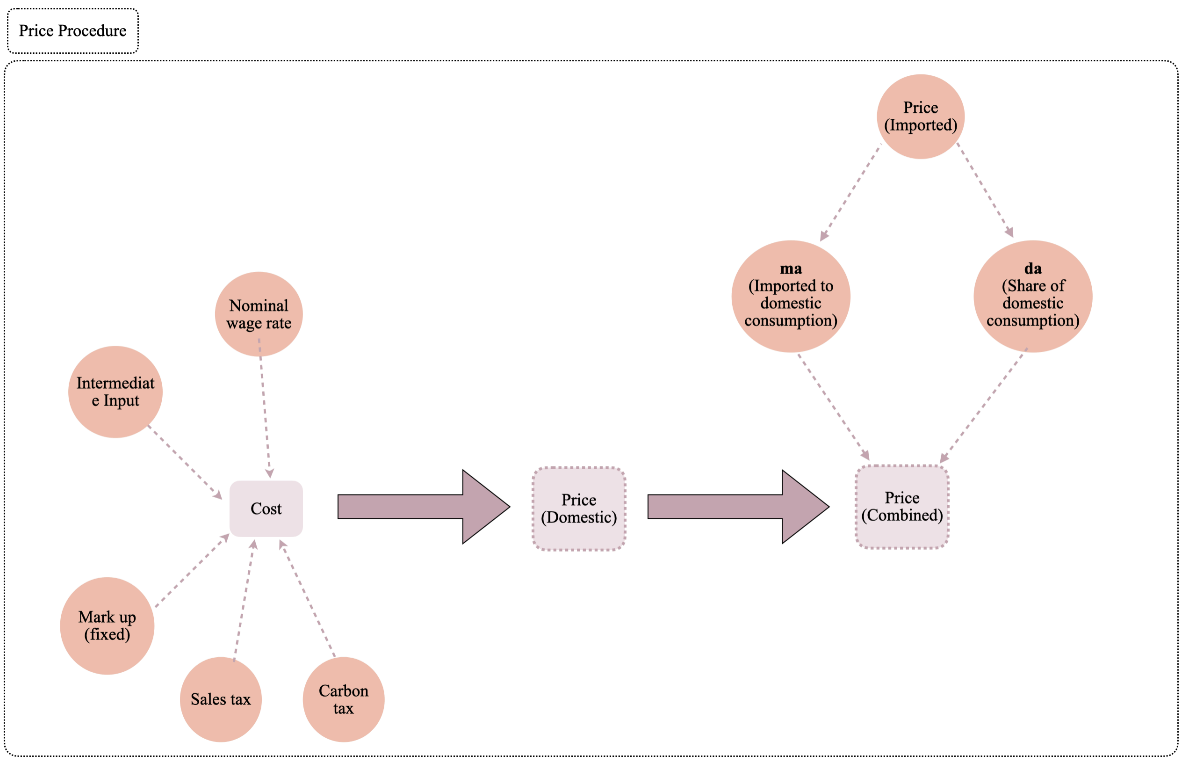


Figure 3.2: Price Procedure

The nominal wage rate in the non-agricultural sectors is shaped by a function that integrates the consumer price index (CPI) and the wage rate of the preceding period according to equation 18 (Storm, 1994). An increase in the CPI raises the nominal wage, which means that we assume that there is nominal wage indexation (to consumer price inflation); note that the indexation is imperfect, in line with empirical evidence. The CPI is calculated using a weighted average of the prices of all commodities according to equation 17. The price consumers pay is the weighted average of the domestic price of a good and the import price of that same good. The Armington specification determines the weights.

The Armington specification is a hypothesis that explains the trade patterns of a country. It assumes that similar goods are differentiated based on the country of origin and therefore are imperfect substitutes. Hence, if the price of an imported good is lowered, it becomes more desirable economically relative to the domestic good, and Indian consumers will buy more of the imported good instead of the domestic good; however, the extent to which consumers substitute domestic goods for (cheaper) imported goods depends on the elasticity of substitution. This so-called 'Armington elasticity' represents the ease with which consumers substitute domestic and international goods as their relative prices change. If this elasticity is high, consumers are more likely to switch between domestic and imported goods based on price changes.

Conversely, a low elasticity forms a more rigid consumption behaviour in response to a change in the import price (relative to the domestic prices), reflecting a stronger preference by Indian consumers for domestically produced goods (somewhat irrespective of prices). This specification has been incorporated in the CGE model to calculate the share of imported goods and the Consumption Price Index (CPI), which can be interpreted as the weighted average price to consumers.

3.2.2 Agricultural Model

The agricultural model determines the production of crops in the three crop sectors in the period. This is done in four steps. First, the total area available for cropping is determined. Next, the acreage for each crop is determined, then the yields per crop are established, and lastly, the production levels, defined as the product of crop yield and acreage under this crop, are obtained.

Before embarking on the model construction, it is vital to elucidate some agronomic terms integral to the 'physical component' of the agricultural model, specifically net sown area, gross cropped area cropped, and the area being irrigated. These quantities play a significant role in guiding the decisions related to the allotment of land to various crop types. Within the confines of this thesis, these fundamental terms and their corresponding values remain unchanged from Storm, 1994. While this approximation may not encompass all nuances, it is a reasonable assumption, given that the capacity for expanding the agricultural land base has been considerably constrained since the mid-1960s (Reserve Bank of India - Publications, 2017).

- The net sown area (nsa) refers to the physical expanse that has undergone cropping. The net sown area in India was 141.43 million hectares of land in 2013-14 (Reserve Bank of India - Publications, 2017).
- The gross cropped area (gca) is derived by adding the area subjected to multiple cropping cycles to the net sown area. The Gross cropped area in India in 2013-14 was 200.86 million hectares (Reserve Bank of India - Publications, 2017).
- The difference between gross cropped and net sown areas is due to multiple cropping on the same land. Under India's climatic conditions, multiple cropping depends (firmly) on irrigation (infrastructure) and irrigated area availability.
- India's gross irrigated area (gia) was 95.77 million hectares in 2013-14.
- The model determines it by agricultural investment (in the previous period) and the total gross irrigated area of the preceding period (equation 1).
- The net irrigated area (nia), which represents the physical expanse under irrigation, is presumed to be a fixed proportion of the gross irrigated area (gia) (equation 2). The net irrigated area in India in 2013-14 was 68.10 million hectares.

Aggregate Crop Intensity (aci) is a function of the ratio of the net irrigated area to the net sown area (equation 3). Subsequently, the gross cropped area (gca) under all crops is the result of the multiplication of net sown area (nsa) and aggregate crop intensity (aci) (equation 4). Consequently, the gross non-irrigated area is the difference between the gross cropped area and the gross irrigated area (equation 5).

- **Step 1: Acreage**

Once these values are established for the entire agricultural sector, the three crops are allocated across gross irrigated and non-irrigated areas. This acreage allocation is a function of relative crop prices. This is captured using the price of a crop relative to the weighted average price of all crops (equation 6). The acreage response functions, drawn from Storm 1992, mirror the nature of standard Nerlovian acreage response functions. Equations 7 and 8 delineate the computations for the irrigated and non-irrigated acreages. The aggregate of crop-wise irrigated acreage and non-irrigated acreage is subject to the constraint outlined in equations 7 and 8. This restriction mandates that the sum of these values must not exceed the total irrigated and gross cropped areas, respectively. Finally, the gross cropped area under every crop is obtained by adding the irrigated and non-irrigated areas as calculated before (equation 9).

- **Step 2: Yields per hectare**

The yield per hectare for each crop is determined as a function of fertiliser use by hectare. For all crop categories, the actual quantity of fertiliser used by hectare is a function of the ratio of fertiliser price to the respective crop's market price, as delineated in equations 10 and 11.

Crop yields are influenced by a plethora of factors, like the quality of seeds, rainfall distribution, soil fertility, and, more recently, the repercussions of extreme climatic conditions. However, in the interest of simplification and model tractability, these variables have yet to be integrated into the current framework, which constitutes a significant limitation of this model.

Consequently, adhering to this simplified approach, the yields of each crop corresponding to the fertiliser application can be obtained using equation 14.

- **Step 3: Crop-wise Production**

The acreage and yields for all the crops have been calculated at this stage. The production can hence be calculated as a product of the area under crop and the yield. Equation 12 captures this relation. At this stage, the crop-wise fertiliser usage and the corresponding input-output coefficient (α_{8i}) capturing fertiliser input per unit of crop output are calculated in Equation 15.

Figure 3.3 captures the agriculture production sub-model.

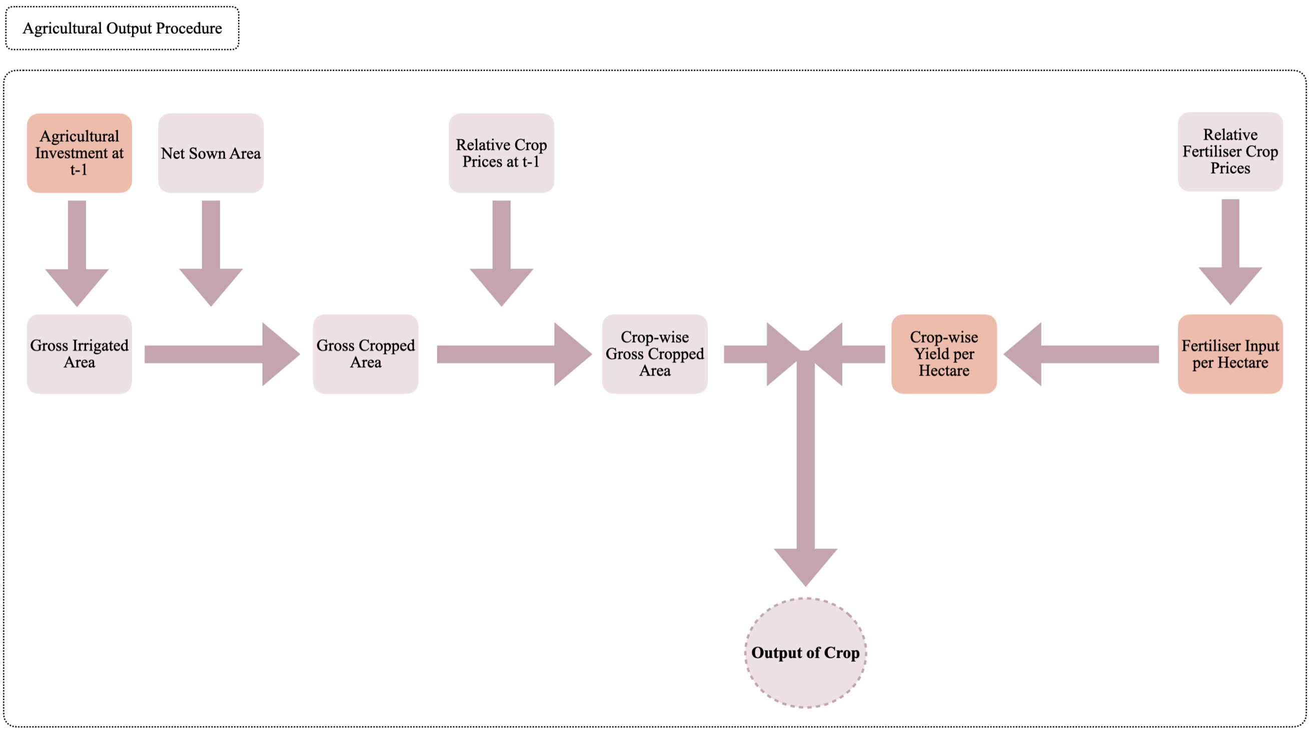


Figure 3.3: Agriculture Output Procedure

3.2.3 Disposable Income

Income has been stratified into **agricultural income, non-agricultural wage income, and non-agricultural markup income**. Each category is reflective of distinct income streams within the broader economic landscape.

Agricultural income is the aggregate value added from agricultural production combined with the government procurement of food grains. This income category captures the revenue from the country's agricultural operations and reflects the fiscal outcomes of government interventions in agricultural markets (equation 25). Figure 3.4 explains the calculation of agricultural income.

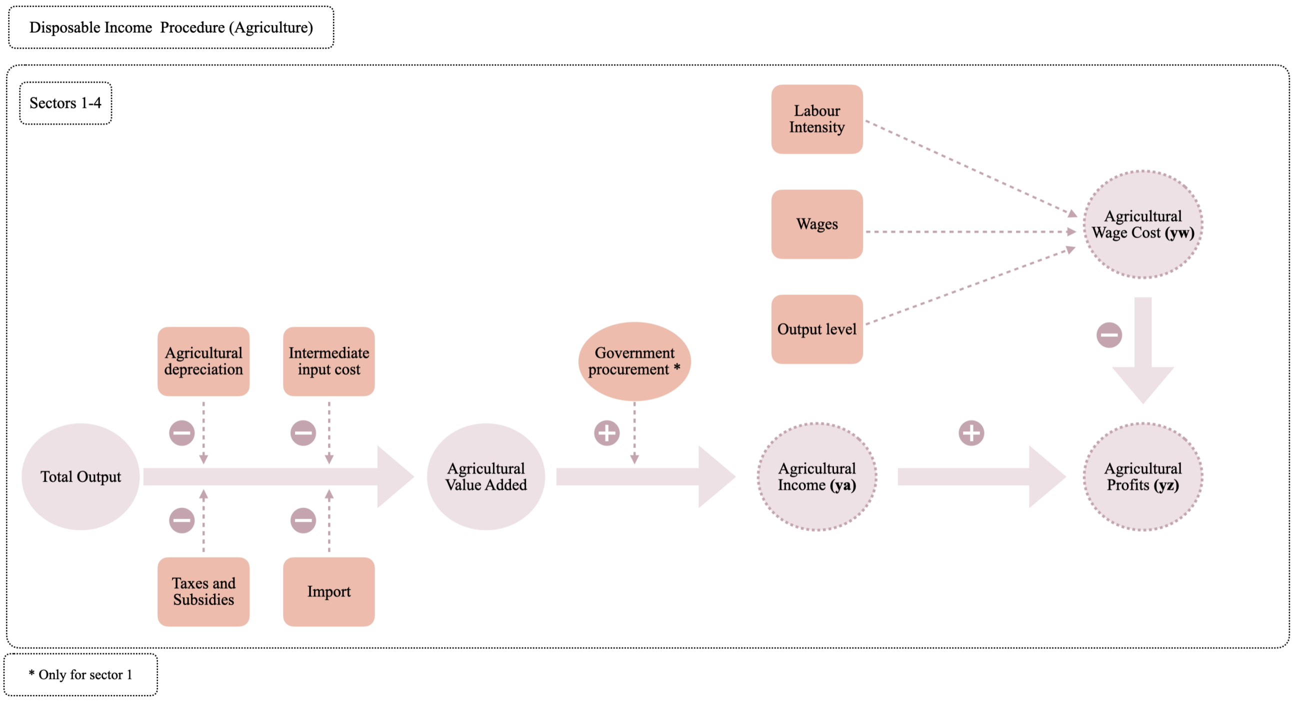


Figure 3.4: Disposable Income Procedure (Agriculture)

Non-agricultural wage income encompasses wage payments associated with the non-agricultural sectors, the government wage bill, transfer payments from the government, and remittances from abroad (equation 24). In the model, the variable costs of non-agricultural firms are deduced as the aggregate sum of domestic material input cost, wage costs, and cost of imported inputs per unit of output. This summation comprehensively measures operational expenses within non-agricultural sectors (equation 26).

The non-agricultural markup income is the product of a predetermined markup rate and the variable costs of the non-agricultural sectors, including the government's interest payment (equation 27). This income category captures the surplus generated in non-agricultural sectors above the variable cost of production, indicating their profitability and contribution to the overall economic output Figure 3.5 is an overview of the calculation of non-agricultural wage income and markup incomes.

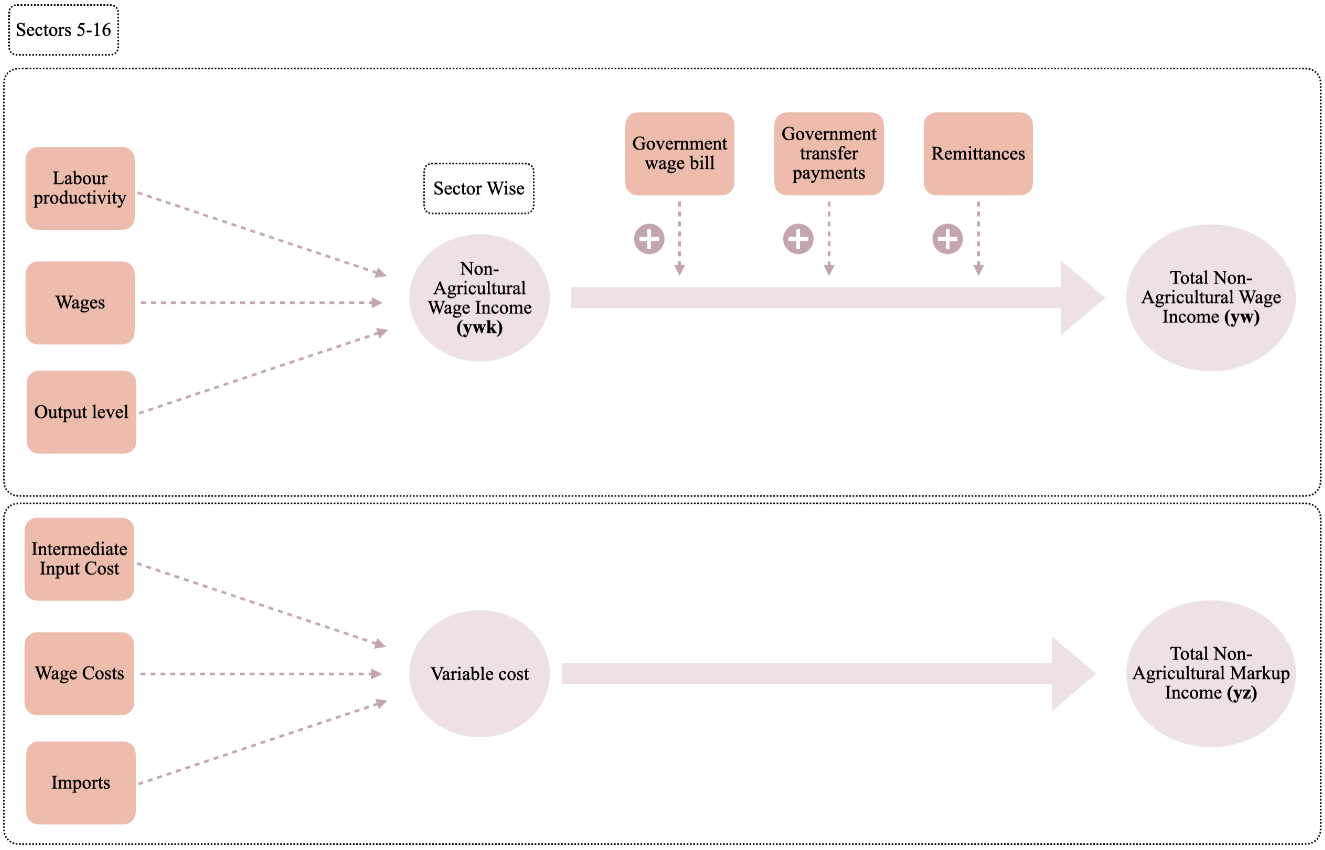


Figure 3.5: Disposable Income Procedure (Non-Agriculture)

After calculating the three kinds of income, they are distributed within different income classes. As mentioned, the model distinguishes between three income classes: rural (agriculture), rural (non-agriculture), and urban (equation 28). Within these broad categories, income is further segregated into three levels, allowing for calculating disposable income for diverse income groups. This classification facilitates a detailed analysis of income distribution across socioeconomic strata within the economy.

3.2.4 Investment

In this model, investment demand has been kept separate from savings supply in accordance with the post-Keynesian approach. Investment in a sector is a sum of private and public investment (equation 36). We assume that public investment is fixed and can be used as a policy instrument. Private investment is modelled as a function of government investment and the terms of trade between agricultural and non-agricultural industries, as mentioned in equations 33, 34 and 35. Total investment by industry (according to the sector of destination) is obtained by adding private and public investment.

Next, real investment by sector of origin is obtained using the relation in (equation 37). It is obtained by multiplying total investment with the matrix of partial capital coefficient representing the compositional structure of capital stock by sector of origin. This matrix is obtained using the SAM and NAS 2017-18 data, as illuminated in section 3.3.1 and is assumed to be fixed. Illustration 3.6 represents this procedure.

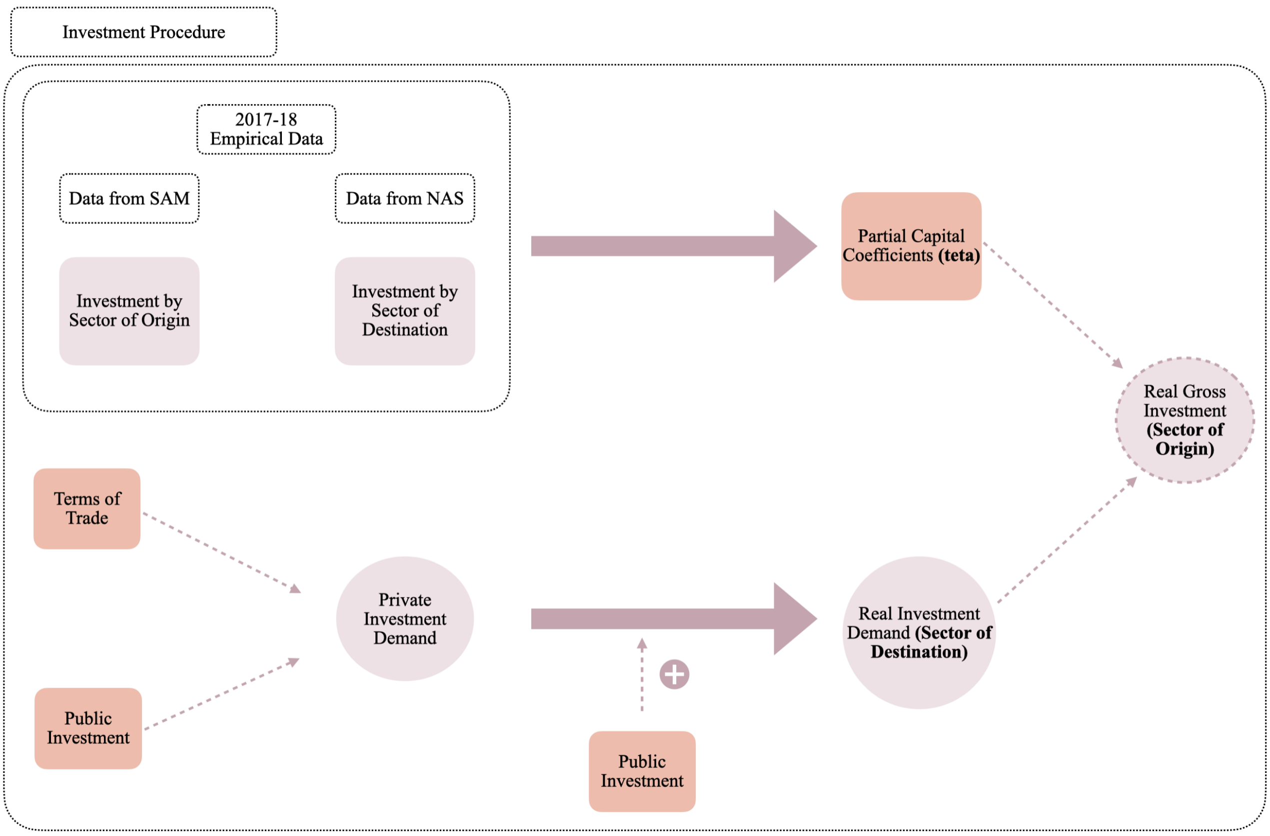


Figure 3.6: Investment Procedure

3.2.5 Consumption

Private savings are determined as a predetermined fixed proportion of disposable income, a relationship encapsulated in Equation 29. Consequently, private consumption for each income class equates to disposable income minus private savings, a relation depicted in Equation 30.

Commodity-specific private consumption has been modelled by utilising the Linear Expenditure System (LES). The LES characterises the consumption of a specific commodity as a function of a fundamental “floor” level, disposable income, the commodity's price and the price of all the other commodities. This system captures the nature of “subsistence level consumption. This LES also takes into account food subsidies. As previously discussed, the floor level of consumption is represented by the constant term in Equation 31. At the same time, the ratio of the marginal propensity to consume to the average propensity to consume delineates the variation in expenditure (in response to changes in real disposable income) from one commodity to another once necessities have been fulfilled. Equation 31 depicts this relation.

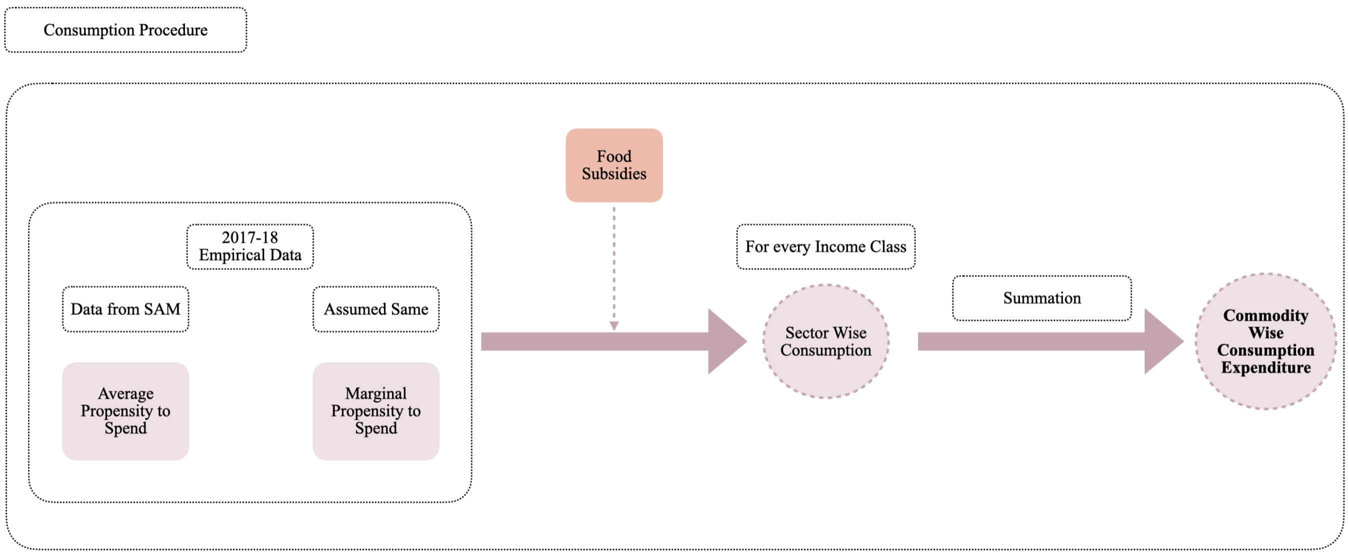


Figure 3.7: Consumption Procedure

3.2.5 Production

The maximum level of production of the non-agricultural commodities and services in the model is determined by using fixed capital-gross production ratios for every non-agricultural sector. This measure constitutes potential output in each sector. Actual output in each sector is determined by demand. Demand consists of the demand for intermediate inputs produced by this sector, private and public commodity-wise consumption demand, and changes in commodity stock. Additionally, exports for this sector are factored into this measure, and imports are accordingly subtracted (equation 21). For each non-agricultural sector, the demand-determined output level is compared with the maximal output dictated by the capital stock and the capital-gross output ratio. At this juncture, the equilibrium conditions are assessed for the within-period analysis. The following section elaborates on these equilibrium conditions. Figure 3.8 provides a comprehensive visual representation of the production procedure.

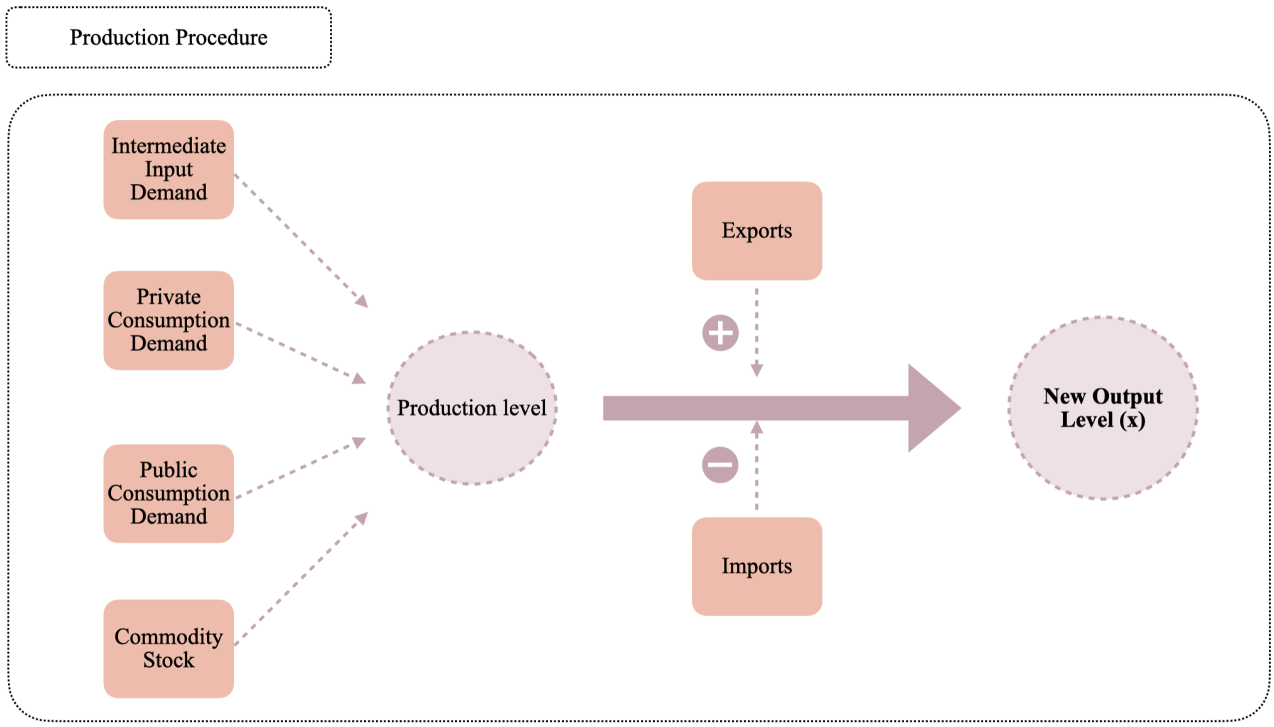


Figure 3.8: Production Procedure

3.2.6 Carbon Emissions and Mitigation Policy Lever

Before diving into the details of the experimental setup, it is crucial to understand the treatment of carbon emissions within the model and how they are computed. Additionally, this section will shed light on the methodology employed for mitigation through reinvestment.

- **Initial Data Inputs**: As the computational process initiates, we are equipped with two primary data inputs: carbon intensities and tax rates.
- **Incorporation of the Tax Rate**: Adhering to the Kaleckian cost-plus rule and with the presumption of fixed markups, the tax rate gets integrated into the price structures. Due to the carbon tax, this results in the costs being shouldered by the consumers.
- **Computing Consumption and Demand**: The next step involves calculating the disposable income with the revised prices. This disposable income subsequently influences consumption patterns, which dictate the demand for various products and services.
- **Production and Carbon Emission Calculation**: Demand metrics then guide the production figures. Once production levels are discerned, the model employs carbon intensities to compute the respective carbon emissions for each sector. These sectoral emissions are aggregated, providing a comprehensive view of national carbon emissions.
- **Reinvestment & Updated Carbon Intensity**: As a period concludes, there may be an opportunity to reinvest based on the model's parameters. If such an opportunity arises, the carbon intensity undergoes an update. However, the methods and mechanisms for this adjustment differ across various scenarios, a topic which is elaborated upon in the succeeding chapter.

3.2.7 Equilibrium Conditions

The excess demand equations are evaluated for each sector upon establishing the aggregate demand, as depicted by (equation 45). Excess demand is the difference between aggregate demand and aggregate supply, which is equal to domestic production plus imports of a commodity. Thus, the equilibrium condition can be assessed as in equation 46.

The agricultural sectors operate under price-clearing mechanisms. Changes in agricultural prices are assumed to balance agricultural supply and demand. However, the first sector (food crops) is subject to a lower boundary due to the enforcement of the Minimum Support Price (MSP). If the price of food crops drops below the MSP, governmental procurement is increased above the predetermined amount to stabilise the price. In that case, the market for food crops is cleared by quantity adjustments.

In scenarios where aggregate demand for non-agricultural goods and services is lower than maximum (potential) output, actual output levels are determined by demand. However, in scenarios where demand surpasses the maximum capacity constraint for non-agricultural sectors, these sectors increase markup rates, as stipulated by (equation 49), to suppress demand so that it falls beneath the maximum capacity. The higher markup rates raise non-agricultural prices and inflation (as measured by the CPI), affecting real incomes, income distribution, demand and overall economic performance.

The solution algorithm checks the magnitude of excess demands in all 16 sectors to ensure it remains within the specified limit. If the excess demand is lower than the threshold across all sectors, the model progresses to achieve a balance in agricultural prices. Figure 3.9 is an overview of the model's functioning. Equations 47-49 identify the equilibrium conditions.

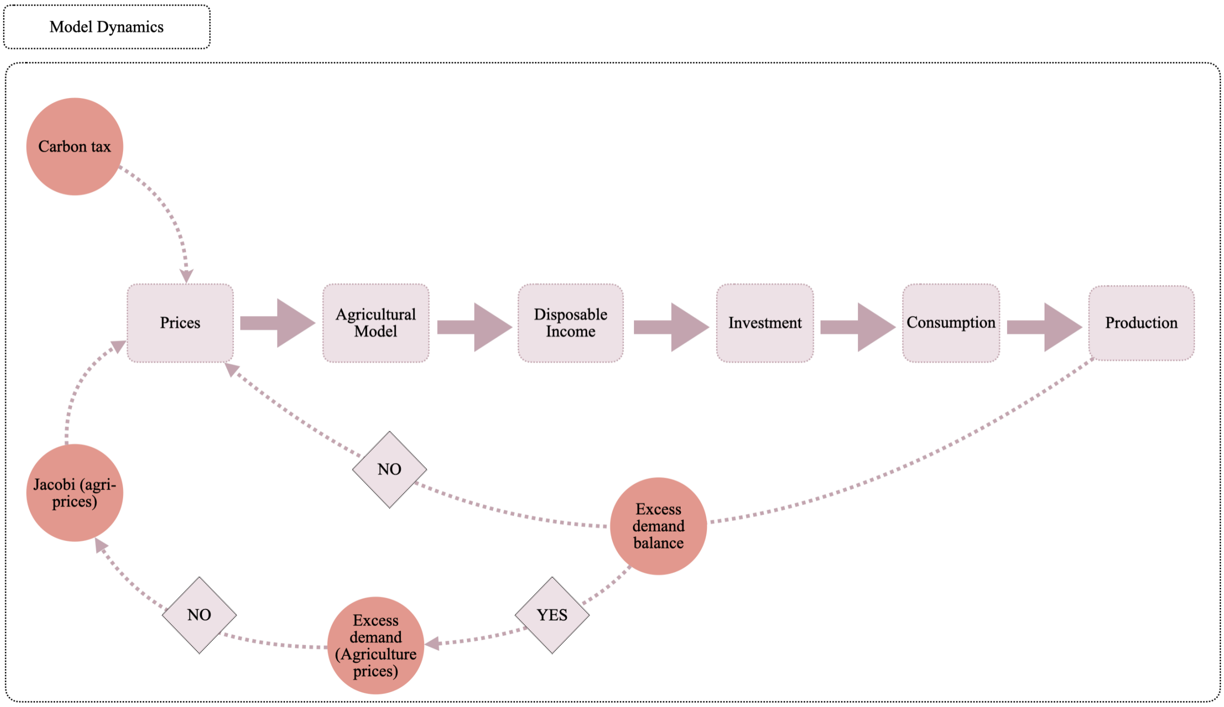


Figure 3.9: Model Dynamics

3.3 Calibration of the Model

Once the structure of the model is established, it needs to be calibrated for initial values, and specific coefficients need to be evaluated. The model primarily uses SAM data to establish initial values and calibrate equations. For certain variables, however, other data sources were used. This section will briefly mention the data sources used for specific variables. Notably, the National Accounts Statistics 2017 (NAS, 2017) from the Government of India's Ministry of Statistics and Programme Implementation is a significant data source. The following is an overview of the data sources used for specific variables.

Several other initial values were obtained from Storm 1992. Notably, values about the agricultural model have not been updated, which is a limitation of this work. The data mentioned before can be found in Appendix D.

Upon successfully constructing and calibrating the model, a series of experiments have been conducted following the research questions of interest. The subsequent chapter provides an in-depth exploration of the experimental methodology employed in these assessments.

Variable	Variable Name	Variable Description	Name of Data File	Data Source
Teta	Matrix of partial capital coefficient	Used to calculate investment by origin given the investment by destination data	Consumption of Fixed Capital by economic activity at current and constant prices	NAS 2017
vw	Labour Productivity	Sector-wise economic output that is achieved per unit of labour input	Measuring Productivity at the Industry Level – The India KLEMS Database	RBI 2022 (Values taken for 2017)
cap	Capital Stock	Sector-wise capital stock	Net Capital Stock by industry	NAS 2017
dep	Capital Stock Depreciation	Sector-wise yearly depreciation	Net Capital Stock by industry	NAS 2017
carbon_int	Carbon Intensity	Carbon emissions per unit output (in Mton/Rupee)	Greenhouse Gas Emissions	OECD Stat 2016

Table 3.2: Additional variable data sources

4. Experimental Setup

In this portion of the thesis, I will discuss the methodological design underpinning the experiments that have been planned and executed in alignment with the research questions. The initial segment will comprehensively examine the carbon revenue cycle within the economic framework. The section delineates how carbon-related revenues are generated, recycled and utilised within the economy. The following section will identify the variables integral to the research questions under consideration. An in-depth understanding of these variables is crucial as it forms the basis of hypothesis testing and further analysis. Finally, the focus will shift towards the detailed description of the experimental framework and the hypothesis established for each experiment. This structured approach is designed to provide a comprehensive view of the research process, thereby enhancing the understanding and evaluation of the results derived from the investigations.

4.1 Carbon Cycle

At this juncture, the model has been updated to reflect the sector dynamics of the 2017-18 fiscal year. The code has undergone modifications to incorporate carbon emissions from a production standpoint and integrate carbon taxation into the economic framework. Before delving into the experimental setup's specifics, examining the impact of carbon taxes on the economy and revenue circulation within the system is beneficial.

The model now incorporates carbon intensity, quantified as the emissions (in Mton) per unit of industry output. Furthermore, a carbon tax is levied per ton of emissions. A sector-wise carbon tax can be interpreted as the tax imposed per output unit. This can be calculated by multiplying the carbon intensity with both the carbon tax and the level of sectoral output. This tax contribution is then added to the government's revenue. Incorporating the carbon tax escalates the cost of production for the sectors. It is postulated that each sector maintains fixed markups, transferring the additional "carbon burden" to the consumer. Consequently, this increase manifests itself in the market prices of commodities. The following is an overview of the “carbon revenue cycle” in the model.

This implies that incorporating a carbon tax posits immediate ramifications on government revenue and consumer expenditure levels due to higher costs. This additional revenue stream creates the potential for reinvestment into efforts aimed at decarbonisation and mitigation. Consequently, the subsequent experiments will delve into the nuances of this carbon tax cycle to derive informed policy insights. Further, these investigations will explore the potential for governmental investment policies utilising the 'carbon revenue' to enable climate change mitigation strategies.

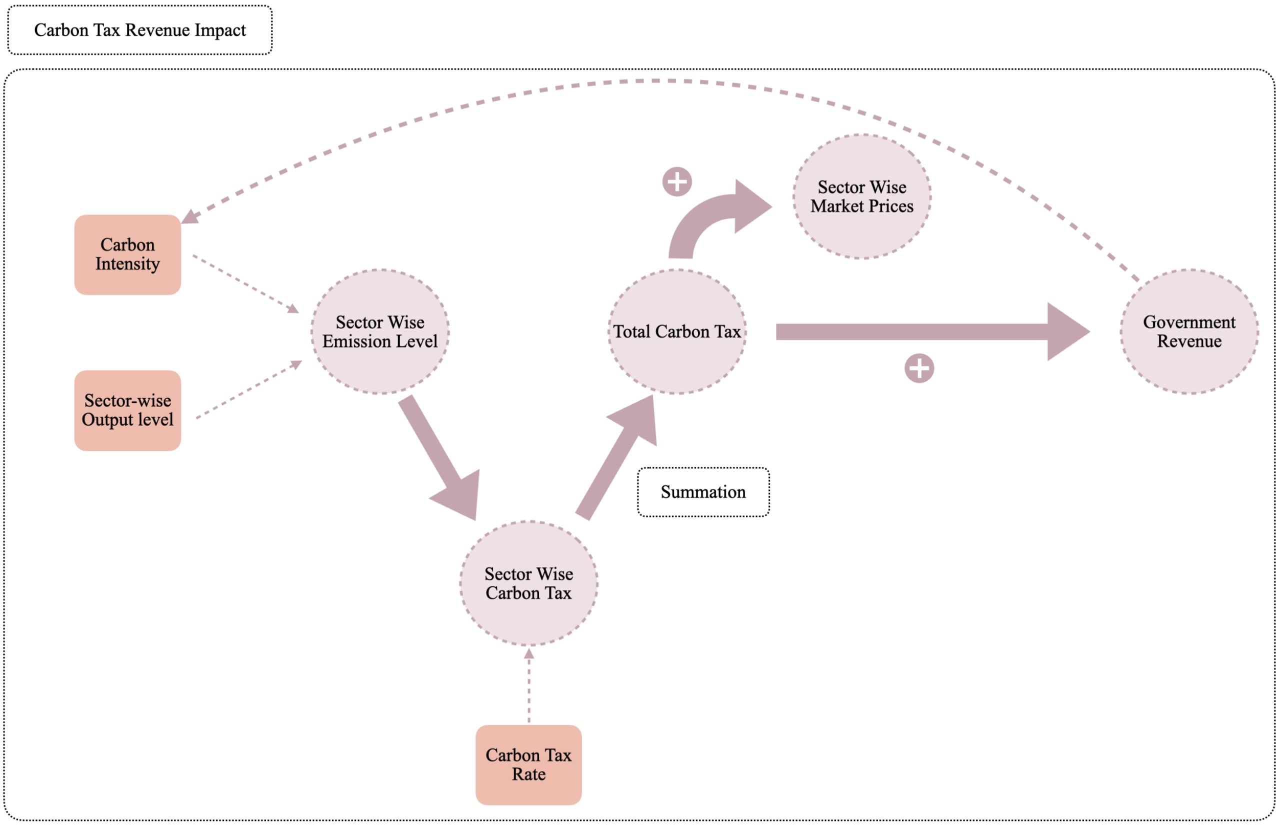


Figure 4.1: Carbon Tax Revenue Cycle

4.2 Key Performance Indicators

Concerning the above discussion and experimental considerations, it is crucial first to delineate the variables of interest that will be instrumental in analysing the experimental results. At the country level, key metrics include real Gross Domestic Product (GDP), country-level (aggregate) carbon emissions, carbon tax revenue, the Consumer Price Index (CPI), and the GDP Deflator. These economic indicators provide a holistic understanding of the nation's economic performance and the impact of carbon taxation. In addition, sector-specific variables such as carbon emissions, carbon tax, and production levels warrant examination. These offer insights into sectoral operations under the influence of carbon taxation and can elucidate sector-specific responses and impacts. Lastly, income and consumer expenditure statistics are crucial at the household level. These metrics shed light on the effects of carbon taxation and related policy shifts on households, particularly how they might alter consumer behaviour, income distribution and (average) living standards.

Focus	Variable Name	Variable
Country Level	Gross Domestic Product (real)	gdp
	Carbon tax revenue	tot_carbon_tax
	Total Carbon Emissions	tot_carbon
	Terms of Trade	tot
	Consumer Price Index	cpi
Sector Level	Sector level carbon emissions	$carbon\_emissions$
	Sectoral price levels	P
	Sectoral output levels	X
Household Level	Total Real Income	yk

Table 4.1: Variables of Interest

4.3 Experimental Setup

So far, the sub-research questions one and two have been answered in Chapter 3. This section will focus on designing experiments that answer the remaining two sub-questions. Sub-question 3 is as follows:

What are the macroeconomic effects of introducing a carbon tax in India, both in the short and the long run?

This sub-question evaluates the broad economic implications of implementing a carbon tax within the system. While India does not have a formal carbon tax, it is subjected to a positive Net Effective Carbon tax (ECR) and various other tax instruments, such as additional fuel taxes (fossil fuels), which function as implicit carbon taxation. This de facto carbon tax equals approximately US$1.6 per tonne, translating to nearly ₹130 (Qutubuddin, 2023). Consequently, in the context of the first experiment, I will introduce this carbon tax while accounting for emissions and consumer expenditure. The tax rate will be subject to an increment of 10% every period, providing an opportunity to assess how the increasing financial burden associated with carbon emissions influences economic and environmental outcomes within the system. The carbon revenue reinvestment will not be implemented in this experiment.

The fourth sub-question is as follows:

What role can carbon pricing play in aligning India's economic growth with its climate mitigation goals?

At this step, I will include carbon revenue reinvestment into the model. The first step will model reinvestment across various industries in correlation with their respective carbon emissions. In essence, this would signify that the industries contributing the highest level of emissions receive the most significant proportion of the investment.

This investment would spur technological advancement, which would, in turn, reduce carbon intensity. The envisaged relationship between the variables could be conceptualised as follows:

$$ci_{i,t+1} = f(ci_{i,t}, inv_{c,i})$$

(ci_i is the carbon intensity of sector i, and $inv_{c,i}$ is the carbon investment)

As an assumption for this experiment, it is assumed that an investment into a sector i would reduce carbon intensity by a function of the relative investment, i.e. investment/total production. Hence,

$$ci_{i,t=1} = (1 - \alpha_i * inv_{c,i}/x_i) * ci_{i,t}$$

In this equation α_i can be construed as a coefficient representing decarbonisation. However, establishing the precise value of this factor would necessitate empirical investigations, which, unfortunately, are not readily discernible within the existing body of literature. For the initial experiment, the value has been provisionally set at 0.01. While this assumption is undeniably broad, it is expected to yield meaningful insights. We can identify which sectors bear the most significant potential for decarbonisation by assigning a low and identical value across all sectors. It is imperative to acknowledge that this is a sweeping assumption, yet the modelling framework can accommodate a comprehensive examination provided it is supplemented with empirically robust coefficient data. This suggests that the study serves as an exploratory foundation upon which future research can expand to derive more comprehensive insights.

As a more targeted third experiment, the investment will be channelled solely into the energy sector. The Institute for Energy Economics and Financial Analysis stated the following concerning India (Assessing the Decarbonisation Pathways of India's Power Sector Giants | IEEFA, 2022):

"Power is a low-hanging sector to decarbonise – there are many proven technologically and commercially viable solutions."

Additionally, according to India's First Biennial Update Report by UNFCCC 2015, 68.7% of GHG emissions in India come from the energy sector (Ministry of Environment et al., 2015). Hence, one policy option could be to channel the investment into renewable technology and decarbonise the energy industry. A McKinsey Sustainability report identifies that India needs an investment of approximately $7.2 trillion of green investments by 2050 (Decarbonising India: Charting a Pathway for Sustainable Growth, 2022). This estimate has been made for India's net zero journey based on the current policy announcements while acknowledging technological adoption, which has been referred to as the line-of-sight (LOS) scenario in the analysis. Out of this investment, 50% needs to be channelled solely into the energy sector. Assuming a zero discount rate, this would amount to ~$0.11 trillion annually, equal to ₹8950 billion annually. Using this as a benchmark and assuming decarbonisation to be a linear process, the carbon intensities would reduce by this data. The equation relating the carbon intensity and investment would be:

$$ci_{energy,t+1} = ci_{energy,t} * inv_c * ci_{0,i}/8950$$

Here $ci_{0,t}$ is the carbon intensity value for the energy sector, given that the entire investment of ₹8950 billion is made. It is important to note that decarbonisation is unlikely to be a linear process, and this assumption allows for elementary analysis.

This is the outline for the experiments that will be conducted for this thesis. However, before summarising the experiment parameters, it is essential to underscore that the carbon tax rate of US$1.6 per tonne is considerably lower than the mean carbon tax rate of the world, which amounts to around US$5.29 per tonne (Cui, 2022). The resulting impact may not be noticeable at this relatively lower rate. The World Bank suggests a carbon tax rate of US$40 - US$60 per tonne to meet the 'well below 2°C' goals of the Paris Agreement (World Bank Group, 2021). Notably, a stark contrast exists between the prevailing rates in India and these suggested rates.

Consequently, a second set of experiments were carried out using a carbon tax rate of US$40, equivalent to ₹3280. This significant increase from the initial rate is expected to offer additional meaningful insights. The following are the summarised experiments. Before running these experiments, I will perform a base run that does not include any carbon tax.

4.3.1 Experiment 0

Experiment 0 is the baseline scenario, wherein the model operates without including a carbon tax. This scenario is the reference against which the outcomes of subsequent experimental scenarios incorporating different carbon tax rates will be compared.

4.3.2 Experiment 1

Experiment 1 run 1				
	Period 1	Period 2	Period 3	Units
$carbon\_tax$	130	143	157.3	₹/$MTon$

Experiment 1 run 2				
	Period 1	Period 2	Period 3	Units
$carbon\_tax$	3280	3608	3968.8	₹/$MTon$

Hypothesis: It is expected that the increase in the tax rate would increase consumer prices and have an inflationary impact in the immediate years without proper reinvestment (which is not implemented in this experiment). This can be viewed using yad, cpi $gdpdefl$ variables. Additionally, the overall output of the industries might go down due to reduced consumption demand. Variables gdp and x will capture these trends.

4.3.2 Experiment 2

Experiment 2 run 1				
	Period 1	Period 2	Period 3	Units
$carbon\_tax$	130	143	157.3	₹/$MTon$
inv_c	N/A	Endogenous and commensurate with sectoral carbon emissions		

Experiment 2 run 2				
	Period 1	Period 2	Period 3	Units
$carbon\_tax$	3280	3608	3968.8	₹/$MTon$
inv_c	N/A	Endogenous and commensurate with sectoral carbon emissions		

Hypothesis: The investment is modelled from year two since it is modelled to introduce a carbon tax in year 1. The reinvestment is expected to drive down carbon emissions, seen in *tot_carbon_emissions* and *carbon_emissions.* The increased tax rate is still expected to increase consumer prices and has an inflationary impact, but it would be lower than in experiment 1.

4.3.3 Experiment 3

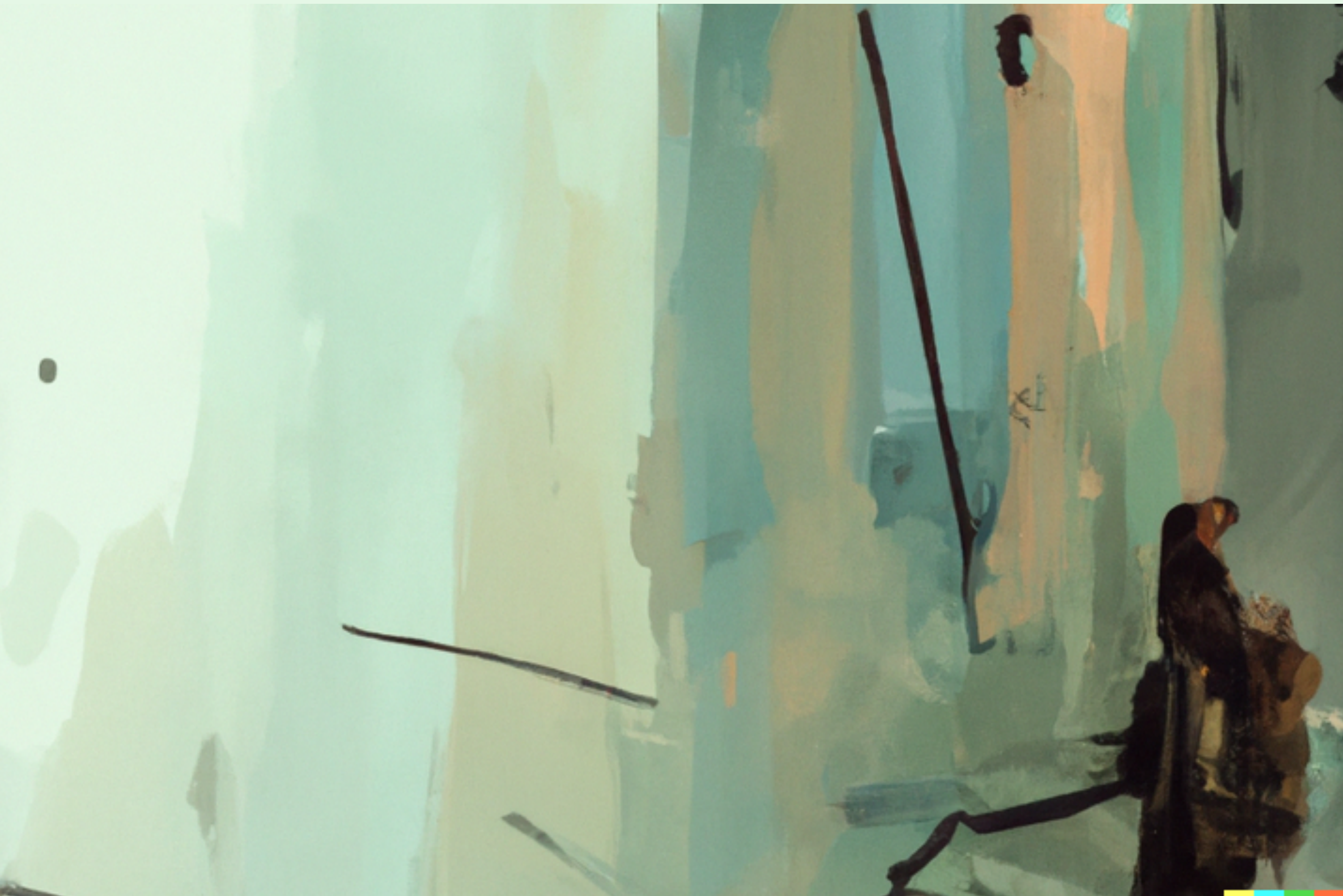
Experiment 3 run 1				
	Period 1	Period 2	Period 3	Units
Required Investment	8950	8950	8950	₹ billion
Carbon Intensity for utilities sector ($ci_{0,i}$)	0.055723163	0.054538848	0.053354534	MT/₹ billion

Experiment 3 run 2				
	Period 1	Period 2	Period 3	Units
Required Investment	8950	8950	8950	₹ billion
Carbon Intensity for utilities sector ($ci_{0,i}$)	0.055723163	0.054538848	0.053354534	MT/₹ billion

Hypothesis: Given that the energy sector is the most polluting, the reduction of emissions would be the largest in this scenario. The impact on all the other variables is uncertain, but it is expected to be similar to the impact in experiment 2.

This concludes part II of the thesis. The following section will discuss and compare the results to derive policy insight.

PART III: RESULTS AND CONCLUSIONS



5. Results and Analysis

In this chapter, I will delve into and juxtapose the outcomes of the scenarios. The initial section offers an in-depth analysis of the results of the baseline scenario that excludes any imposition of carbon taxes. By detailing this scenario, I aim to shed light on the inherent dynamics of the Indian economy. After this, I will elucidate the ramifications of introducing various carbon tax rates and their associated reinvestment strategies. Central to this discussion will be the carbon emission levels on a national level, complemented by a comparative evaluation of the national, sectoral, and household economic repercussions. The following section discusses and summarises the key insights obtained from the scenario analysis and the policy implications that can be derived from this analysis

5.1 Baseline Results:

This section of the thesis is dedicated to discussing the findings derived from each distinct scenario. Before advancing towards a more comprehensive analysis, it is advantageous to outline the parameters defining the varied iterations of the experiments. Seven unique experimental setups were created, each representing a distinctive economic model under the implementation of carbon taxes. Each of these experimental iterations was categorised based on the intensity of the imposed tax rate, which was predetermined as either 'low' or 'high', as delineated in the preceding chapter. Moreover, reinvestment was introduced in the second and third scenarios. This practice entailed utilising the revenues from the carbon taxes in two different mechanisms. The tax revenues were reinvested proportionately to the sectoral output in the second scenario. In contrast, in the third scenario, these funds were intentionally directed towards specific sectors as dictated by carbon intensities, as discussed in the previous chapter. Table 5.1 provides an overview of all the scenarios.

Scenario	Code Name	Carbon Tax	Reinvestment
Baseline	b_l	-	-
Scenario 1 Run 1	s1_r1	Low	-
Scenario 1 Run 2	s1_r2	High	-
Scenario 2 Run 1	s2_r1	Low	Proportionate
Scenario 2 Run 2	s2_r2	High	Proportionate
Scenario 3 Run 1	s3_r1	Low	Directed
Scenario 3 Run 2	s3_r2	High	Directed

Table 5.1: Scenarios Overview

5.1.1 Baseline Scenario

- **GDP and Carbon Emissions**

The real Gross Domestic Product (GDP) exhibits a substantial growth of **6.7%** from the first to the second period, followed by a rise of **6.8%** from the second to the third. This increase is paired with noticeable inflation, reflected in a **6.4%** growth of the Consumer Price Index (CPI) from the first to the second period and a further **6.1%** rise from the second to the third. A similar real GDP growth rate and inflation (CPI growth rate) represent a 'healthy and expanding' economy. Additionally, this means that the (nominal) GDP growth offsets part of the inflation. Table 5.2 shows the real GDP growth over the three periods.

	Period 1	Period 2	Period 3
Real GDP (in million rupees)	59,806,095.12	63,912,678.75	68,252,217.44

Table 5.2: Real GDP in the baseline scenario (in million rupees)

The observed economic expansion is concurrently marked by a consistent and significant increase in carbon emissions, registering a rise of **10.7%** from the initial to the subsequent time frame and a further augmentation of **10.8%** from the second to the third period. This progression in carbon emissions across the three periods is visually encapsulated in Table 5.3. An important observation from the analysis is the substantial disparity in carbon emissions across various sectors. The sector-wise distribution of carbon emissions is illustrated in Figure 5.1. Even with a similar growth rate of carbon emissions across all sectors, the absolute contribution manifests a pronounced skewness.

	Period 1	Period 2	Period 3
Carbon Emissions (in million metric tons)	3263.54	3608.03	3985.93

Table 5.3: Carbon emissions in the baseline scenario (in million metric tons)

In descending order of pollution contribution, sectors 12 (utilities), 11 (other manufacturing), 13 (construction), 5 (mining), and 14 (transport and trade services) emerge as the predominant contributors to the overall carbon footprint. These five sectors cumulatively account for over **95%** of all carbon emissions, with the utility sector alone shouldering over **67%** of the burden.

While elevated emissions from sectors 5, 11, 12, and 13 are predictable given their inherent carbon intensities and significant production volumes and would typically be categorised under 'heavy industries', the service sector (sector 14) warrants a closer examination. Even though they possess only median carbon intensity levels, these sectors create considerable carbon emissions, attributable primarily to their high output levels. Conversely, the agricultural and affiliated services, represented by sectors 1-4 and 6-8, exhibit a marginal carbon footprint, constituting approximately **1.37%** of the aggregate emissions. This minimal impact can be ascribed both to their lower carbon intensities and output levels.

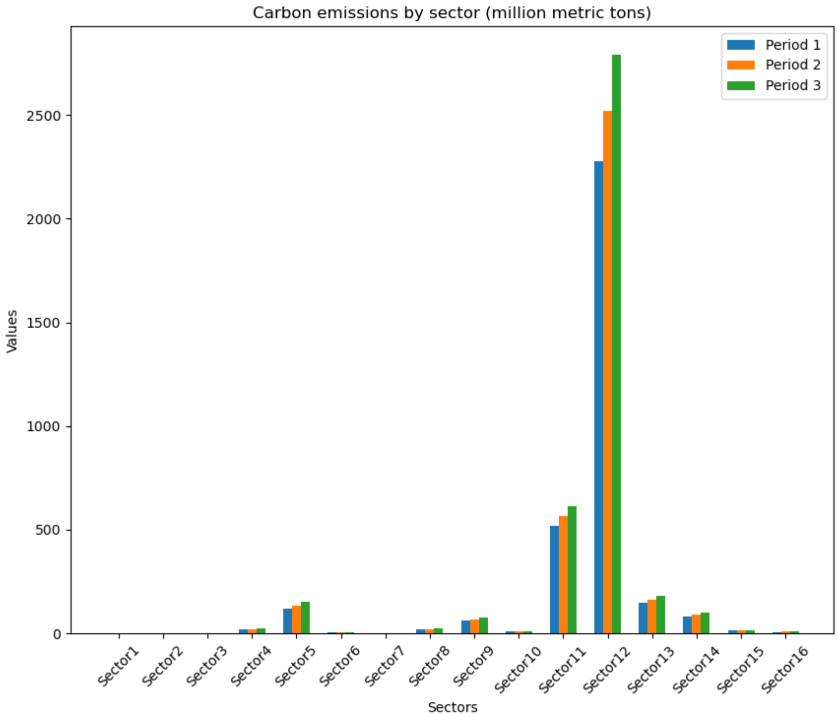


Figure 5.1: Carbon emissions by sector baseline

This segment of the findings underscores the imperative of deploying precise and efficacious policy mechanisms to address carbon emissions. Adopting a reinvestment strategy contingent on carbon emissions, as delineated in Scenario 2 of this study, or a more nuanced, targeted reinvestment approach, as elucidated in Scenario 3, provides the most promising avenues for achieving decarbonisation.

- ## Structure of the Economy

In Figure 5.2, the real output levels of various sectors are presented. Notably, the sectors with the most substantial contributions are, in descending order: Sector 11 (other manufacturing), sector 13 (construction), sector 12 (utilities), sector 5 (mining), and sector 14 (transport and trade services). As previously discussed, it is imperative to highlight the considerable overlap between the sectors with the highest outputs and those with the most significant pollutant emissions.

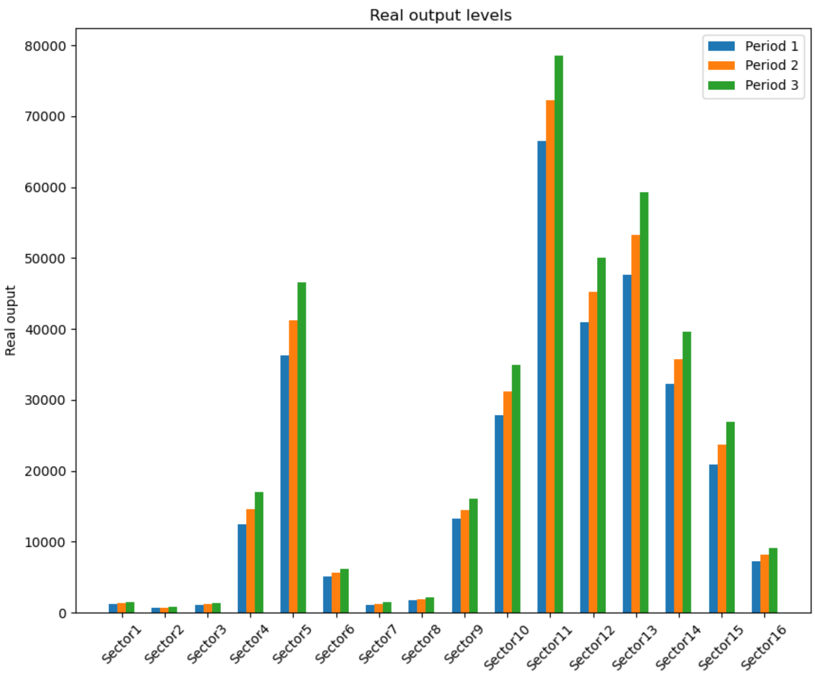


Figure 5.2: Real Output levels (baseline)

Apart from sector 4 (animal husbandry and forestry), the remaining agricultural sectors (i.e. 1-3) have significantly smaller output levels. However, it can be seen that the agricultural output levels are rising faster than non-agricultural sectors. This can be visualised in Figure 5.3.

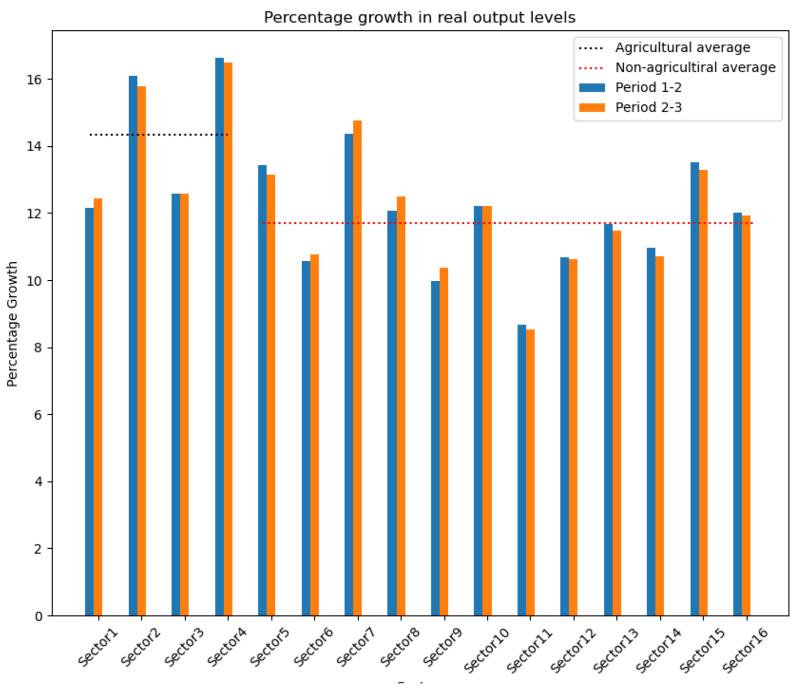


Figure 5.3: Percentage growth in real output levels (baseline)

The observed data suggests that although the proportion of agricultural sectors in the economy remains comparatively minor relative to non-agricultural sectors, there is a discernible acceleration in the growth rate of the former. This nuanced shift underscores a gradual structural transformation within the economic landscape. Such changes can be critically assessed through the ‘terms of trade’ metric, which, in turn, will wield considerable implications for income distribution across the economy. The next portion delves deeper into this aspect.

- **Terms of Trade**

A pivotal insight is obtained by evaluating the agricultural to non-agricultural terms of trade (TOT). This metric, characterised by the ratio of agricultural sectors' price index to non-agricultural sectors, elucidates the price relationship between agricultural and non-agricultural commodities. It serves as a tool for gauging the comparative economic potency of the agricultural sector vis-à-vis the non-agricultural sector in a specific economy. Notably, shifts in this metric over periods provide insights into the economy's structural evolution, either favouring or disadvantaging the agricultural sectors. In the baseline scenario, a **0.5%** and **0.6%** growth rate across the three periods is documented in Table 5.4, suggesting a marginally more robust growth trajectory for the agricultural sector than its non-agricultural counterparts.

	Period 1	Period 2	Period 3
Terms of Trade	27.12	27.26	27.42

Table 5.4: Terms of Trade

To further clarify the 'terms of trade' metric, one can view it as an index reflecting the economic contribution of the agricultural sector in comparison to the non-agricultural sectors. A value of one hundred (100) indicates a balance where the economic contributions of both agricultural and non-agricultural sectors are equal. A value smaller than a hundred reflects an economy where the agricultural sector contribution is smaller than that of non-agricultural sectors. As seen in Table 5.4, the terms of trade depict an economy where the agricultural sectors have a smaller contribution to the GDP, but their influence is noticeably, yet marginally, increasing.

This growth in TOT indicates that agricultural prices are surging at a faster pace than those of non-agricultural sectors. This can also be seen in Figure 5.4, where the average increase in agricultural prices is marginally higher than in non-agricultural prices. Given that the primary income for the first three economic classes (households 1-3) emanates from agricultural profits, this surge enhances their income levels. Conversely, rural non-agricultural classes (households 4-6) – whose earnings are predominantly from agricultural wages – experience a downturn in their real wage due to inflationary pressures. The escalation in agricultural prices indirectly boosts non-agricultural sector prices due to the higher cost of agricultural intermediary goods. This results in an inflationary trend, predominantly impacting the agricultural sector and consequently diminishing the real wage of households 4-6.

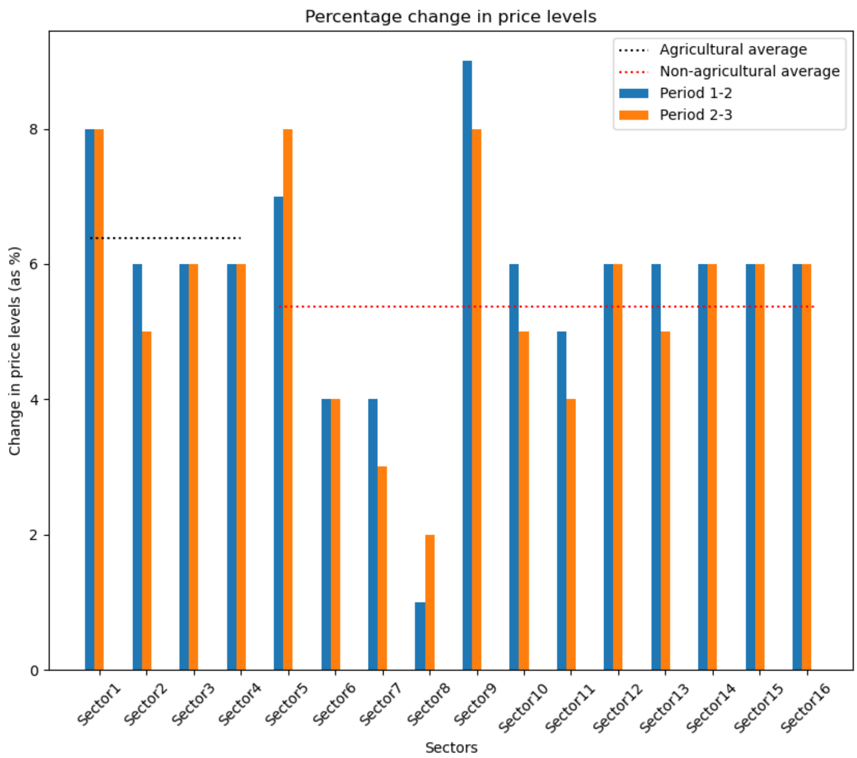


Figure 5.4: Percentage change in price levels (baseline)

For the urban classes, the ripple effect causes consumer prices to rise, affecting the real wage across different classes. Specifically, the real wage of the lowest urban class (household 7), predominantly reliant on non-agricultural wage income, declines across the three periods. This decline is attributed to inflated prices and fixed profit markups of industries, which depresses the wage share and is evident in household 7's dwindling nominal and real income. In contrast, households 8 and 9, primarily deriving their income from profit markups in non-agricultural industries, observe income growth over the three periods. The change in the share of real income over the three periods for different income classes can be seen in Figure 5.5.

Interestingly, while the change in real income shares of rural households is minor, the changes are highly pronounced for urban classes. This change is occurring at the cost of the lowest urban class. The income increase of the upper two urban classes is almost entirely offset by the loss experienced by the lowest urban class. As discussed above, this phenomenon can be attributed to fixed markup rates in non-agricultural sectors and inflationary pressures, which erode wage income for the lowest urban class.

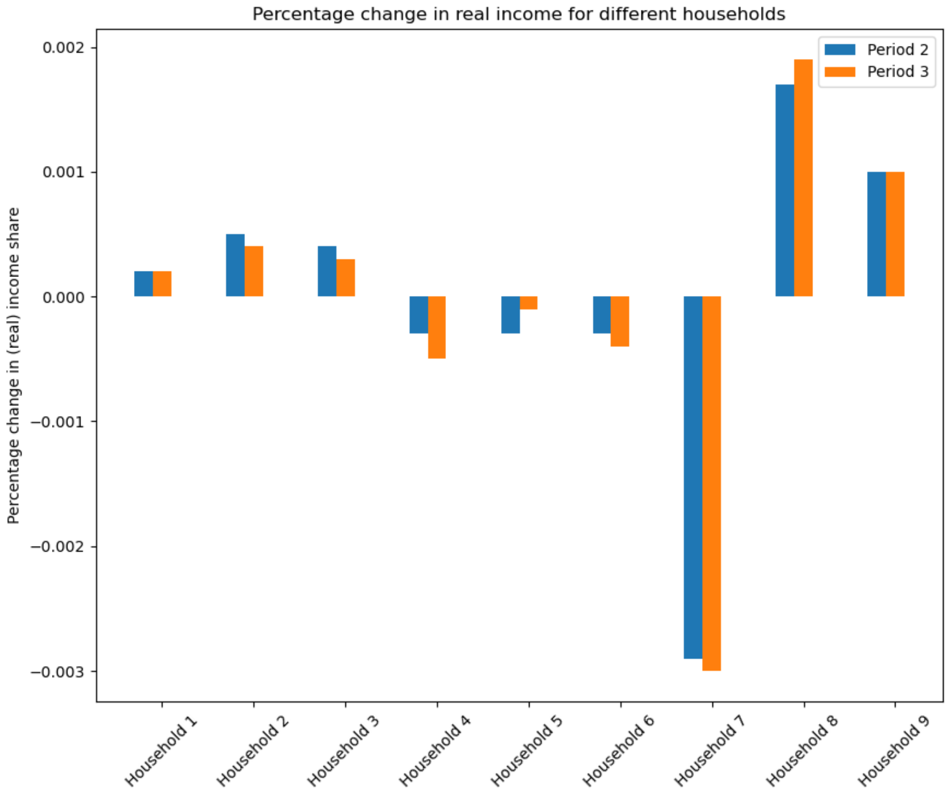


Figure 5.5: Percentage change in real income (baseline)

- **Main Takeaways**

In this base case analysis, it becomes evident that even though the agricultural sectors contribute a smaller proportion to real GDP, their contribution has steadily increased over various periods, as indicated by the ascending TOT values. This uptick in TOT is primarily attributed to a steeper rise in the contribution of agricultural sectors to the GDP. This, in turn, increases agricultural prices. When agricultural prices surge, they, in turn, push up non-agricultural input prices, subsequently affecting all goods' market prices and leading to inflation. This domino effect of rising non-agricultural prices can hamper the growth of corresponding sectors. The escalating agricultural prices are a bottleneck for the growth of non-agricultural sectors, creating a ripple effect that culminates in inflation, thereby diminishing real income.

It is worth noting that these shifts affect both rural and urban poverty levels. In light of these observations, exploring the implications of introducing carbon taxes on different income classes becomes intriguing. Carbon emissions are escalating rapidly. However, their sources are concentrated in a few significant sectors, namely, utilities (sector 12), other manufacturing (sector 11), construction (sector 13), mining (sector 5), and transport and trade services (sector 14).

As I introduce carbon taxes in the subsequent scenarios, it remains to be seen how they will shape income levels, constrain carbon emissions, and influence GDP contributions. In the subsequent section, we delineate the outcomes of various scenarios by meticulously examining individual Key Performance Indicators (KPIs) and contrasting the alterations in their values across all scenarios. The detailed results of all scenarios can be found in Appendix E.

5.2 Analysis

5.2.1 GDP and Carbon Emissions

In this part, I compare real GDP and carbon emissions under varied tax structures at a national level. Figure 5.6 provides a comparative view of the GDP across different scenarios. From the data presented, it is evident that the peak GDP corresponds to the base case. Throughout three periods, the GDP for scenarios with a lower tax rate ($1.6) mirrors the base case scenario quite closely. In comparison, while the GDP for scenarios E1R1, E2R1, and E3R1 is slightly below that of the base scenario, this disparity over the three periods is minimal and insignificant.

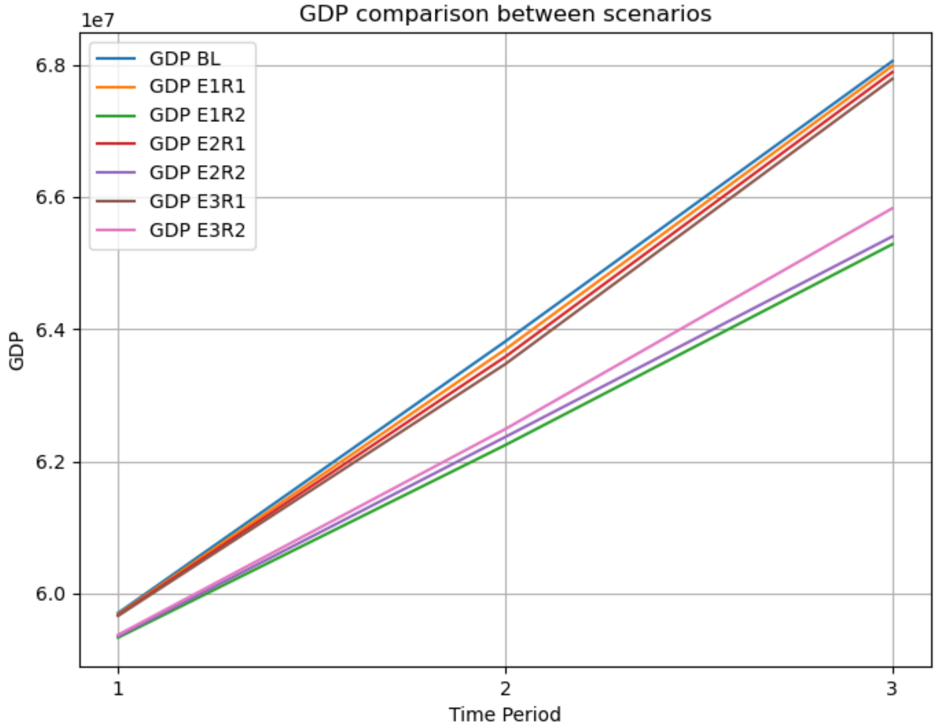


Figure 5.6: GDP comparison between scenarios (in million rupees)

A pattern emerges when observing the GDP data. The GDP ranks highest for the base case, followed by the scenario without reinvestment (E1R1). After that, the GDP for proportional reinvestment (E2R1) precedes the targeted reinvestment scenario (E3R1). This ordering is particularly intriguing as it suggests that the reinvestments do not adequately alleviate the carbon tax's economic strain. In essence, the adverse economic repercussions of the tax surpass the benefits achieved by reducing carbon intensities. The imposition of the additional tax escalates prices to an extent where reinvestments do not exhibit any perceptible influence, rendering the lower tax rate inefficacious.

When evaluating the elevated tax rate of $40, a distinctive variation is observed, highlighting the effectiveness of reinvestment. In this context, the reinvestments act as a buffer, mitigating the economic setbacks inflicted by the tax, albeit only partially. The GDP for the E3R2 scenario surpasses that of E2R2, indicating that a targeted reinvestment strategy is more conducive to climate mitigation than a proportional strategy. Both these scenarios outperform E1R2, which solely imposes an added tax burden without any accompanying reinvestment, thus causing a significant economic downturn. This portion underscores a critical insight:

While adequate reinvestment can counteract the economic challenges a carbon tax presents, it is imperative to ensure that the tax rate is sufficiently high. This would enable reinvestment strategies to effectively reduce carbon intensities, striking a balance between economic growth and climate mitigation.

In the endeavour to understand the potential for decarbonisation through various strategies, Figure 5.7 offers a comprehensive overview of carbon emission levels across different tax strategies. Predictably, the carbon emissions peak in the base case, with subsequent levels observed for the E3R1, E2R1, and E1R1 scenarios. Given the absence of constraints on emission levels, the base case registering the highest emission levels is logical. However, a diminishing gap becomes apparent when comparing the E1R1 scenario with no reinvestment against the E3R1 and E2R1 scenarios that do. This contradicts expectations; reductions in carbon intensity should naturally lead to decreased emissions and lower differences between the scenarios.

Moreover, scenarios E3R1 and E2R1 register smaller GDPs, indicating lower carbon emissions should have been observed. A plausible explanation is that the impact of the carbon tax is not ‘adverse’ enough for key polluting sectors. It is conceivable that low carbon tax rates and subsequent reinvestment enables high-emission sectors, like the energy sector, to maintain their output levels. As a result, carbon emissions remain elevated, without significant reductions in carbon intensities, due to ineffective reinvestment.

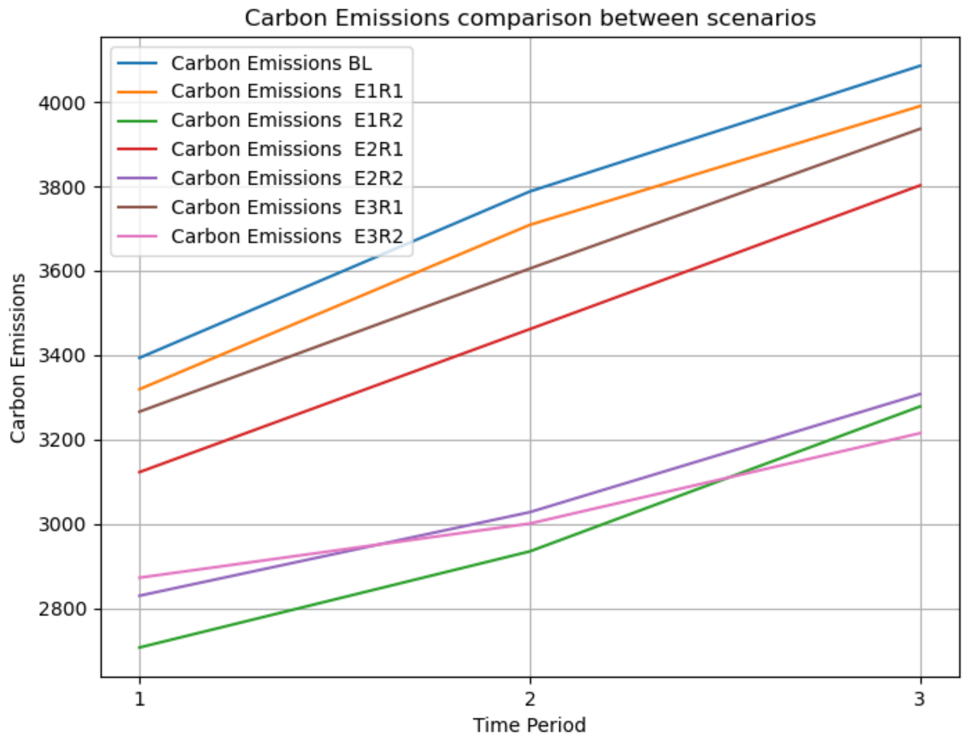


Figure 5.7: Carbon Emissions comparison between scenarios (in million metric tons)

Given that many high-emission sectors are pivotal with greater propensities to consume and provide substantial quantities of intermediate goods, any price escalation ripples through the economy. This culminates in inflated prices across the board, curbing overall consumption and stifling economic growth, as manifested in the GDP figures.

A distinct trend materialises upon increasing the carbon tax rate for the second iteration across various scenarios. Initially, carbon emission levels are the most attenuated for the E1R2 scenario, followed by E2R2 and E3R2. Such a pattern is anticipated, given the notably suppressed GDP and output levels associated with the absence of reinvestment in the E1R2 scenario. In the subsequent period, with the incorporation of reinvestment protocols, the emissions affiliated with the E3R2 scenario are lesser than those of E2R2. This transition underscores the efficacy of a targeted reinvestment strategy in mitigating carbon intensities. By the third period, the carbon emissions corresponding to E3R2 diminish further and are lower than E1R2 and E2R2. Such a trajectory accentuates the preeminence of a targeted investment strategy, especially in tandem with a higher carbon tax rate. Moreover, the optimal scenario, while accepting a reduction in GDP, aligns with this strategy, suggesting its overarching superiority when considering national-level indicators.

At this stage, it is essential to recognise the inherent limitations of the model used in this analysis. The assumptions regarding the decarbonisation process and coefficients introduce uncertainty that makes definitive conclusions challenging. Nonetheless, this analysis serves as a valuable foundation. It underscores the concept that the position of a sector on its decarbonisation trajectory, when combined with its technological capacity for further decarbonisation, can inform the crafting of tax and reinvestment strategies. These strategies, when effectively combined, have the potential to strike a delicate balance between optimising economic interests—represented in this case by GDP—and achieving meaningful carbon mitigation. By understanding these nuances, policymakers and industry leaders can better tailor interventions catering to environmental and economic objectives, ensuring a holistic approach to sustainable development. The next portion looks at terms of trade under different scenarios to understand the impact of carbon taxation on the economy's structure.

5.2.2 Terms of Trade and Sectoral Output Levels

In Section 5.1, the significance of the terms of trade (TOT) was elaborated upon, highlighting its pertinence as a metric to gauge the temporal evolution of the agricultural sector relative to the non-agricultural sector in the economy. This evolution is depicted in Figure 5.8, which showcases the trajectory of TOT across diverse scenarios.

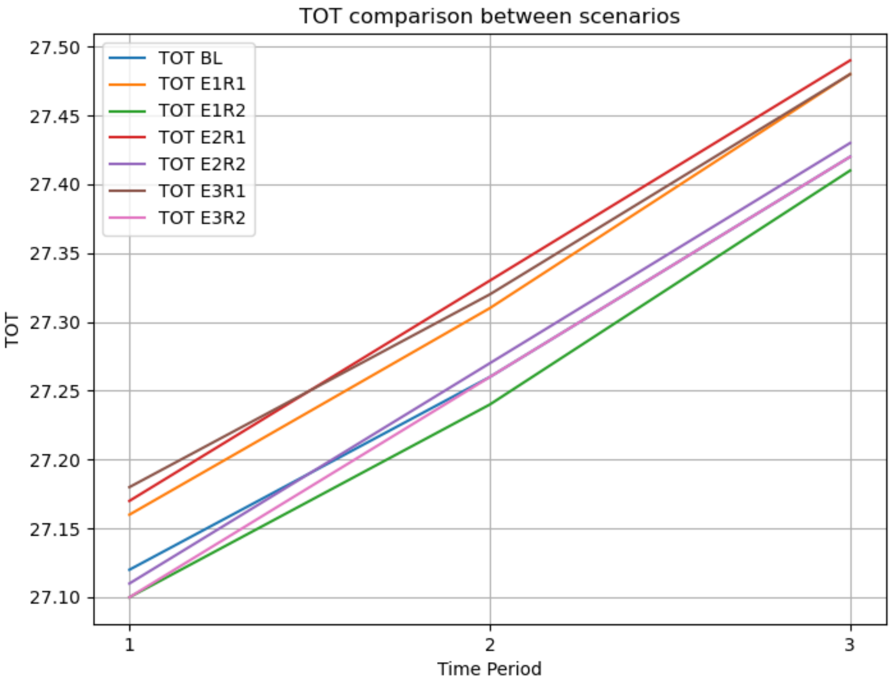


Figure 5.8: Terms of Trade comparison between scenarios

A discernible trend across these scenarios is the progressive increase in the TOT. This ascending trajectory suggests that the agricultural sector's contribution to the GDP is outpacing that of the non-agricultural sectors. A more granular examination reveals that scenarios with lower carbon tax rates consistently exhibit higher TOT values compared to their higher tax rate counterparts and the baseline. This potentially alludes to the greater adverse effect of a higher carbon tax rate on the agricultural sector compared to the non-agricultural sectors.

One plausible explanation for this trend lies in the economic interplay of costs. Despite the primary brunt of the tax being borne by heavy polluters, the ensuing costs permeate downstream, affecting consumers and sectors dependent on intermediate inputs. This cascading effect inflates prices across the board, with predominant polluters like utilities, manufacturing, and transport sectors amplifying costs for sectors reliant on their outputs. With a higher tax rate, the inflationary effects harmonise across both agricultural and non-agricultural sectors, preserving the structural balance of the economy.

In contrast, a milder tax rate might not curtail the output of pollutant sectors as drastically but still indirectly shifts the inter-sectoral balance. However, the variance in terms of trade (TOT) across different scenarios, though observable, is not pronounced enough to draw conclusive inferences. The proportional outputs of each sector are depicted in Appendix E5. From this representation, it is apparent that the economic structure remains largely unaltered by diverse tax interventions across three distinct periods. However, this observation is interpreted cautiously, as it may suggest that the model is not adequately sensitive to external perturbations. While this specific analysis was not undertaken within the present study's scope, it presents a promising area of improvement for future research.

5.2.3 Household Insights

Examining the real income shares at the individual household level provides a nuanced understanding, revealing several significant patterns and trends that merit further exploration. Tables 5.5, 5.6 and 5.7 show the change in household real income share statistics for all scenarios. The table has been broken down for simplification:

- **Agriculture profit income - households 1-3**

In the baseline, there was an observed increase in the households' income. After introducing low tax rates, specifically E1R1, E2R1, and E3R1, there is a discernible decline in the growth of real income shares, though they remain above zero. Among the four scenarios, the lowest income levels are observed in E3R1, which incorporates a targeted reinvestment strategy. E2R1 follows this, while E1R1 registers the highest income levels, succeeded by the Baseline scenario. From this data, one can infer that the absence of a carbon tax is most advantageous for the income of households within the agricultural sector, albeit the change in income under different scenarios remains marginal.

Conversely, in the context of a higher tax rate, the agricultural households' income share turns negative for E2R2 and E1R2. E3R2 exhibits a marginally positive income, suggesting that a targeted strategy yields the most favourable outcomes even under elevated tax rates. It is crucial to emphasise that imposing a high tax rate is detrimental to these households. This could escalate poverty rates, particularly for the most vulnerable, exemplified by household 1. Such an adverse impact presents a tangible risk and must be considered seriously when considering adopting an aggressive tax strategy.

		Household		
Scenario	**Period**	**1 (Rural-Agro 1)**	**2 (Rural-Agro 2)**	**3 (Rural-Agro 3)**
bl	**1-2**	0.024	0.046	0.036
	2-3	0.049	0.082	0.070
e1r1	**1-2**	0.022	0.042	0.033
	2-3	0.043	0.072	0.062
e1r2	**1-2**	-0.002	-0.004	-0.003
	2-3	-0.004	-0.007	-0.006
e2r1	**1-2**	0.020	0.038	0.030
	2-3	0.041	0.069	0.059
e2r2	**1-2**	-0.001	-0.003	-0.002
	2-3	-0.003	-0.005	-0.004
e3r1	**1-2**	0.018	0.034	0.027
	2-3	0.038	0.064	0.055
e3r2	**1-2**	0.002	0.003	0.004
	2-3	0.004	0.006	0.008

Table 5.5:Rural Agricultural Households

- ### Agriculture wage income - households 4-6

In the baseline scenario, the real income of households 4-6 is declining. This trend remains consistent across scenarios involving lower carbon tax rates. Notably, the income shares for households 5 and 6 become less negative under the reinvestment scenarios E2R1 and E3R1. However, one must exercise caution in interpreting this as a positive development. The diminished negative income share could manifest from other income classes incurring larger losses, thereby making the share of households 5 and 6 comparatively less harmful. The magnitude of this change, though, remains marginal.

Upon examination of scenarios with a higher carbon tax rate, households 5 and 6 present a less negative to slightly positive growth, specifically within the E2R2 and E3R2 scenarios. This shift could indicate income redistribution, where a significant portion is reallocated from agricultural households to non-agricultural ones. This can be attributed to the escalated wage costs in relation to profits, a consequence of heightened production expenses borne from the added tax burden and the inflated cost of intermediate goods. While households 5 and 6 exhibit relative stability under these conditions, household 4's situation remains concerning. As the least affluent among the three, household 4 shows negative growth, posing a substantial risk of descending into poverty. Fundamentally, although the elevated tax rates appear less detrimental to this particular income bracket, these households continue to face a constriction in their negative income share, albeit to a lesser degree. However, it should be noted that for these households, the targeted strategy (E3R2) and proportional strategy (E2R2) with high tax rates seems to be the best strategy. Table 5.6 represent these values.

		Household		
Scenario	**Period**	**4 (Rural-Non-Agro 1)**	**5 (Rural-Non-Agro 2)**	**6 (Rural-Non-Agro 3)**
bl	**1-2**	-0.034	-0.028	-0.026
	2-3	-0.081	-0.041	-0.062
e1r1	**1-2**	-0.028	-0.023	-0.022
	2-3	-0.067	-0.034	-0.051
e1r2	**1-2**	-0.009	-0.008	-0.007
	2-3	-0.022	-0.011	-0.017
e2r1	**1-2**	-0.020	-0.016	-0.015
	2-3	-0.047	-0.023	-0.036
e2r2	**1-2**	-0.002	0.002	0.002
	2-3	-0.005	0.002	0.004
e3r1	**1-2**	-0.022	-0.018	-0.017
	2-3	-0.052	-0.026	-0.040
e3r2	**1-2**	-0.002	0.002	0.002
	2-3	-0.002	0.003	0.004

Table 5.6:Rural Non-Agricultural Households

- ## Non-agricultural Income - households 7-9

Urban households exhibit distinct reactions across all three classifications. For the most economically disadvantaged urban household, denoted as Household 7, all the scenarios consistently indicate a decline in the share of real income over the three periods. The attenuated negative growth is most apparent in the E2R1 scenario, characterised by a low tax rate combined with proportional investment. Intriguingly, this strategy seems less favourable for the other two urban households. However, it is imperative to acknowledge that both the E2R1 and E2R2 scenarios, premised on proportional investment, produce more favourable outcomes for Household 7.

For Household 8, an urban middle-class bracket, an intriguing pattern emerges. Despite positive growth across all scenarios, the most favourable outcome is evident in the E3R2 scenario, which couples a high tax with targeted investment. This suggests that, notwithstanding the high tax imposition, this urban bracket registers robust growth, surpassing even Household 9, the most affluent urban class. Given that this household derives its income from both wages and profit income, and household seven predominantly from wage income, it can be inferred that under the E3R2 scenario, wage income experiences a decline, whereas profit income thrives. Another observation is that while household seven sources its income from a diverse range of non-agricultural sectors, household 8 garners its income from specific sectors, such as the service sector, which are essentially not accessible to household 7. This could imply that the services sector flourishes under this scenario.

In the context of Household 9, the E1R2 scenario emerges as the most advantageous. This high tax, without reinvestment scenario, suggests that while other classifications may bear the brunt of the tax and experience a decline in real income, Household 9 witnesses an uptick. This can be attributed to a significant portion of its income deriving from non-agricultural profit markups and governmental interest payments. Irrespective of the chosen scenarios, this urban elite consistently enjoys positive growth in its real income share, prospering under both high and low tax conditions.

		Household		
Scenario	**Period**	**7 (Urban 1)**	**8 (Urban 2)**	**9 (Urban 3)**
bl	**1-2**	-0.289	0.173	0.099
	2-3	-0.586	0.366	0.204
e1r1	**1-2**	-0.289	0.173	0.092
	2-3	-0.587	0.367	0.194
e1r2	**1-2**	-0.311	0.169	0.175
	2-3	-0.630	0.358	0.338
e2r1	**1-2**	-0.187	0.112	0.039
	2-3	-0.379	0.237	0.079
e2r2	**1-2**	-0.191	0.114	0.082
	2-3	-0.387	0.242	0.156
e3r1	**1-2**	-0.294	0.186	0.085
	2-3	-0.596	0.395	0.162
e3r2	**1-2**	-0.300	0.190	0.100
	2-3	-0.608	0.403	0.183

Table 5.7: Urban Households

Overview of Households

Table 5.8 provides a comprehensive overview of the income share preferences and growth trends across different households. This table serves as a condensed representation of the preceding analysis, offering a visual narrative of how income distribution shifts under each proposed scenario. Each scenario is ranked based on its perceived benefit to every household: a rank of '1' signifies the most favourable scenario, while a rank of '7' indicates the least preferred. Notably, households with a negative best-case scenario are accompanied by a negative sign. An intriguing observation is the recurring preference for the E3R2 scenario across the households; it emerges as the most favoured on average. However, its repercussions are notable in the rural agricultural sectors and the urban poor, underscoring its potentially detrimental effects. Similarly, the E2R2 scenario, despite its advantages, appears suboptimal for a significant number of households. The subsequent chapter distils the primary conclusions from the evaluated scenarios and delineates the limitations of the methodology employed.

	Households								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
bl	1	1	1	7	7	7	3	4	2
e1r1	2	2	2	6	6	6	4	3	4
e1r2	7	7	7	3	3	3	7	5	1
e2r1	3	3	3	4	4	4	1 (-)	7	7
e2r2	6	6	6	2	2	2	2	6	6
e3r1	4	4	4	5	5	5	5	2	5
e3r2	5	5	5	1 (-)	1	1	6	1	3

Table 5.8: Households preferences for different scenarios

6. Conclusions and Limitations

This section will use insights from the previously discussed results to derive policy implications and draw pertinent conclusions. This analysis will enable a comprehensive understanding of the potential implications of our research findings on policymaking. Subsequently, the limitations inherent in the present study will be assessed. This will provide a balanced view of the findings and contribute towards identifying avenues for further research in this domain.

6.1 Conclusions

In this study, I developed a Computable General Equilibrium (CGE) model that integrates carbon emissions from a production perspective. This augmented model facilitates a comprehensive evaluation of the economic implications of carbon taxes on emission levels. Several compelling observations emerge through scenario analysis, specifically by running six distinct scenarios beyond the baseline.

A prominent observation made during the study is that a limited number of sectors, precisely five, emerge as the main contributors to emissions, accounting for more than 95% of total emissions. The energy sector, predominantly dependent on coal, is the most significant contributor. It is pertinent to mention that the country has significantly expanded its non-fossil fuel capacity in the past five years since the data was sourced. This shift slightly alters the current scenario. Nevertheless, emissions from the utility sector remain staggeringly high even in 2022, exceeding 60% (Singh, 2023). Such data underscores the pressing need for targeted investments in decarbonisation, emphasising the transition to green energy and the exploration of low-carbon fuels as potentially rapid pathways to effective mitigation.

The analysis revealed that merely imposing a nominal carbon tax (based on the current standard rate) is insufficient to effect substantial carbon mitigation. Moreover, such a rate could negatively impact specific income brackets. Conversely, a higher tax rate, while it might affect income distribution adversely, can assure a reduction in carbon emissions. Consequently, it is more prudent to institute a higher tax rate accompanied by adequate reinvestment rather than adopting a lower tax rate that might neither aid in decarbonisation nor benefit the economy.

Regardless of the tax approach adopted, there is an incontrovertible reduction in production outputs, leading to a subsequent contraction in GDP. However, striking the right balance between an adequately rigorous carbon tax and a reinvestment strategy predicated on the decarbonisation coefficient can carve an optimal trajectory toward decarbonisation. This pathway aims to attenuate carbon emissions without severely compromising the economy's vitality.

Two investment strategies, namely proportional and targeted reinvestment, were studied in depth. Modelling results suggest a targeted reinvestment strategy offers superior GDP enhancement and carbon mitigation outcomes. This strategy also manifests a more equitable distribution of benefits and burdens across various societal strata. Acknowledging the potential risks associated with such a policy, particularly the erosion of agricultural profit income, is paramount. Hence, any proposal advocating such measures should incorporate supplementary provisions like subsidies, ensuring the socio-economically vulnerable segments are safeguarded against undue hardships.

One of the intrinsic merits of the targeted strategy is its direct focus on decarbonising the most egregious offender: the energy sector. This direct intervention achieves its primary emission reduction objective and yields relatively favourable economic outcomes for GDP and household incomes.

When contemplating any carbon tax policy, it is crucial to consider its potential hazards to specific households, particularly those in the lower income bracket. These policies can inadvertently lead to a decline in the income levels of these vulnerable households, further exacerbating existing socioeconomic disparities. Another macroeconomic consequence of such a tax strategy is the potential Gross Domestic Product (GDP) deflation.

6.2 Limitations and Future Work

This study should acknowledge several limitations in the broader scope and specific technical details. Initially, I will delve into the constraints related to the model's architecture and underlying assumptions. These technical limitations influence the model's robustness, applicability, and interpretability in real-world scenarios. Understanding these nuances is vital to ensure that the findings and implications drawn from the model are contextualised appropriately.

- **Model Limitations**

Future work stemming from this research could take several directions to enhance the effectiveness and precision of the existing model. Firstly, the model's export levels and wage growth are currently exogenous and could be modified to be endogenous, allowing for a more in-depth understanding of how changes within the system might affect export levels. Next, the agricultural sub-model within the framework could be updated better to capture this sector's intricacies and recent developments.

Another area of future improvement is to update the model's marginal propensity to consume coefficients for all households. They are assumed to be equal to an average propensity to consume. These updates and additions will enhance the robustness of the model and its utility in shaping effective climate change mitigation policies.

A further area of exploration is the relationship between green investment and carbon intensity. The term identified as the coefficient of decarbonisation in the thesis warrants further investigation. By accurately estimating these coefficients, sectors with the highest potential for decarbonisation could be identified. Moreover, these estimates could provide insights into determining an 'ideal' tax rate that aligns with governmental mitigation goals while simultaneously minimising the reduction in GDP.

Another dimension that warrants re-evaluation pertains to the pricing mechanism currently implemented in the model. In the present setup, the entirety of the tax burden is transferred to the cost price of commodities, effectively implying that consumers bear the full brunt of the tax. Exploring alternative pricing mechanisms that do not shift the entire tax incidence onto consumers could offer a more refined understanding of the economic dynamics. This current pricing method might contribute to why we observe that the sectoral output exhibits limited sensitivity to variations in the model parameters. By revisiting and potentially recalibrating this aspect, the model could yield more nuanced and realistic insights into the interplay between tax policies and market responses.

Lastly, the model has yet to undergo sensitivity analysis concerning specific stochastic variables embedded in the equations. These variables, primarily derived from Storm (1994), warrant further examination and refinement to ascertain the model's robustness. Experimenting with these parameters could provide a deeper understanding of their influence on the model's outcomes.

- **Analysis Limitation**

This study evaluated the effects of two distinct tax rates: the current de facto carbon tax rate (low) and a recommended higher rate. Although the results underscore the greater effectiveness of the higher tax rate, a more thorough analysis would entail examining a range of tax rates. Unfortunately, due to time constraints, this was not possible. Such a comprehensive exploration would provide a clearer perspective on which rate aligns best with our specified Key Performance Indicators (KPIs).

The relationships and coefficients related to decarbonisation employed in this study serve primarily as placeholder values. Consequently, while this approach facilitates the observation of overarching trends, it restricts deeper, more nuanced insights. It is imperative to acknowledge that these placeholder values, while illustrative, may only capture part of the complexity of decarbonisation dynamics.

Although this research touched upon the conceptual repercussions of poverty and economic strain resulting from carbon tax implementation, there is a need for a more granular examination. Specifically, understanding the direct ramifications of carbon taxation on vulnerable populations, such as the number of individuals potentially driven into poverty, would provide a clearer picture of the socio-economic implications.

Lastly, the model must account for these extreme events in light of escalating extreme weather events attributed to climate change. Subjecting the model to potential shocks like floods, famines, or heatwaves would gauge its resilience and predictive capabilities. Incorporating these extreme events is paramount for assessing model robustness and ensuring that derived policy insights are both comprehensive and forward-thinking.

6.3 Reflections

This project provided me with an invaluable opportunity to delve deeply into the intricacies of the modelling paradigm, particularly within the context of economic dynamics. Through this undertaking, I gained insights into the mechanics of capturing the broader spectrum of an economy and ventured into the nuances of integrating carbon emissions and their intensities into the model.

At the current juncture, while the model may not offer definitive policy recommendations, it serves as an invaluable tool for discerning trends and juxtaposing various investment strategies. As elucidated in this thesis, the targeted strategy emerges as a more favourable approach than others. Moving forward, it would be prudent to explore and analyse an even wider range of strategies to ensure comprehensive understanding and to identify the most effective mechanisms for achieving our goals.

Given the current global landscape, where sustainability and carbon neutrality are pressing concerns, the importance of a robust and statistically sound model cannot be understated. Such a model is a potent instrument for policy analysis, offering deep insights that can guide policy-making in the right direction. However, one limitation I encountered in the current configuration is its focus on domestic carbon emissions. For a more comprehensive analysis, global emission levels should ideally be integrated, considering the interconnectedness of today's global economies and the shared responsibility of addressing climate change.

While the present state of the model may not be ripe for direct governmental advice, with further refinements, I believe in its potential to become an indispensable tool in policy formulation and economic planning.

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APPENDIX A - SAM Data

The following is an overview of all the sectors and their mapping.

Sector Code	Name	Mapping to Aggregated SAM)
maiz	Maize	1
sorg	Sorghum and millet	1
rice	Rice	1
whea	Wheat and barley	1
ocer	Other cereals	1
gram	Gram	1
ppea	Pigeon peas (arhar)	1
puls	Other pulses	1
gnut	Groundnuts	1
rape	Rapeseed and mustard	1
oils	Other oilseeds	1
cass	Cassava	2
ipot	Irish potatoes	2
spot	Sweet potatoes	2
root	Other roots	2
leaf	Leafy vegetables	2
vege	Other vegetables	2
sugr	Sugarcane	1
toba	Tobacco	3
cott	Cotton	1
jute	Jute and other fibers	3
nuts	Nuts	2
bana	Bananas and plantains	2
frui	Other fruits	2
teal	Leaf tea	3
coff	Coffee	3
coco	Cocoa	3
flwr	Cut flowers	3
rubb	Rubber	3
ocrp	Other crops	3

catt	Cattle	4
milk	Raw milk	4
poul	Poultry	4
eggs	Eggs	4
smlr	Small ruminants	4
oliv	Other livestock	4
fore	Forestry	4
aqua	Aquaculture	4
fish	Capture fisheries	5
coal	Coal and lignite	5
coil	Crude oil	5
ngas	Natural gas	5
omin	Other mining	5
meat	Meat processing	6
fsea	Fish and seafood processing	6
dair	Dairy	6
fveg	Fruit and vegetable processing	7
foil	Fats and oils	7
mmll	Maize milling	7
smll	Sorghum and millet milling	7
rmll	Rice milling	7
wmll	Wheat and barley milling	7
gmll	Other grain milling	7
sref	Sugar refining	7
pcof	Coffee processing	7
ptea	Tea processing	7
food	Other foods	6
feed	Animal feed	6
beve	Beverages	6
ptob	Tobacco processing	6
yarn	Cotton yarn	6
text	Textiles	11
clth	Clothing	11
leat	Leather and footwear	11

wood	Wood products	11
papr	Paper products and publishing	11
prnt	Printing and recorded media	11
petr	Petroleum products	10
fert	Fertilizers and herbicides	8
phar	Pharmaceuticals	10
chem	Other chemicals	10
nmet	Non-metal minerals	10
iron	Iron and steel	10
nfmt	Non-ferrous metals	10
metl	Other metal products	10
mach	Machinery and other equipment	9
ecom	Consumer electronics and components	9
comp	Computers and peripherals	9
cequ	Communication equipment	9
oeeq	Other electronic equipment	9
equi	Electrical equipment	9
vehi	Vehicles and transport equipment	9
furn	Furniture	9
oman	Other manufacturing	9
repr	Repair and installation of equipment	9
elec	Electricity	12
gass	Gas and steam	12
watr	Water supply and sewage	12
cons	Construction	13
trad	Wholesale and retail trade	14
rtrn	Railway transport	14
ltrn	Land transport	14
wtrn	Water transport	14
atrn	Air transport	14
tran	Transport services	14
stor	Storage and wahehousing	14

hotl	Accommodation	15
rest	Restaurants and food services	15
comm	Information and communication	15
fsrv	Finance	15
insu	Insurance	15
real	Real estate activities	15
ownd	Ownership of dwellings	15
legl	Legal services	15
csrv	Computer related services	15
rent	Renting of machinery and equipment	15
bsrv	Other business services	15
padm	Public administration	16
educ	Education	16
heal	Health and social work	16
scsv	Social and personal services	16
osrv	Other services	16

APPENDIX B - List of Equations

The Agricultural Sub Model

(1) $gia_t = \omega_0 + \omega_1 j_{a,t-1} + \omega_2 gia_{t-1}$

(2) $nia = \Sigma gia$

(3) $aci = \gamma_0 + \gamma_1 [nia/nsa]$

(4) $gca = aci \times nsa$

(5) $ngca = gca - gia$

(6) $p_i = p_i / \sum_{j=1}^{3} \zeta_j p_j$ **with** $\zeta_j = [p_j x_{sj} / \sum_{j=1}^{3} p_j x_{sj}]$

(7) $\log(\mathbf{ngca}_{i,t}) = \chi_{0i} + \chi_{1i} \tilde{p}_{i,t-1} + \chi_{2i} \log(\mathbf{ngca}_{i,t-1})$ **where** $\sum_{i=1}^{3} ngca_i = ngca$

(8) $\log(\mathbf{gia}_{i,t}) = \chi_{3i} + \chi_{4i} \tilde{p}_{i,t-1} + \chi_{5i} \log(\mathbf{gia}_{i,t-1})$ **where** $\sum_{i=1}^{3} gia_i = gia$

(9) $gca_i = ngca_i + gia_i$ **where** i=1,2,3

(10) $\log(\mathrm{fert}_i) = \nu_{0i} + \nu_{1i} \log(p_8/p_i)$ **where** i=1,2,3

(11) $\log(\mathrm{yld}_i) = \epsilon_{0i} + \epsilon_{1i} \log(fert_i)$ **where** i=1,2,3

(12) $x_{si} = yld_i gca_i$ **where** i=1,2,3

(13) $x_{s5} = \tilde{x}_{s5}$

(14) $frt_i = fert_i gca_i$ **where** i=1,2,3

(15) $\alpha_{8i} = frt_i / x_{si}$

Prices and Wages

(16) $p_{si} = (1 + \tau_{si})p_{zi}$ **where** i = 1,…,16

(17) $$cpi = \sum_{j=1}^{16} \omega_{ci} p_{si}$$

(18) $\omega_{i,t} = \theta_{0i} cpi_t^{\theta_{1i}} w_{i,t-1}^{\theta_{2i}}$ **where** i = 5,…,16, g

(19) $$p_j = (1 + ci_j * ct)(1 + \tau_j)(1 - \sigma_j)(1 + \pi_j)\left[\sum_{i=1}^{16} \alpha_{ij} p_{zi} + w_j \beta_j + \alpha_{oj} r (1 + t_{mj}) \tilde{p}_{mj}\right]$$

where j = 5,…,16

Production and Depreciation

(20) $\bar{x} = K_i / \kappa_i$ **where** i = 5,…,16

(21) $$p_{ki} = \sum_{j=a}^{16} \vartheta_{ji} p_j$$ **where** j = a, 5,…,16

(22) $Q_a = \delta_a p_{ka} K_a$

(23) $Q = \delta_i p_{ki} K_i$ **where** i = 5,…,16

Sector-wise Income

(24) $Y_{wi} = w_i \bar{\beta}_i x_{si}$ **where** i = 1,…,16

(25) $$Y_{ai} = p_1(x_{s1} - z_1) + p_1^* z_1 + \sum_{i=2}^{4} (p_i x_{si}) - \sum_{i=1}^{16} (p_i \alpha_{ij} x_{si} - r p_{mi} \alpha_{0i} x_{si} - p_i(\tau_i + \sigma_i) x_{si})$$

where i = 1,…,4

(26) $$v_{cj} = \sum_{i=1}^{16} (\alpha_{ij} p_i) + w_j \beta_j + \alpha_{0j} r p_{mj}$$ **where** j = 5,…,16

(27) $Y_{zi} = Y_{ai} - Y_{wi}$ **where** i = 1,…,4

$Y_{zi} = \pi_i \nu_{ci} x_{si} - N_{gi}$ **where** i = 5,….,16

Class-wise Income

(28) $Y_k = \sum_{i=1}^{16} (\xi_{ki} Y_{wi} + \Phi_{ki} Y_{zi}) + \Psi_k w_g l_g + \zeta_k \bar{V} + \Upsilon_k rF + \Theta_k V$ **where** k = 1,….,9

Private savings and consumption

(29) $S_k = \bar{\sigma}_k (1 - \tau_{dk}) Y_k$ **where** k = 1,….,9

(30) $D_k = (1 - \bar{\sigma}_k)(1 - \tau_{dk}) Y_k$ **where** k = 1,…,9

(31) $c_{ki} = \gamma_{ki} - f_{ki} + (\mu_{ki}/p_{si})[D_k + \sum_{i=1}^{16} ((p_{si} - \bar{p}_i) f_{ki} - p_{si} \gamma_{ki})]$ **where** k = 1,…,9

(32) $c_i = \sum_{k=1}^{9} (c_{ki} + f_{ki})$ **where** i = 1,…,16

Private investment demand

(33) $\hat{p} = \sum_{i=1}^{4} \varphi_i p_{zi} / \sum_{i=5}^{16} \xi_i p_{zi}$ **with** $\varphi_i = p_{zi} x_{si} / \sum_{i=1}^{4} p_{zi} x_{si}$ **and** $\xi_j = [p_{zi} x_{si} / \sum_{i=5}^{16} p_{zi} x_{si}$

(34) $j_{pa,i} = \varphi_{a1} [\hat{p}_{t-1}]^{\varphi_{a2}} [j_{ga,t-1}]^{\varphi_{a3}}$

(35) $j_{pi,t} = \varphi_{i1} [y_{zi,t}/p_{ki,t}]^{\varphi_{i2}} [j_{gi,t-1}]^{\varphi_{i3}}$

(36) $j_i = j_{gi} + j_{pi}$

(37) $i_i = \sum_{j=a}^{16} \vartheta_{ij} j_j$ **where** i = a, 5, ….,16

Exports and Imports

(38) $e_i = \bar{e}_{0i}(\bar{p}_{wi}/p_{ei})^{\eta_i}$ **where** i = 1,….,16

(39) $p_{ei} = p_i/((1+\sigma_{ei})r)$ **where** i = 1,….,16

(40) $p_{mi} = (1+t_{mi})r\bar{p}_{mi}$ **where** i = 1,….,16

(41) $\mu_{arm^i} = [(p_i/p_{mi})(\phi_i/(1-\phi_i))]^{\sigma_{ai}}$ **where** i = 1,….,16 **and** $\mu_{arm^i} = m_i/d_i$

(42) $m_i = \mu_{arm^i} d_i$ **where** i = 1,….,16

Stock Changes

(43) $\Delta st_{g1} = z_1 - \sum_{k=1}^{9} f_{k1}$

$\Delta st_{gi} = \Delta s\bar{t}_{gi}$

(44) $\Delta st_i = \Delta st_{gi} + \Delta st_{pi}$

Excess Demand

(45) $x_{di} = \sum \alpha_{ij}x_{sj} + c_i + g_i + i_i + \Delta st_i + e_i$ **where** i = 1,…,16

(46) $ed_i = x_{di} - x_{si} - m_i$ **where** i = 1,…,16

Equilibrium

(47) $ed_i = 0$ **where** i = 1,…,16

(48) $z_i - \bar{z}_i \geq 0 \perp (p_i - p_i^*) \geq 0$ **where** i = 1

(49) $(\bar{x}_i - x_{si}) \geq 0 \perp \pi_i^* \geq 0$ **where** i = 5,…,16

Government Accounts

(50)

$$R_1 = \sum_{i=1}^{4} [\tau_i p_i x_{si}] + \sum_{i=5}^{16} [\tau_i (1 + \pi_i) \nu_{ci} x_{si}] + \sum_{i=1}^{16} [\tau_{si} p_i c_i] + \sum_{i=1}^{16} [t_{mi} r \bar{p}_{mi} m_i] + \sum_{i=1}^{16} [t_{mi} \alpha_{0i} r \bar{p}_{mi} x_i]$$

(51) $R_2 = \sum_{i=1}^{9} [\tau_{dk} Y_k]$ **where** k= 1,…,9

(52) $R = \sum_{i=1}^{2} [R_i] + \sum_{i=5}^{16} [N_{gi}]$

(53) $U_1 = \sum_{i=1}^{4} \sigma_i p_i x_{si} + \sum_{i=5}^{16} \sigma_i (1 + \pi_i) \nu_{ci} x_{si}$

(54) $U_2 = (p_{s1} - \bar{p}_1) f_{n1} + p_{s1} f_{a1}$

(55) $U_3 = \sum_{i=1}^{16} (p_i - r p_{ei}) e_i$

(56) $\bar{U} = U_1 + U_2 + U_3$

(57) $Z = (p_1^* - p_1) z_1$

(58) $C_T = \sum_{j=1}^{16} [x_j c i_j]$

(59) $G = \sum_{i=1}^{16} [p_i g_i] + \bar{U} + V + \bar{V} + Z + w_g l_g + (1 - \phi_z) Q + C_T$

Government Saving

(60) $S_g = R - G$

Gross Domestic Product

(61) $Y_f = Y_a + Y_w + Y_z + Q_a + \phi_z Q + w_g l_g + \sum_{i=5}^{16} N_i$

(62) $Y_m = Y_f + R_f + \bar{L}$

Current Account Deficit

(63) $H = \sum_{i=1}^{16} [rp_{mi} m_i] + \sum_{i=1}^{16} [rp_{mi} \alpha_{0i} x_{si}] - \sum_{i=1}^{9} [rp_{ei} e_i] - rF$

Savings-Investment Balance

(64) $S_a + S_w + S_z + S_g + H + Q_a + Q = \sum_{i=1}^{16} [p_i i_i + p_i \Delta st_i]$

Inter-Temporal Relations

(65) $\omega_{ci,t+1} = [p_{i,t} c_{i,t}] / \sum_{k=1}^{9} D_k$ **where** i = 1,…,16

(66) $K_{i,t+1} = (1 - \delta_i) K_{i,t} + j_{i,t}$ **where** i = a,5,…,16

(67) $z^*_{gi,t+1} = z^*_{gi,t} + \Delta stk_{gi,t+1}$ **here** i = 1,…,16

APPENDIX C - List of Variables

a = Agricultural

g = Government

w = Non-Agricultural Wage Income

z = Non-Agricultural Mark-Up Income

α_{8i}	Amount of fertiliser input required per unit of output of crops (i=1,2,3)
aci	Aggregate Cropping Intensity
$fert_i$	Fertiliser consumption per hectare of crop (i=1,2,3)
frt_i	Aggregate fertiliser consumption by crop (i=1,2,3)
gca	Gross cropped area in ten million hectares (total)
gca_i	Gross cropped area under crop i in ten million hectares (i=1,2,3)
gia	Gross irrigated area in ten million hectares (total)
gia_i	Gross irrigated area under crop i in ten million hectares (i=1,2,3)
j_i	Aggregate investment for sector i (I=1,…,16)
$ngca$	Aggregate gross non-irrigated area in ten million hectares
$ngca_i$	Gross non-irrigated are under crop i in ten million hectares (I=1,2,3)
nia	Net irrigated area in ten million hectares
nsa	Net sown area in ten million hectares
$\tilde{p}_i$	Relative price of crop I wrt the weighted average price of competing crops
p_i	Market price of commodity
x_{si}	Level of sectoral output
yld_i	Yield of sector
τ_i	Weight of crop n relative price of other crops
c_i	Total consumption expenditure by sector
c_{ki}	Consumption expenditure by sector for income class k
D_k	Consumption demand from income class k
cpi	Consumer Price Index
f_{ki}	Food grains issuance to income class k
G	Public Expenditure

g_i	Public Consumption of good i
H_i	Current. Account deficit or foreign savings
i_i	Real investment by sector of origin where i=a,5,…,16
j_i	Real investment by sector of destination where I=a,5,…,16
j_{gi}	Real public investment by sector of destination where i=a,5,…,16
j_{pi}	Real private investment by sector of destination where i=a,5,…,16
K_i	Capital stock by sector
l_g	Government employment
m_i	Competitive level of imports sector wise
N_{gi}	Revenues from public enterprises where i=5,…,16
$\hat{p}$	Terms of trade (agriculture to non agriculture)
ci_i	Sector wise carbon intensity (MTon/output)
ct	Carbon tax (tax/MTon)

APPENDIX D - Additional Calibration Data

D.1 Value of TETA - Matrix of partial capital coefficient.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0002	0.0001	0.0001	0.0001	0.0000	0.0002	0.0004	0.0001	0.0003	0.0003	0.0016	0.0011	0.0003
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.1083	0.0269	0.0576	0.0469	0.0055	0.0762	0.1901	0.0375	0.1156	0.1140	0.7129	0.5004	0.1561
7	0.0010	0.0002	0.0005	0.0004	0.0000	0.0007	0.0017	0.0003	0.0010	0.0010	0.0064	0.0045	0.0014
8	0.0003	0.0001	0.0002	0.0001	0.0000	0.0002	0.0005	0.0001	0.0003	0.0003	0.0019	0.0013	0.0004
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.1482	0.0368	0.0788	0.0641	0.0076	0.1042	0.2600	0.0512	0.1581	0.1560	0.9752	0.6845	0.2136
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0092	0.0023	0.0049	0.0040	0.0005	0.0065	0.0162	0.0032	0.0098	0.0097	0.0607	0.0426	0.0133
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

D.2 Value of Labour Productivity

Sector Number	VW	Sector Number	VW
1	114.07	9	1825.39
2	109.22	10	7757.89
3	144.97	11	2645.81
4	112.39	12	2865.38
5	6416.66	13	490.56
6	995.67	14	476.71
7	2152.67	15	711.27
8	3522.66	16	1092.20

D.3 Capital Stock Depreciation and Depreciation Rate

	cap	dpr
msp_crop	19490.2	0.0762
nmsp_crop	11159.3	0.0000
nmsp_cash	7163.0	0.0000
ani_for	3269.2	0.0000
min	9592.1	0.0457
oth_agri	18083.9	0.0063
mil_agri	14717.3	0.0063
fert_agri	1742.2	0.0063
elec_manu	19665.5	0.1622
chem_manu	49059.7	0.1622
othe_manu	9666.5	0.1622
util	31085.8	0.0160
cons	14149.0	0.4330
tras_trad	96618.0	0.0840
oth_serv	112241.1	0.0520
pub_serv	75728.2	0.0124

D.4 Carbon Intensity

Sector Number	carbon_int	Sector Number	carbon_int
1	0.001357	9	0.004731
2	0.001357	10	0.000268
3	0.001357	11	0.007821
4	0.001357	12	0.055723
5	0.003219	13	0.003062
6	0.001119	14	0.002579
7	0.001119	15	0.000595
8	0.001119	16	0.000975

APPENDIX E - Results.

E.1 Base case scenario

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59,806,095.12	63,912,678.75	68,252,217.44	-	0.07	0.07
Terms of Trade	27.12	27.26	27.42	-	0.01	0.01
Savings investment balance	17,085,741.74	17,544,854.13	18,123,877.62	-	0.03	0.03
CPI	48.30	51.37	54.22	-	0.06	0.06
Trade balance (E-M)	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.01	-0.02
Carbon emissions	3,263.54	3,608.03	3,985.93	-	0.11	0.10
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.90	27.87	30.15	-	0.08	0.08
2	18.20	19.37	20.38	-	0.06	0.05
3	23.80	25.18	26.60	-	0.06	0.06
4	26.94	28.54	30.38	-	0.06	0.06
5	68.44	73.32	78.84	-	0.07	0.08
6	66.90	69.79	72.37	-	0.04	0.04
7	22.20	23.00	23.64	-	0.04	0.03
8	28.97	29.28	29.84	-	0.01	0.02
9	72.40	78.57	84.82	-	0.09	0.08
10	84.53	89.33	93.86	-	0.06	0.05
11	62.05	65.08	67.78	-	0.05	0.04
12	32.79	34.63	36.57	-	0.06	0.06
13	155.85	164.46	172.64	-	0.06	0.05
14	94.04	100.04	106.46	-	0.06	0.06
15	22.90	24.26	25.81	-	0.06	0.06
16	81.60	86.60	91.44	-	0.06	0.06
Sector Statistics - Production				GROWTH		

	P1	P2	P3	P1	P2	P3
1	1,170.71	1,312.99	1,476.27	-	0.12	0.12
2	605.44	702.77	813.70	-	0.16	0.16
3	1,013.34	1,140.70	1,284.20	-	0.13	0.13
4	12,479.71	14,553.69	16,955.28	-	0.17	0.17
5	36,305.69	41,184.38	46,596.92	-	0.13	0.13
6	5,060.74	5,595.81	6,198.15	-	0.11	0.11
7	1,092.31	1,249.27	1,433.65	-	0.14	0.15
8	1,694.64	1,899.20	2,136.53	-	0.12	0.12
9	13,189.10	14,503.12	16,009.20	-	0.10	0.10
10	27,782.04	31,170.63	34,978.85	-	0.12	0.12
11	66,555.64	72,326.97	78,506.11	-	0.09	0.09
12	40,885.93	45,255.88	50,059.43	-	0.11	0.11
13	47,635.96	53,201.87	59,298.11	-	0.12	0.11
14	32,221.77	35,758.06	39,585.52	-	0.11	0.11
15	20,917.66	23,745.21	26,904.10	-	0.14	0.13
16	7,281.25	8,156.54	9,130.14	-	0.12	0.12

	Carbon Emissions			Growth		
	P1	P2	P3	P1	P2	P3
1	1.59	1.78	2.00	-	0.12	0.12
2	0.82	0.95	1.10	-	0.16	0.16
3	1.38	1.55	1.74	-	0.13	0.13
4	16.93	19.75	23.01	-	0.17	0.17
5	116.87	132.57	150.00	-	0.13	0.13
6	5.66	6.26	6.94	-	0.11	0.11
7	1.22	1.40	1.60	-	0.14	0.15
8	1.90	2.13	2.39	-	0.12	0.12
9	62.40	68.61	75.74	-	0.10	0.10
10	7.45	8.35	9.37	-	0.12	0.12
11	520.53	565.67	614.00	-	0.09	0.09
12	2278.29	2521.79	2789.46	-	0.11	0.11
13	145.86	162.90	181.57	-	0.12	0.11
14	83.10	92.22	102.09	-	0.11	0.11
15	12.45	14.13	16.01	-	0.14	0.13
16	7.10	7.95	8.90	-	0.12	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	316.81	385.78	0.01	0.01	0.01	-	0.0002	0.0002
2	879.70	955.26	1151.35	0.04	0.04	0.04	-	0.0005	0.0004
3	1380.17	1489.53	1788.61	0.06	0.06	0.06	-	0.0004	0.0003
4	248.75	257.96	293.45	0.01	0.01	0.01	-	-0.0003	-0.0005
5	941.62	1002.58	1192.92	0.04	0.04	0.04	-	-0.0003	-0.0001
6	1888.00	2018.05	2398.05	0.08	0.08	0.08	-	-0.0003	-0.0004
7	286.83	233.16	187.09	0.01	0.01	0.01	-	-0.0029	-0.0030
8	1494.61	1647.38	2026.11	0.06	0.06	0.07	-	0.0017	0.0019
9	16602.05	17830.78	21318.30	0.69	0.69	0.69	-	0.0010	0.0010

E.2 Experiment 1 Run 1

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59,795,654.08	63,902,065.06	68,241,364.71	-	0.069	0.068
Terms of Trade	27.16	27.31	27.48	-	0.006	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	3319.16	3708.80	3990.47	-	0.117	0.076
CPI	48.30	52.40	56.41	-	0.085	0.077
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.86	27.43	29.70	-	0.061	0.083
2	18.17	19.08	20.10	-	0.050	0.053
3	23.76	24.83	26.25	-	0.045	0.057
4	26.90	28.17	30.02	-	0.047	0.066
5	68.40	72.96	78.53	-	0.067	0.076
6	66.81	68.95	71.57	-	0.032	0.038
7	22.17	22.75	23.41	-	0.026	0.029
8	28.94	28.99	29.57	-	0.002	0.020
9	72.33	77.86	84.14	-	0.077	0.081
10	84.47	88.79	93.39	-	0.051	0.052
11	62.03	64.95	67.71	-	0.047	0.043
12	32.78	34.60	36.56	-	0.055	0.057
13	155.79	163.96	172.30	-	0.052	0.051
14	93.99	99.64	106.14	-	0.060	0.065
15	22.88	24.09	25.66	-	0.053	0.065
16	81.53	85.91	90.80	-	0.054	0.057
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1168.71	1291.98	1454.13	-	0.11	0.13
2	604.47	692.23	802.31	-	0.15	0.16
3	1011.82	1124.73	1267.50	-	0.11	0.13

4	12462.24	14364.49	16751.81	-	0.15	0.17
5	36283.90	40978.46	46410.53	-	0.13	0.13
6	5054.16	5528.66	6129.97	-	0.09	0.11
7	1091.00	1235.53	1419.32	-	0.13	0.15
8	1692.78	1880.20	2117.30	-	0.11	0.13
9	13175.91	14372.59	15881.13	-	0.09	0.10
10	27762.60	30983.61	34803.95	-	0.12	0.12
11	66535.68	72182.31	78427.60	-	0.08	0.09
12	40877.75	45210.62	50054.43	-	0.11	0.11
13	47616.90	53042.26	59179.51	-	0.11	0.12
14	32205.65	35615.03	39466.76	-	0.11	0.11
15	20900.93	23579.00	26742.68	-	0.13	0.13
16	7274.69	8091.29	9066.23	-	0.11	0.12

Carbon Emissions				Growth		
	P1	P2	P3	P1	P2	P3
1	1.59	1.75	1.97	-	0.11	0.13
2	0.82	0.94	1.09	-	0.15	0.16
3	1.37	1.53	1.72	-	0.11	0.13
4	16.91	19.49	22.73	-	0.15	0.17
5	116.80	131.91	149.40	-	0.13	0.13
6	5.66	6.19	6.86	-	0.09	0.11
7	1.22	1.38	1.59	-	0.13	0.15
8	1.89	2.10	2.37	-	0.11	0.13
9	62.34	68.00	75.13	-	0.09	0.10
10	7.44	8.30	9.33	-	0.12	0.12
11	520.38	564.54	613.38	-	0.08	0.09
12	2277.83	2519.27	2789.18	-	0.11	0.11
13	145.80	162.42	181.21	-	0.11	0.12
14	83.06	91.85	101.78	-	0.11	0.11
15	12.44	14.03	15.91	-	0.13	0.13
16	7.09	7.89	8.84	-	0.11	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	316.29	390.80	0.018	0.019	0.019	-	0.00033	0.00065
2	879.70	954.26	1161.38	0.055	0.056	0.057	-	0.00063	0.00109
3	1380.17	1488.74	1796.35	0.087	0.087	0.088	-	0.00050	0.00094
4	1620.28	1730.48	2045.30	0.102	0.102	0.101	-	-0.00042	-0.00101
5	1860.40	1989.25	2364.38	0.117	0.117	0.116	-	-0.00035	-0.00051
6	2100.51	2247.18	2666.94	0.132	0.132	0.131	-	-0.00033	-0.00077
7	2340.62	2435.72	2727.39	0.147	0.143	0.134	-	-0.00438	-0.00887
8	2580.74	2812.26	3469.91	0.163	0.165	0.171	-	0.00261	0.00554
9	2820.85	3049.07	3699.60	0.178	0.179	0.182	-	0.00140	0.00294

E.3 Experiment 1 Run 2

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59335297.36	62245970.14	65284024.00	-	0.049	0.049
Terms of Trade	27.10	27.24	27.41	-	0.005	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	2706.75	2934.66	3278.32	-	0.084	0.117
CPI	49.36	56.18	63.45	-	0.138	0.129
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.64	23.14	25.02	-	-0.098	0.082
2	17.84	16.08	16.92	-	-0.099	0.052
3	23.09	20.90	22.08	-	-0.095	0.056
4	25.86	23.69	25.22	-	-0.084	0.064
5	60.23	60.86	65.44	-	0.010	0.075
6	63.56	57.92	60.07	-	-0.089	0.037
7	20.87	19.09	19.62	-	-0.085	0.028
8	26.94	24.31	24.77	-	-0.098	0.019
9	66.61	65.21	70.40	-	-0.021	0.080
10	75.23	74.14	77.90	-	-0.014	0.051
11	52.74	54.01	56.25	-	0.024	0.041
12	27.54	28.75	30.35	-	0.044	0.056
13	134.03	136.50	143.29	-	0.018	0.050
14	81.81	83.03	88.36	-	0.015	0.064
15	20.61	20.13	21.42	-	-0.023	0.064
16	74.26	71.88	75.90	-	-0.032	0.056
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1159.00	1089.78	1225.30	-	-0.06	0.12
2	593.33	583.30	675.38	-	-0.02	0.16

3	982.94	946.78	1065.88	-	-0.04	0.13
4	11980.52	12079.56	14072.88	-	0.01	0.17
5	31949.00	34183.03	38675.44	-	0.07	0.13
6	4807.70	4644.52	5144.46	-	-0.03	0.11
7	1026.77	1036.89	1189.93	-	0.01	0.15
8	1576.02	1576.33	1773.32	-	0.00	0.12
9	12133.97	12037.59	13287.64	-	-0.01	0.10
10	24726.02	25871.62	29032.44	-	0.05	0.12
11	56572.30	60031.38	65160.07	-	0.06	0.09
12	34344.18	37562.38	41549.33	-	0.09	0.11
13	40966.92	44157.55	49217.43	-	0.08	0.11
14	28032.94	29679.19	32855.98	-	0.06	0.11
15	18825.89	19708.53	22330.40	-	0.05	0.13
16	6625.93	6769.93	7578.02	-	0.02	0.12

	Carbon Emissions			Growth		
	P1	P2	P3	P1	P2	P3
1	1.57	1.48	1.66	-	-0.06	0.12
2	0.81	0.79	0.92	-	-0.02	0.16
3	1.33	1.28	1.45	-	-0.04	0.13
4	16.26	16.39	19.10	-	0.01	0.17
5	102.84	110.04	124.50	-	0.07	0.13
6	5.38	5.20	5.76	-	-0.03	0.11
7	1.15	1.16	1.33	-	0.01	0.15
8	1.76	1.76	1.98	-	0.00	0.12
9	57.41	56.95	62.86	-	-0.01	0.10
10	6.63	6.93	7.78	-	0.05	0.12
11	442.45	469.51	509.62	-	0.06	0.09
12	1913.76	2093.09	2315.25	-	0.09	0.11
13	125.44	135.21	150.70	-	0.08	0.11
14	72.30	76.54	84.74	-	0.06	0.11
15	11.20	11.73	13.29	-	0.05	0.13
16	6.46	6.60	7.39	-	0.02	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	310.14	369.05	0.018	0.018	0.018	-	-0.00003	-0.00006
2	879.70	942.48	1123.12	0.055	0.055	0.055	-	-0.00006	-0.00010
3	1380.17	1479.42	1764.39	0.087	0.087	0.087	-	-0.00005	-0.00008
4	1620.28	1735.32	2064.82	0.102	0.102	0.102	-	-0.00014	-0.00033
5	1860.40	1993.25	2376.09	0.117	0.117	0.117	-	-0.00012	-0.00017
6	2100.51	2250.90	2681.90	0.132	0.132	0.132	-	-0.00011	-0.00026
7	2340.62	2430.22	2707.53	0.147	0.143	0.133	-	-0.00470	-0.00953
8	2580.74	2811.26	3466.17	0.163	0.165	0.171	-	0.00255	0.00542
9	2820.85	3070.26	3768.97	0.178	0.180	0.185	-	0.00264	0.00511

E.4 Experiment 2 Run 1

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59674609.98	63580988.19	67886966.11	-	0.065	0.068
Terms of Trade	27.17	27.33	27.49	-	0.006	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	3122.63	3461.59	3842.50	-	0.109	0.110
CPI	48.30	52.91	57.53	-	0.096	0.087
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.88	27.46	29.73	-	0.061	0.083
2	18.19	19.10	20.12	-	0.050	0.053
3	23.79	24.85	26.28	-	0.045	0.057
4	26.93	28.20	30.05	-	0.047	0.066
5	68.47	73.03	78.61	-	0.067	0.076
6	66.88	69.02	71.64	-	0.032	0.038
7	22.20	22.77	23.43	-	0.026	0.029
8	28.97	29.02	29.60	-	0.002	0.020
9	72.40	77.94	84.22	-	0.077	0.081
10	84.56	88.88	93.48	-	0.051	0.052
11	62.09	65.01	67.78	-	0.047	0.043
12	32.82	34.63	36.60	-	0.055	0.057
13	155.94	164.13	172.47	-	0.052	0.051
14	94.09	99.74	106.25	-	0.060	0.065
15	22.90	24.11	25.68	-	0.053	0.065
16	81.61	85.99	90.89	-	0.054	0.057
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1169.88	1293.27	1455.58	-	0.11	0.13
2	605.08	692.93	803.12	-	0.15	0.16

3	1012.84	1125.86	1268.77	-	0.11	0.13
4	12474.70	14378.86	16768.56	-	0.15	0.17
5	36320.19	41019.43	46456.94	-	0.13	0.13
6	5059.21	5534.19	6136.10	-	0.09	0.11
7	1092.09	1236.76	1420.74	-	0.13	0.15
8	1694.47	1882.08	2119.42	-	0.11	0.13
9	13189.09	14386.96	15897.01	-	0.09	0.10
10	27790.36	31014.59	34838.76	-	0.12	0.12
11	66602.21	72254.50	78506.03	-	0.08	0.09
12	40918.63	45255.83	50104.48	-	0.11	0.11
13	47664.52	53095.30	59238.69	-	0.11	0.12
14	32237.86	35650.64	39506.23	-	0.11	0.11
15	20921.83	23602.57	26769.42	-	0.13	0.13
16	7281.97	8099.38	9075.30	-	0.11	0.12

Carbon Emissions				Growth		
	P1	P2	P3	P1	P2	P3
1	1.59	1.75	1.98	-	0.11	0.13
2	0.82	0.94	1.09	-	0.15	0.16
3	1.37	1.53	1.72	-	0.11	0.13
4	16.93	19.51	22.75	-	0.15	0.17
5	116.91	132.04	149.54	-	0.13	0.13
6	5.66	6.19	6.87	-	0.09	0.11
7	1.22	1.38	1.59	-	0.13	0.15
8	1.90	2.11	2.37	-	0.11	0.13
9	62.40	68.06	75.21	-	0.09	0.10
10	7.45	8.31	9.34	-	0.12	0.12
11	520.90	565.10	614.00	-	0.08	0.09
12	2280.11	2521.79	2791.97	-	0.11	0.11
13	145.95	162.58	181.39	-	0.11	0.12
14	83.14	91.94	101.89	-	0.11	0.11
15	12.45	14.04	15.93	-	0.13	0.13
16	7.10	7.90	8.85	-	0.11	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	315.72	389.47	0.018	0.019	0.019	-	0.00030	0.00062
2	879.70	953.16	1158.98	0.055	0.056	0.057	-	0.00057	0.00104
3	1380.17	1487.87	1794.38	0.087	0.087	0.088	-	0.00045	0.00089
4	1620.28	1732.66	2054.11	0.102	0.102	0.101	-	-0.00030	-0.00070
5	1860.40	1991.05	2369.66	0.117	0.117	0.117	-	-0.00024	-0.00036
6	2100.51	2248.86	2673.69	0.132	0.132	0.132	-	-0.00023	-0.00054
7	2340.62	2462.10	2822.72	0.147	0.145	0.139	-	-0.00283	-0.00573
8	2580.74	2796.51	3411.22	0.163	0.164	0.168	-	0.00169	0.00358
9	2820.85	3035.31	3647.82	0.178	0.178	0.180	-	0.00059	0.00120

E.5 Experiment 2 Run 2

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59356607.12	62368608.68	65401926.92	-	0.051	0.049
Terms of Trade	27.11	27.27	27.43	-	0.006	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	2829.52	3027.66	3307.63	-	0.070	0.092
CPI	49.14	54.88	60.82	-	0.117	0.108
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.67	23.16	25.05	-	-0.098	0.082
2	17.85	16.10	16.93	-	-0.099	0.052
3	23.11	20.92	22.10	-	-0.095	0.056
4	25.89	23.71	25.24	-	-0.084	0.064
5	60.29	60.92	65.51	-	0.010	0.075
6	63.62	57.98	60.13	-	-0.089	0.037
7	20.89	19.11	19.64	-	-0.085	0.028
8	26.97	24.33	24.79	-	-0.098	0.019
9	66.67	65.28	70.47	-	-0.021	0.080
10	75.31	74.22	77.98	-	-0.014	0.051
11	52.80	54.07	56.31	-	0.024	0.041
12	27.57	28.77	30.38	-	0.044	0.056
13	134.17	136.64	143.44	-	0.018	0.050
14	81.90	83.12	88.45	-	0.015	0.064
15	20.63	20.15	21.45	-	-0.023	0.064
16	74.33	71.95	75.97	-	-0.032	0.056
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1160.16	1090.87	1226.53	-	-0.06	0.12
2	593.93	583.89	676.05	-	-0.02	0.16
3	983.93	947.73	1066.95	-	-0.04	0.13

4	11992.51	12091.64	14086.95	-	0.01	0.17
5	31980.95	34217.22	38714.12	-	0.07	0.13
6	4812.51	4649.17	5149.61	-	-0.03	0.11
7	1027.80	1037.93	1191.12	-	0.01	0.15
8	1577.59	1577.91	1775.09	-	0.00	0.12
9	12146.10	12049.63	13300.93	-	-0.01	0.10
10	24750.75	25897.49	29061.48	-	0.05	0.12
11	56628.87	60091.41	65225.23	-	0.06	0.09
12	34378.52	37599.94	41590.88	-	0.09	0.11
13	41007.89	44201.71	49266.65	-	0.08	0.11
14	28060.97	29708.87	32888.83	-	0.06	0.11
15	18844.72	19728.23	22352.73	-	0.05	0.13
16	6632.56	6776.70	7585.60	-	0.02	0.12

	Carbon Emissions			Growth		
	P1	P2	P3	P1	P2	P3
1	1.57	1.48	1.66	-	-0.06	0.12
2	0.81	0.79	0.92	-	-0.02	0.16
3	1.34	1.29	1.45	-	-0.04	0.13
4	16.27	16.41	19.12	-	0.01	0.17
5	102.95	110.15	124.62	-	0.07	0.13
6	5.39	5.20	5.76	-	-0.03	0.11
7	1.15	1.16	1.33	-	0.01	0.15
8	1.77	1.77	1.99	-	0.00	0.12
9	57.46	57.01	62.93	-	-0.01	0.10
10	6.63	6.94	7.79	-	0.05	0.12
11	442.89	469.97	510.13	-	0.06	0.09
12	1915.67	2095.18	2317.57	-	0.09	0.11
13	125.57	135.35	150.85	-	0.08	0.11
14	72.37	76.62	84.82	-	0.06	0.11
15	11.21	11.74	13.30	-	0.05	0.13
16	6.47	6.61	7.40	-	0.02	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	310.29	369.52	0.018	0.018	0.018	-	-0.00002	-0.00004
2	879.70	942.76	1123.95	0.055	0.055	0.055	-	-0.00004	-0.00007
3	1380.17	1479.64	1765.08	0.087	0.087	0.087	-	-0.00003	-0.00006
4	1620.28	1737.17	2072.28	0.102	0.102	0.102	-	-0.00003	-0.00007
5	1860.40	1995.66	2383.15	0.117	0.117	0.117	-	0.00003	0.00004
6	2100.51	2253.15	2690.93	0.132	0.132	0.132	-	0.00002	0.00006
7	2340.62	2461.12	2819.17	0.147	0.145	0.139	-	-0.00289	-0.00585
8	2580.74	2797.10	3413.40	0.163	0.164	0.168	-	0.00172	0.00366
9	2820.85	3046.36	3684.55	0.178	0.179	0.181	-	0.00124	0.00236

E.6 Experiment 3 Run 1

NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59664584.70	63470950.42	67785097.84	-	0.064	0.068
Terms of Trade	27.18	27.32	27.48	-	0.005	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	3265.89	3605.19	3986.48	-	0.104	0.106
CPI	48.30	53.43	58.65	-	0.106	0.098
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.91	27.48	29.76	-	0.061	0.083
2	18.21	19.12	20.14	-	0.050	0.053
3	23.81	24.88	26.30	-	0.045	0.057
4	26.96	28.22	30.08	-	0.047	0.066
5	68.54	73.10	78.69	-	0.067	0.076
6	66.95	69.09	71.72	-	0.032	0.038
7	22.22	22.79	23.45	-	0.026	0.029
8	29.00	29.05	29.63	-	0.002	0.020
9	72.47	78.02	84.31	-	0.077	0.081
10	84.64	88.97	93.58	-	0.051	0.052
11	62.16	65.08	67.84	-	0.047	0.043
12	32.85	34.67	36.64	-	0.055	0.057
13	156.10	164.29	172.64	-	0.052	0.051
14	94.18	99.84	106.35	-	0.060	0.065
15	22.93	24.14	25.71	-	0.053	0.065
16	81.69	86.08	90.98	-	0.054	0.057
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1171.05	1294.57	1457.04	-	0.11	0.13
2	605.68	693.62	803.92	-	0.15	0.16
3	1013.85	1126.98	1270.04	-	0.11	0.13

4	12487.18	14393.24	16785.33	-	0.15	0.17
5	36356.51	41060.45	46503.40	-	0.13	0.13
6	5064.27	5539.73	6142.24	-	0.09	0.11
7	1093.18	1238.00	1422.16	-	0.13	0.15
8	1696.17	1883.97	2121.53	-	0.11	0.13
9	13202.27	14401.35	15912.91	-	0.09	0.10
10	27818.15	31045.60	34873.60	-	0.12	0.12
11	66668.81	72326.75	78584.53	-	0.08	0.09
12	40959.55	45301.09	50154.59	-	0.11	0.11
13	47712.18	53148.40	59297.93	-	0.11	0.12
14	32270.10	35686.29	39545.73	-	0.11	0.11
15	20942.75	23626.18	26796.19	-	0.13	0.13
16	7289.25	8107.48	9084.37	-	0.11	0.12

	Carbon Emissions			Growth		
	P1	P2	P3	P1	P2	P3
1	1.59	1.76	1.98	-	0.11	0.13
2	0.82	0.94	1.09	-	0.15	0.16
3	1.38	1.53	1.72	-	0.11	0.13
4	16.95	19.53	22.78	-	0.15	0.17
5	117.03	132.17	149.69	-	0.13	0.13
6	5.67	6.20	6.87	-	0.09	0.11
7	1.22	1.39	1.59	-	0.13	0.15
8	1.90	2.11	2.37	-	0.11	0.13
9	62.46	68.13	75.28	-	0.09	0.10
10	7.46	8.32	9.35	-	0.12	0.12
11	521.42	565.67	614.61	-	0.08	0.09
12	2282.39	2524.31	2794.76	-	0.11	0.11
13	146.09	162.74	181.57	-	0.11	0.12
14	83.22	92.03	101.99	-	0.11	0.11
15	12.46	14.06	15.94	-	0.13	0.13
16	7.11	7.90	8.86	-	0.11	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	315.28	388.08	0.018	0.019	0.019	-	0.00027	0.00058
2	879.70	952.32	1156.53	0.055	0.056	0.057	-	0.00052	0.00097
3	1380.17	1487.21	1792.34	0.087	0.087	0.088	-	0.00041	0.00083
4	1620.28	1732.07	2051.70	0.102	0.102	0.101	-	-0.00033	-0.00079
5	1860.40	1990.56	2368.21	0.117	0.117	0.117	-	-0.00027	-0.00040
6	2100.51	2248.40	2671.84	0.132	0.132	0.131	-	-0.00025	-0.00060
7	2340.62	2434.54	2723.15	0.147	0.143	0.134	-	-0.00445	-0.00901
8	2580.74	2815.72	3482.77	0.163	0.165	0.171	-	0.00282	0.00597
9	2820.85	3047.17	3687.42	0.178	0.179	0.181	-	0.00129	0.00245

E.7 Experiment 3 Run 2

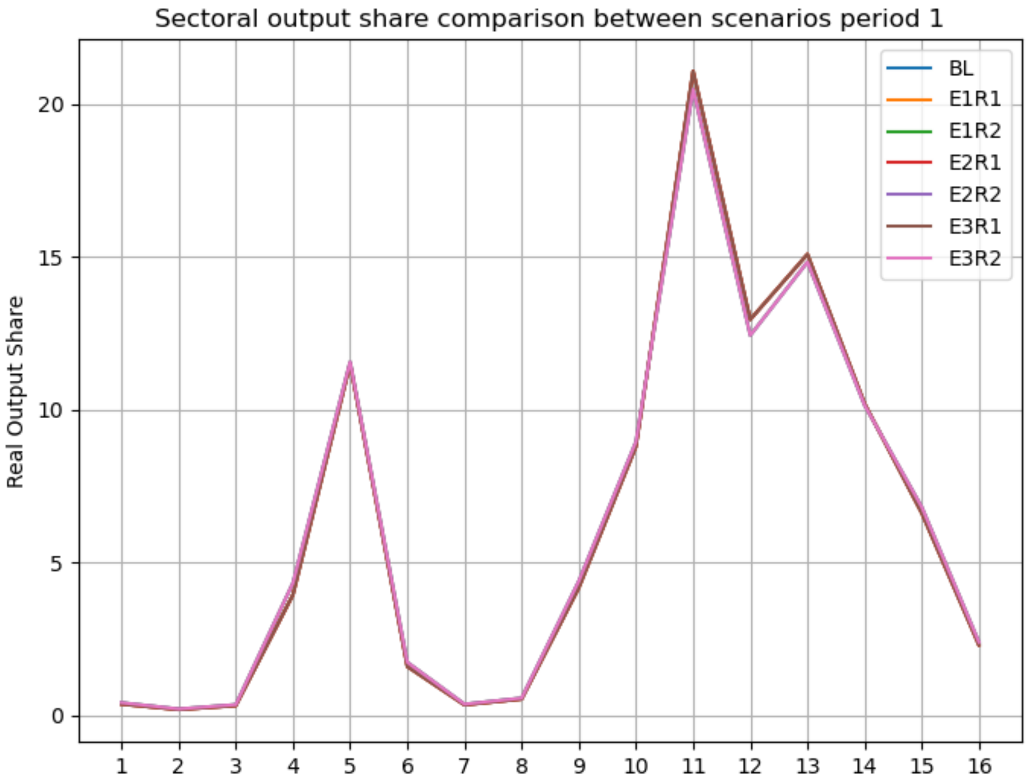
NATIONAL ACCOUNTS						
				GROWTH		
	P1	P2	P3	P1	P2	P3
Real GDP	59376720.64	62488014.24	65827428.00	-	0.052	0.053
Terms of Trade	27.10	27.26	27.42	-	0.006	0.006
S-I Balance	17,085,741.74	17,544,541.32	18,123,776.21	-	0.027	0.033
Carbon emissions	2872.29	3000.65	3214.94	-	0.045	0.071
CPI	49.19	55.46	62.04	-	0.127	0.119
E-M	-2,313,593.71	-2,283,049.65	-2,239,142.71	-	-0.013	-0.019
SECTORAL STATISTICS						
Sector Statistics - Prices				GROWTH		
	P1	P2	P3	P1	P2	P3
1	25.69	23.18	25.07	-	-0.098	0.082
2	17.87	16.11	16.95	-	-0.099	0.052
3	23.13	20.94	22.12	-	-0.095	0.056
4	25.91	23.73	25.27	-	-0.084	0.064
5	60.35	60.98	65.57	-	0.010	0.075
6	63.68	58.04	60.19	-	-0.089	0.037
7	20.91	19.13	19.66	-	-0.085	0.028
8	27.00	24.35	24.82	-	-0.098	0.019
9	66.74	65.34	70.54	-	-0.021	0.080
10	75.38	74.29	78.06	-	-0.014	0.051
11	52.85	54.12	56.37	-	0.024	0.041
12	27.60	28.80	30.41	-	0.044	0.056
13	134.30	136.77	143.58	-	0.018	0.050
14	81.98	83.20	88.54	-	0.015	0.064
15	20.65	20.17	21.47	-	-0.023	0.064
16	74.40	72.02	76.05	-	-0.032	0.056
Sector Statistics - Production				GROWTH		
	P1	P2	P3	P1	P2	P3
1	1161.32	1091.96	1227.76	-	-0.06	0.12
2	594.52	584.47	676.73	-	-0.02	0.16
3	984.91	948.68	1068.02	-	-0.04	0.13

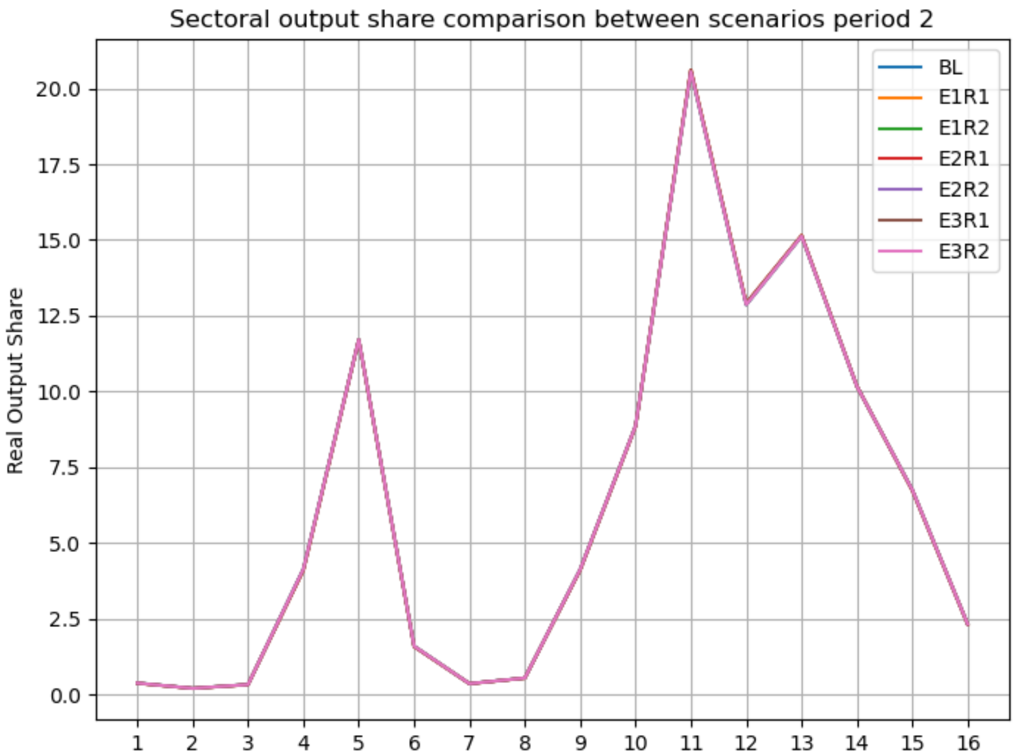
4	12004.50	12103.74	14101.04	-	0.01	0.17
5	32012.93	34251.43	38752.83	-	0.07	0.13
6	4817.32	4653.82	5154.76	-	-0.03	0.11
7	1028.83	1038.97	1192.31	-	0.01	0.15
8	1579.17	1579.49	1776.87	-	0.00	0.12
9	12158.25	12061.68	13314.23	-	-0.01	0.10
10	24775.50	25923.39	29090.54	-	0.05	0.12
11	56685.50	60151.51	65290.45	-	0.06	0.09
12	34412.90	37637.54	41632.47	-	0.09	0.11
13	41048.90	44245.91	49315.91	-	0.08	0.11
14	28089.03	29738.58	32921.72	-	0.06	0.11
15	18863.57	19747.96	22375.09	-	0.05	0.13
16	6639.19	6783.47	7593.18	-	0.02	0.12

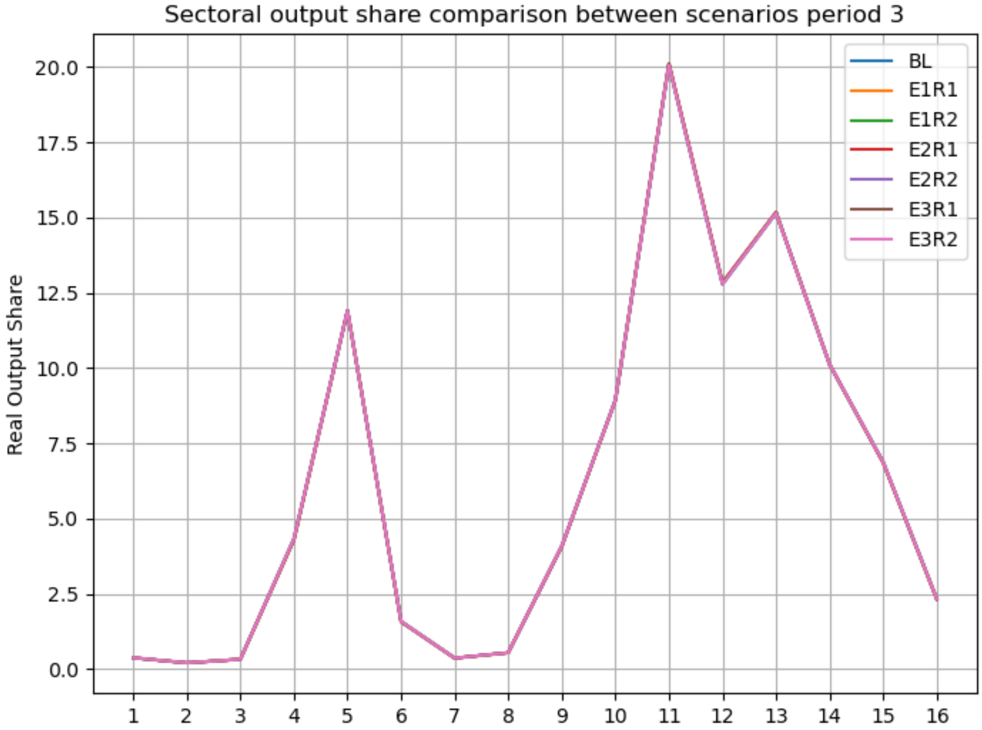
	Carbon Emissions			Growth		
	P1	P2	P3	P1	P2	P3
1	1.58	1.48	1.67	-	-0.06	0.12
2	0.81	0.79	0.92	-	-0.02	0.16
3	1.34	1.29	1.45	-	-0.04	0.13
4	16.29	16.42	19.14	-	0.01	0.17
5	103.05	110.26	124.75	-	0.07	0.13
6	5.39	5.21	5.77	-	-0.03	0.11
7	1.15	1.16	1.33	-	0.01	0.15
8	1.77	1.77	1.99	-	0.00	0.12
9	57.52	57.06	62.99	-	-0.01	0.10
10	6.64	6.95	7.80	-	0.05	0.12
11	443.34	470.44	510.64	-	0.06	0.09
12	1917.59	2097.28	2319.89	-	0.09	0.11
13	125.69	135.48	151.01	-	0.08	0.11
14	72.44	76.70	84.91	-	0.06	0.11
15	11.22	11.75	13.31	-	0.05	0.13
16	6.47	6.61	7.40	-	0.02	0.12

Household Statistics - Real Income				SHARE			CHANGE SHARE		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	289.66	311.14	372.66	0.018	0.018	0.018	-	0.00003	0.00006
2	879.70	944.26	1129.03	0.055	0.055	0.056	-	0.00005	0.00009
3	1380.17	1481.19	1770.64	0.087	0.087	0.087	-	0.00006	0.00012
4	1620.28	1737.22	2073.21	0.102	0.102	0.102	-	-0.00003	-0.00003
5	1860.40	1995.69	2383.22	0.117	0.117	0.117	-	0.00003	0.00004
6	2100.51	2253.17	2691.02	0.132	0.132	0.132	-	0.00003	0.00006
7	2340.62	2433.00	2717.57	0.147	0.143	0.134	-	-0.00454	-0.00920
8	2580.74	2816.69	3486.41	0.163	0.165	0.172	-	0.00287	0.00610
9	2820.85	3050.90	3698.28	0.178	0.179	0.182	-	0.00151	0.00276

E.5 Sectoral output comparison






Sectoral output share comparison between scenarios period 3
Real Output Share
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
BL
E1R1
E1R2
E2R1
E2R2
E3R1
E3R2