# Trade Liberalization and Wealth Inequality

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**Abstract**

Previous studies of the effect of trade liberalization on income inequality have yielded conflicting results. All of these studies have used comparative statics analysis in settings without wealth accumulation. None have incorporated the dynamics of wealth accumulation. This paper examines the dynamic effects of trade liberalization on wealth inequality and welfare. I develop a heterogeneous agent model with an incomplete asset market, small open economy with two production sectors, specific-factor trade model with costly-switching sector-specific labor and perfectly mobile capital across sector and border, and iceberg cost as the trade barrier. Measured by the Gini coefficient of wealth, trade liberalization, defined as the elimination of trade barrier, initially increases wealth inequality before tapering towards a more equitable wealth distribution in the long run. However, there is a long-run increase in between-sector wage inequality. The counterfactual analysis demonstrates a peak increase in wealth inequality of 0.8% at 3 years after the policy implementation, and a 0.6% long-run decrease in the long run. Also, GDP increases by 3.7% in the long run, and households switch to the Non-tradable sector. Moreover, a decrease in trade barrier for imported goods leads to an increase in GDP, households switch to the Non-tradable sector, and wealth inequality also decreases in the long run. I also briefly discuss the welfare and politico-economic aspects of trade policies. Comparing the steady states, trade liberalization leads to an average of 3.5% welfare improvement across all households, as measured by the consumption equivalent variation. However, not all households benefit from the trade liberalization policy and the associated transition.

Keywords: Trade liberalization, wealth inequality, welfare, heterogeneous-agent model, politico-economics
JEL classification numbers: F10, F40, E60

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# 1 Introduction

What is the effect of trade liberalization on wealth inequality in the short and long run? Many of the existing literature do not sufficiently study the dynamics of inequality as a result of trade liberalization. This is due to the comparative statics setting or steady states analysis employed by previous literature. None of the studies have investigated the effects towards households' wealth and saving.

To answer this question, I develop, calibrate and simulate a dynamic general equilibrium macroeconomic model with the following features: (1) a small open economy with exogenous world interest rate and prices of Tradable goods, (2) two sectors of production – Home Tradable (TH) and Non-tradable (N) sectors, (3) three types of consumption and investment goods – Home Tradable, Non-tradable, and Foreign Tradable goods, (4) infinitely-lived heterogeneous households, (5) incomplete asset markets with idiosyncratic and uninsurable unemployment risk, (6) iceberg cost trade barriers incurring on goods traded across borders, (7) perfectly mobile capital across borders and sectors, (8) capital accumulation and a capital market where households' saving or borrowing is aggregated, and (9) sector-specific labor supply in two sectors of production with costly sector switching. These features provide a rich framework to analyze both the short-run and long-run effects of trade liberalization.

Trade liberalization and inequality have been two of the most polarizing subjects in both economic and political discussions. Zhu and Trefler (2005) apply trade and wage data from the World Trade Database to a mixture of comparative advantage and endowment-based trade models. They find rising wage inequality in both Northern and Southern countries. This is due to the shifts in production from the least skill-intensive Northern to the most skill-intensive Southern, decreasing the demand for least-skilled workers in the North and increasing the demand for skilled labor in the South. Helpman, Itskhoki and Redding (2010) construct a heterogeneous firm model with trade and find that wage inequality is higher in trade equilibrium than in autarky. The initially closed economy experiences the increases in wage inequality, due to dispersion of firm revenue, when open to trade. There are two opposing forces – the falling between-group wage inequality and the rising within-group wage inequality, both of which are the result of reallocation of resources. A counterfactual analysis by Helpman et al. (2014) using Brazilian data finds that exporter status, in addition to differences between firms, raises wage inequality by ten percent. They also nearly match the Gini coefficient of wage inequality in Brazil.

Artuç, Chaudhuri, and McLaren (2010) finds that welfare improves after trade liberalization. The authors construct a macroeconomic-style model with utility-maximizing households and the mechanism of costly inter-sectorial labor mobility. To simulate the trade liberalization, specific tariff initially applied to world output price of the sector of interest is removed. They find in the U.S. Current Population Survey data that, although the import-competing sector experiences lower wages after trade liberalization, the welfare gain occurs from the increase in the option value of switching out of the sector in which trade is liberalized.

The original work on the political economy of international trade was done by Grossman and Helpman (1994). In their model of static multi-sector economy, special interest groups lobby the own-welfare maximizing government for trade protection. Ossa (2014) documents the optimal tariff incentivized by the positive terms-of-trade effect due to the increase in relative wages and high-profitability industries, and the trade war by means of retaliation to the tariff.

It is well documented that income equality can be exacerbated by trade, but little is quantitatively known about its effect on wealth inequality. Furthermore, rising wealth inequality has been observed in the U.S. data, as Díaz-Giménez, Glover and Ríos-Rull (2011) note the steady increase of Gini coefficient of household net worth over time. Trade openness and trade liberalization might explain this phenomenon. Though Artuç, Chaudhuri and McLaren (2010) introduce sector-specific capital used in production, their model does not analyze household wealth and saving behavior.

The most recent papers that study trade liberalization and inequality dynamics are Tang (2015) and Bellon (2016), both of which are based on entrepreneurs, firms and labor market dynamics. Through heterogeneous entrepreneurial productivity, Tang (2015) finds that while international trade increases aggregate output and workers' wages, income inequality among entrepreneurs rises. Bellon (2016) illustrates the stylized relationship between wage inequality and trade liberalization. Using an event study analysis, he finds that wage inequality is dynamically related to trade liberalization in non-monotonically fashion. That is, inequality initially rises for 6 years after liberalization. The overshooting then tapers in the next 10 years, but this decline is not enough to offset the initial increase. The stylized data are also rationalized with the dynamic heterogeneous firms and workers screening model with costly labor adjustments.

Trade liberalization and wealth inequality played key roles in the United Kingdom's referendum to withdraw from the European Union. Dhingra et al. (2016) estimate a welfare loss from the post-Brexit trade barriers of around 1.3% – 2.6% of the UK's GDP. Once they take into account for dynamic effects, they find an even larger loss of 6.3 to 9.5 percent, and likely even larger effects due to the lack of the increase in productivity and R&D, and vertical integration associated with the EU trade.

This paper seeks to address the issue of trade liberalization, wealth and inequality dynamics in the macroeconomic settings. The primary research question is: what are the dynamic effects of trade liberalization on wealth inequality and welfare? The key variables in focus of this paper are Gini coefficient of wealth, and households' welfare changes. Unlike prior papers, my model allows for the analysis of a much wider array of aggregate-level macroeconomic variables, such as labor supply, prices, exchange rate, sector wages, GDP, sector production, capital accumulation and allocation, saving, and foreign ownership of assets. Furthermore, this setting also lends the possibility of incorporating the politico-economics and households' preferred policy choices into the international trade analysis.

The model employs features from various literature in harmonizing micro-founded macroeconomics and international trade theory. Examples include specific factors trade model, iceberg trade cost, open-economy macroeconomics, the basic heterogeneous households setup as Huggett (1993), and the intuition of international trade and costly labor mobility by Artuç, Chaudhuri, and McLaren (2010). A brief discussion on politico-economics is due to Corbae, D'Erasmo, and Kuruscu (2009). The solution algorithm is also similar to Krusell and Smith (1998) as prices of outputs and trade barriers also determine the aggregate state variables of wages and capital demand, which are related to one another due to the marginal products.

The key mechanism driving the wealth inequality effect, apart from precautionary saving, is as follows. Lower trade barrier leads to a change in demand and supply of the three types of goods. This causes a change in relative wages and capital allocation in each sector, causing household's income and demand for each good to change. Seeing the change in wages, households switch to the sector in which they earn the highest income. This switch is costly and must be financed by asset holdings; hence, the wealth distribution changes. The sector choices by households also change labor supply; thus, wages, capital allocation, and prices are further changed, creating a feedback mechanism that can cause even more dramatic changes in the distribution of wealth.

The remainder of this paper is structured as follows. Section 2 outlines the model used in the analysis, the dynamic programming problem, and the definition of equilibrium. Section 3 first discusses the solution algorithm and calibration. It then introduces two counterfactual experiments – trade liberalization as the bilateral elimination of trade barriers on both exported and imported goods, and a unilateral decrease in trade barriers for the imported good. Section 4 continues with welfare measurement from the two experiments in the previous section. The welfare effect, the political economy of trade liberalization, and myopic voting are briefly discussed. Finally, Section 5 concludes.

# 2 Model

The point of departure for the model starts as a wealth-heterogeneous agent model due to incomplete asset market with borrowing constraint and uninsurable idiosyncratic employment risk as introduced by Huggett (1993). In this model, time flows discretely and infinitely from $t = 1, \ldots, \infty$. The economy is a small open economy with production. The country in consideration is an atomistic "Home" country and "Foreign" refers to the rest of the world. Capital assets are perfectly mobile across borders and production sectors, taking the exogenous world interest rate as given. The economy is divided into two sectors, producing two types of goods – Home Tradable and Non-tradable goods – using capital and sector-specific labor. Households have sector-specific skills, which are costly to acquire upon switching sectors. Three types of goods are demanded for consumption and investment, with Foreign Tradable good being imported. The exchange rate is defined as the Home price of the Foreign currency. All goods traded across borders are subject to an iceberg cost of trading.

## 2.1 Iceberg Cost of Trading, Prices of Tradable Goods and Exchange Rate

In this analysis, the price of the Foreign Tradable good has the unit of Foreign currency and is set to one as the numeraire, so that

$$p_t^{TF} = 1.$$

Furthermore, due to the assumption of a small open economy, the price of the Home Tradable good has the unit of Home currency and is also set to one, so that

$$p_t^{TH} = 1.$$

To convert the price of the Foreign Tradable good and the value of any transaction with Foreign countries to the units of the Home currency, the exchange rate $E_t$ is defined as the Home currency price for Foreign currencies. A higher value of $E_t$ implies a depreciation of the Home currency.

Goods which have been imported or exported are subject to iceberg-type cost of trading in the spirit of Samuelson (1954). In particular, $1 - \tau_t^{TH} \in [0, 1]$ fraction of the Home Tradable goods exported actually arrive in the Foreign countries, and $1 - \tau_t^{TF} \in [0, 1]$ fraction of the Foreign Tradable goods imported arrive in the Home country. The trade barrier is said to be prohibitive when $\tau_t^{TH} = 1$ and $\tau_t^{TF} = 1$. Likewise, there is no trade barrier when $\tau_t^{TH} = 0$ and $\tau_t^{TF} = 0$.

This iceberg cost is absorbed by the end users of the good. That is, when a Foreign Tradable good is imported into the Home country at the Home currency price of $E_t p_t^{TF}$, the price the consumer pays for the Foreign Tradable good in period $t$ is $E_t p_t^{TF} / \left(1 - \tau_t^{TF}\right)$. Similarly, when a Home Tradable good priced at $p_t^{TH}$ is exported, only $1 - \tau_t^{TH}$ of the exported goods are not destroyed; thus, the net price of the exported Home Tradable good is $p_t^{TH} \left(1 - \tau_t^{TH}\right)$.

## 2.2 Households

### 2.2.1 Intertemporal Problem

There is unit mass of infinitely-lived households that differ by their asset holdings, and employment status. Households are also differentiated by their sector of employment denoted by type $i_t \in \{TH, N\}$ in period $t$. Each household is subject to the identical and exogenous borrowing constraint for asset holdings $a_{t+1}$ such that

$$a_{t+1} \quad \geq \quad \underline{a}.$$

Each household chooses the plan of consumption $\{c_t\}_{t=1}^{\infty}$, asset holdings $\{a_{t+1}\}_{t=1}^{\infty}$, and employment sectors $\{i_{t+1}\}_{t=1}^{\infty}$ to maximize the expected discounted sum of lifetime utility given by

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u\left(c_t\right)\right]$$

Households have constant relative risk aversion utility given by

$$u\left(c\right) \quad = \quad \frac{c^{1-\sigma} - 1}{1 - \sigma}$$

where $\sigma$ measures the degree of risk aversion.

In each period, each receives a shock representing their employment state $\varepsilon_t \in \{1, u\}$, where $0 < u < 1$, which follows a Markov process with transition function $\Pr(\varepsilon_{t+1} \mid \varepsilon_t)$. Each household earns $\varepsilon_t$ fraction of wage income in its respective sector $i_t$. When $\varepsilon_t = 1$, such household is said to be employed and inelastically supplies labor to earn the full sector $i$ wage $w_t^i$. Otherwise, a household is said to be unemployed and earns $uw_t^i$ unemployment benefits. Each household pays or earns real interest on the carried-over assets $a_t$ borrowed or saved from period $t-1$ at the world real interest rate $r^w$. In period $t$, a household is said to be borrowing if it chooses $a_{t+1} < 0$ and saving when $a_{t+1} > 0$. Due to the idiosyncratic unemployment risk and market incompleteness, saving is essential as self-insurance. In the event of household switching from sector $i$ to sector $i'$ in the next period, such a household must pay a switching cost $\chi_t^{i,i'}$. The intertemporal budget constraint of each household is therefore

$$c_t + a_{t+1} + \mathbb{I}\{i_{t+1} \neq i_t\}\chi_t^{i,i'} = (1 + r^w) a_t + w_t^i \varepsilon_t.$$

Finally, the distribution of households over assets, employment states, and sectors at time $t$ is $\Gamma_t(a_t, \varepsilon_t, i_t)$.

### 2.2.2 Intratemporal Problem

Given the optimal consumption bundle $c_t$ in period $t$, each household minimizes its expenditure in each period by choosing the optimal combination of Home Tradable ($TH$), Foreign Tradable ($TF$), and Non-tradable ($N$) goods to consume. The consumption bundle $c_t$ is a Cobb-Douglas composite basket with $1 - \nu \in (0, 1)$ share of Non-tradable goods and $\nu$ share of Tradable goods. The share of Tradable goods consists of $\psi \in (0, 1)$ share of Home Tradable goods and $1 - \psi$ share of Foreign Tradable goods. The prices for the Home Tradable, Foreign Tradable, and Non-tradable goods purchased by households are $p_t^{TH}$, $E_t p_t^{TF} / (1 - \tau_t^{TF})$, and $p_t^N$, respectively. The intratemporal problem in period $t$ is an expenditure minimization problem of

$$\min_{\{c_t^{TH}, c_t^{TF}, c_t^N\}} \quad p_t^{TH} c_t^{TH} + \left[E_t p_t^{TF} / \left(1 - \tau_t^{TF}\right)\right] c_t^{TF} + p_t^N c_t^N$$

subject to

$$c_t = \left[\left(c_t^{TH}\right)^{\psi}\left(c_t^{TF}\right)^{1-\psi}\right]^{\nu}\left(c_t^N\right)^{1-\nu}$$

The Cobb-Douglas price index $P_t$ is defined as

$$P_t = \left(\frac{p_t^{TH}}{\nu\psi}\right)^{\nu\psi}\left[\frac{E_t p_t^{TF} / \left(1 - \tau_t^{TF}\right)}{\nu(1-\psi)}\right]^{\nu(1-\psi)}\left(\frac{p_t^N}{1-\nu}\right)^{1-\nu}.$$

Each household's intratemporal demand functions for each type of good are the standard Cobb-Douglas demand functions given by

$$p_t^{TH} c_t^{TH} = \nu\psi P_t c_t \quad , \quad \left[E_t p_t^{TF} / \left(1 - \tau_t^{TF}\right)\right] c_t^{TF} = \nu(1-\psi) P_t c_t \quad , \text{ and } \quad p_t^N c_t^N = (1-\nu) P_t c_t.$$

The economy-wide aggregate consumption is defined as

$$C_t \quad = \quad \int c_t \mathrm{d}\Gamma_t \left(a_t, \varepsilon_t, i_t\right).$$

Given the distribution of households $\Gamma_t$ and the independence of prices in the aggregation, the aggregate demand functions for each type of good are

$$p_t^{TH} C_t^{TH} = \nu\psi P_t C_t \qquad , \qquad \left[E_t p_t^{TF} / \left(1 - \tau_t^{TF}\right)\right] C_t^{TF} = \nu\left(1-\psi\right) P_t C_t \qquad , \text{ and } \qquad p_t^N C_t^N = \left(1-\nu\right) P_t C_t.$$

## 2.3 Firms

There are two sectors which produce two different types of goods in the Home economy – Home Tradable goods and Non-tradable goods – denoted by $i \in \{TH, N\}$, respectively. The Home economy cannot produce Foreign Tradable goods. In period $t$, each representative firm employs labor with sector $i$ specific skill and rents homogeneous capital, denoted by $L_t^i$ and $K_t^i$, respectively. Each sector uses a Cobb-Douglas constant returns to scale production function, where $\alpha \in (0,1)$ is the capital share and $A^i$ is sector total factor productivity. The output of sector $i$ is therefore

$$Y_t^i \quad = \quad A^i \left(K_t^i\right)^{\alpha} \left(L_t^i\right)^{1-\alpha}.$$

The cost of depreciation is borne entirely by firms. Given the world interest rate $r^w$, the rental rate on capital is $r^w + \delta$. The wage rate for the employed labor in sector $i$ is $w_t^i$. Each unit of good $i$ is sold at the price $p_t^i$. Each firm maximizes its nominal profit function

$$\Pi_t^i \quad = \quad p_t^i A^i \left(K_t^i\right)^{\alpha} \left(L_t^i\right)^{1-\alpha} - P_t\left[\left(r^w + \delta\right) K_t^i + w_t^i L_t^i\right].$$

It can be easily shown that the capital demand and wage rate of sector $i \in \{TH, N\}$ are

$$K_t^i \quad = \quad \left(\frac{p_t^i}{P_t}\right)^{\frac{1}{1-\alpha}} \left(\frac{\alpha A^i}{r^w + \delta}\right)^{\frac{1}{1-\alpha}} L_t^i$$

and

$$w_t^i \quad = \quad \left(\frac{p_t^i}{P_t}\right)^{\frac{1}{1-\alpha}} \left(1-\alpha\right) A^i \left(\frac{\alpha A^i}{r^w + \delta}\right)^{\frac{\alpha}{1-\alpha}}.$$

Due to constant returns to scale, firms' profits are zero; thus, households' dividends received from the ownership of firms are zero in every period.

## 2.4 Labor Market and Switching Cost

A household who receives the employment shock $\varepsilon_t = 1$ is employed and inelastically supplies labor in the sector it currently belongs. Thus, the total labor supply for sector $i \in \{TH, N\}$ consists of all households with skill in sector $i$ and employment status $\varepsilon_t = 1$ in period $t$ and can be written as

$$L_t^i = \int \mathbb{I}\left\{i_t = i, \varepsilon_t = 1\right\} \mathrm{d}\Gamma_t\left(a_t, i_t, \varepsilon_t\right).$$

The employment status shock evolves according to the Markov transition matrix

$$\Pi = \begin{pmatrix} \Pr\left(\varepsilon_{t+1} = 1 \mid \varepsilon_t = 1\right) & \Pr\left(\varepsilon_{t+1} = u \mid \varepsilon_t = 1\right) \\ \Pr\left(\varepsilon_{t+1} = 1 \mid \varepsilon_t = u\right) & \Pr\left(\varepsilon_{t+1} = u \mid \varepsilon_t = u\right) \end{pmatrix}.$$

The mass of Home households is constant at one, which rules out immigration and population growth. As a result, the Markov transition matrix yields a stationary unemployment rate equal to $\overline{u}$. Furthermore, due to the unit mass population, the unemployment rate in period $t$ is

$$u_t = 1 - L_t^T - L_t^N.$$

A household which currently belongs to sector $i$ in period $t$ and wishes to migrate to sector $i' \neq i$ in period $t+1$ must pay the switching cost $\chi \geq 0$ proportion of the current wage rate in sector $i'$

$$\chi_t^{i,i'} = \chi w_t^{i'}.$$

This switching cost can be associated with the cost of retraining to acquire new skills required in sector $i'$. Furthermore, it mandatorily faces $\varepsilon_{t+1} = u$. That is, such household must become unemployed and earn the transfer income equals to $uw_{t+1}^{i'}$ in period $t+1$. This is in line with the required period of job matching after retraining. Hence, there are two sources of switching cost for the household who wishes to migrate from sector $i$ to $i'$ in the next period – (1) the explicit switching cost, and (2) the implicit cost of the mandatory period of unemployment.

## 2.5 Capital Market, Capital Accumulation and Investment

Current asset holdings $a_t$ are aggregated over the distribution of households into the domestic supply of capital stock. That is,

$$K_t^{domestic} = \int a_t \mathrm{d}\Gamma_t \left(a_t, i_t, \varepsilon_t\right).$$

In each period, the total capital demanded in each sectors, $K_t^{TH}$ and $K_t^N$, is determined by firms' profit maximization problem. The capital demand is satisfied by capital supplied domestically and, if insufficiently supplied, by assets borrowed from abroad $K_t^{foreign}$. Both capital demand and supply are measured in the real unit of composite capital goods. Thus, capital market clearing requires that

$$K_t^{TH} + K_t^N = K_t^{domestic} + K_t^{foreign}.$$

That is, if $K_t^{TH} + K_t^N > K_t^{domestic}$, then $K_t^{foreign} > 0$ – there is Foreign portfolio investment in the Home country. Otherwise, the Home country lends to Foreign countries and owns assets abroad when $K_t^{foreign} < 0$.

At the beginning of period $t$, the Home economy is initially endowed with the domestic supply of capital stock $K_t^{domestic}$ and net foreign capital stock $K_{t-1}^{foreign}$. Each firm demands capital $K_t^i$, $i \in \{TH, N\}$ according to its profit maximization problem. Suppose $K_t^{TH} + K_t^N > K_t^{domestic} + K_{t-1}^{foreign}$, that is, Home firms demand more capital than it could be supplied, then Home economy borrows $K_t^{foreign} - K_{t-1}^{foreign}$ from abroad. The total capital stock available in the Home economy is $K_t^{domestic} + K_t^{foreign}$, which is distributed to each sector $i \in \{TH, N\}$ for the production of goods, $Y_t^{TH}$ and $Y_t^N$. After production, depreciated capital is equal to $\delta\left(K_t^{TH} + K_t^N\right) = \delta\left(K_t^{domestic} + K_t^{foreign}\right)$, which is replaced by investment. After adjusting for depreciation, Foreign-owned assets $K_t^{foreign}$ are carried forward to period $t+1$. Domestic assets, $K_t^{domestic}$, are also returned to households, which may choose to consume, $c_t$, or save, $a_{t+1}$. Savings $a_{t+1}$ by Home households at the end of period $t$ are aggregated into the domestic supply of capital stock, $K_{t+1}^{domestic}$. This timeline for capital formation and usage across time periods can be summarized graphically in Figure 2.1.

Changes in the level of capital stock in the Home country can arise from three sources. First, the domestic aggregation of households' optimal asset holdings, $a_{t+1}$, as determined by households' intertemporal problem,yields the domestic supply of capital stock $K_{t+1}^{domestic} = \int a_{t+1} \mathrm{d}\Gamma_t \left(a_t, \varepsilon_t, i_t\right)$ in period $t+1$, less current domestic supply of capital stock, $K_t^{domestic}$. Second, the foreign ownership of Home asset $K_t^{foreign}$ in period $t$, less Foreign-owned asset $K_{t-1}^{foreign}$ carried over from period $t-1$. Third, the depreciated domestic

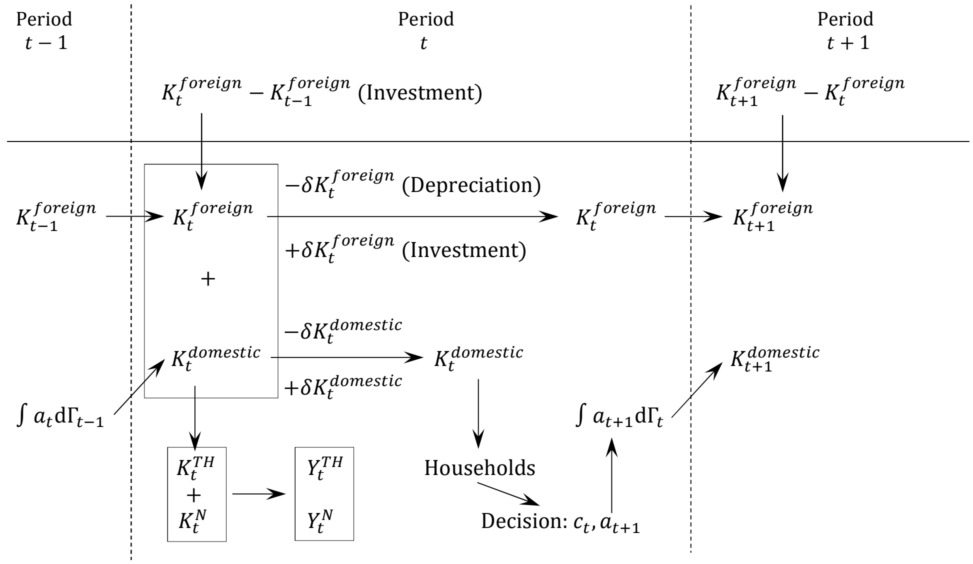


Figure 2.1: Timeline of Capital Formation and Accumulation in Home Country

and foreign capital stock, $\delta\left(K_t^{domestic} + K_t^{foreign}\right) = \delta\left(K_t^{TH} + K_t^{N}\right)$, used in the production are replaced in period $t$. Capital investment $X_t$ in the Home country at time $t$ is

$$X_t = \left[K_{t+1}^{domestic} - (1-\delta)\, K_t^{domestic}\right] + \left[(1+\delta)\, E_t K_t^{foreign} - E_t K_{t-1}^{foreign}\right].$$

Note that the domestic capital stock is valued at the domestic price index $P_t$, while the Foreign-owned asset is valued at the price and exchange rate of $E_t P_t$, taking into account both domestic price level and exchange rate. From the investment determined by the capital accumulation equation, three types of goods – Home Tradable, Foreign Tradable, and Non-tradable – are required to manufacture the capital good. Assuming that capital good is manufactured using Cobb-Douglas technology with the same composition of three types of goods as in the consumers' intratemporal problem in Section 2.2.2, the expenditure minimization problem is

$$\min_{\left\{X_t^{TH}, X_t^{TF}, X_t^{N}\right\}} \quad p_t^{TH} X_t^{TH} + \left[E_t p_t^{TF} / \left(1-\tau_t^{TF}\right)\right] X_t^{TF} + p_t^{N} X_t^{N}$$

subject to

$$X_t = \left[\left(X_t^{TH}\right)^{\psi} \left(X_t^{TF}\right)^{1-\psi}\right]^{\nu} \left(X_t^{N}\right)^{1-\nu}.$$

Thus, the input demand functions for the production of the capital good are

$$p_t^{TH} X_t^{TH} = \nu\psi P_t X_t \quad , \quad \left[E_t p_t^{TF} / \left(1-\tau_t^{TF}\right)\right] X_t^{TF} = \nu\,(1-\psi)\, P_t X_t \quad \text{, and} \quad p_t^{N} X_t^{N} = (1-\nu)\, P_t X_t.$$

This specification of investment and capital good manufacturing is taken from Bajona and Kehoe (2010).

### 2.6 Balance of Payments

The Home country exports the residual supply of the Home Tradable good, which is the output of Home Tradable good, less the demand by Home consumers and capital good production. The quantity of exported goods is $Y_t^{TH} - C_t^{TH} - X_t^{TH}$. I assume that the exports of the Home Tradable good to Foreign countries are settled in the Home currency. Furthermore, due to the iceberg costs, only $1 - \tau_t^{TH}$ proportion of total exports arrive in the Foreign country. Thus, the exported good is valued at the relative price $p_t^{TH}\left(1 - \tau_t^{TH}\right)/P_t$.

Since the Home country cannot produce Foreign Tradable good, it must be wholly imported as demanded by consumers and capital good production. Because the price of the Foreign Tradable good is denominated in Foreign currency, the imported good is valued at the relative price of $E_t p_t^{TF}/P_t$. While the price the consumer pays is $E_t p_t^{TF}/\left(1 - \tau_t^{TF}\right)$, the demand function for imports is $C_t^{TF} + X_t^{TF}$.

The real net exports in period $t$ are given by

$$NX_t = \left(1 - \tau_t^{TH}\right)\frac{p_t^{TH}}{P_t}\left(Y_t^{TH} - C_t^{TH} - X_t^{TH}\right) - \frac{E_t p_t^{TF}}{P_t}\left(C_t^{TF} + X_t^{TF}\right).$$

Given the constant world interest rate $r^w$, the exchange rate $E_t$, and the definition of Foreign-owned Home assets $K_t^{foreign}$ in Section 2.5, the net return on investment from abroad is $-r^w E_t K_t^{foreign}$. That is, if assets borrowed from abroad are $K_t^{foreign} > 0$, then the net return from investment abroad is negative, and vice versa. Thus, combining net exports and the net return on investment abroad, the current account in period $t$ is defined by

$$CA_t = NX_t - r^w E_t K_t^{foreign}.$$

With the definition of the Foreign-owned Home asset, the capital and financial account is defined as the net change in foreign ownership of the Home country assets. The nominal value of Foreign-owned Home assets in period $t$ is $P_t E_t K_t^{foreign}$. The nominal value of the stock of Foreign-owned Home assets in period $t-1$ is $P_t E_t K_{t-1}^{foreign}$, adjusted by the current price level and exchange rate. The real capital and financial account in period $t$ is given by

$$KFA_t = E_t K_t^{foreign} - E_t K_{t-1}^{foreign}.$$

In the steady state, $KFA = 0$ since $K_t^{foreign} = K_{t-1}^{foreign}$ as prices and the exchange rate remain constant and there is no change in the net foreign ownership of the Home assets. Thus, $CA = 0$ in the steady state as well. With both current account and capital and financial account defined, the balance of payments requires that

$$CA_t + KFA_t = 0.$$

## 2.7 Market Clearing Conditions

Since the Non-tradable good must be produced and consumed within the Home country, the market for the Non-tradable good must be cleared domestically. The market clearing condition for the Non-tradable good is

$$Y_t^N = C_t^N + X_t^N.$$

The balance of payments encapsulates the relative prices, Foreign-owned Home assets, and Home demand for Home Tradable good. As described above, the balance of payments must be zero so that

$$CA_t + KFA_t = 0.$$

The equilibrium in the labor market is determined by the labor demand of each sector $i \in \{TH, N\}$ and the employed households' inelastic labor supply. The labor market clearing condition is

$$L_t^{TH} + L_t^N = \int \mathbb{I}\{\varepsilon_t = 1\} \, \mathrm{d}\Gamma_t(a_t, \varepsilon_t, i_t).$$

The equilibrium in the capital market is determined by the capital demand of each sector and the available capital stock from Home households' aggregate asset holdings and Foreign-owned assets. Therefore, the capital market clearing condition is

$$K_t^{TH} + K_t^N = \int a_t \mathrm{d}\Gamma_t(a_t, \varepsilon_t, i_t) + K_t^{foreign}.$$

## 2.8 National Income Accounting and the Aggregate Resource Constraint

For the purpose of national income accounting, real GDP can be defined using the output produced by each sector, labor switching cost, and transfer income as

$$Y_t = \left(\frac{p_t^{TH}}{P_t}\right) Y_t^{TH} + \left(\frac{p_t^{N}}{P_t}\right) Y_t^{N} + \int \mathbb{I}\left\{i_{t+1} \neq i_t\right\} \chi_t^{i,i'} \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right) + \int \mathbb{I}\left\{\varepsilon_t = u\right\} w_t^i \varepsilon_t \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right).$$

Equivalently, real GDP can also be calculated using the income approach from wage income, transfer income, gross return on capital, and labor switching cost as

$$Y_t = \int w_t^i \varepsilon_t \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right) + \left(r^w + \delta\right)\left[\int a_t \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right) + K_t^{foreign}\right] + \int \mathbb{I}\left\{i_{t+1} \neq i_t\right\} \chi_t^{i,i'} \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right).$$

Furthermore, real GDP can also be calculated using the expenditure approach from consumption, investment, net exports, transfer income, and labor switching cost as

$$Y_t = C_t + X_t + NX_t + \int \mathbb{I}\left\{\varepsilon_t = u\right\} w_t^i \varepsilon_t \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right) + \int \mathbb{I}\left\{i_{t+1} \neq i_t\right\} \chi_t^{i,i'} \mathrm{d}\Gamma_t\left(a_t, \varepsilon_t, i_t\right).$$

Thus, the calculation of real GDP in all three approaches yields the exactly the same results.

## 2.9 Recursive Formulation

In this subsection, the model as defined in Section 2.1-2.7 is translated into a recursive formulation.

### 2.9.1 Individual Decisions

The value function for households in the Home Tradable goods sector is given by

$$V^{i=TH}\left(a, \varepsilon; \Gamma, p\right) = \max_{i' \in \{TH, N\}} \left\{V^{i=TH, i'=TH}\left(a, \varepsilon; \Gamma, p\right), V^{i=TH, i'=N}\left(a, \varepsilon; \Gamma, p\right)\right\}$$

where

$$\begin{aligned} V^{i=TH, i'=TH}\left(a, \varepsilon; \Gamma, p\right) &= \max_{c, a'} \left\{u\left(c\right) + \beta \mathbb{E}\left[V^{i'=TH}\left(a', \varepsilon'; \Gamma', p'\right) \mid \varepsilon\right]\right\} \\ \text{subject to} \quad & c + a' = \left(1 + r^w\right) a + w^{TH} \varepsilon \end{aligned}$$

and

$$\begin{aligned} V^{i=TH,i'=N}\left(a,\varepsilon;\Gamma,p\right) &= \max_{c,a'}\left\{u\left(c\right)+\beta V^{i'=N}\left(a',\varepsilon'=u;\Gamma',p'\right)\right\} \\ \text{subject to} &\quad c+a'+\chi^{TH,N}=\left(1+r^{w}\right)a+w^{TH}\varepsilon \\ &\quad \chi^{TH,N}=\chi w^{N}. \end{aligned}$$

The value function for households in the Non-tradable goods sector is given by

$$V^{i=N}\left(a,\varepsilon;\Gamma,p\right)=\max_{i'\in\{TH,N\}}\left\{V^{i=N,i'=N}\left(a,\varepsilon;\Gamma,p\right),V^{i=N,i'=TH}\left(a,\varepsilon;\Gamma,p\right)\right\}$$

where

$$\begin{aligned} V^{i=N,i'=N}\left(a,\varepsilon;\Gamma,p\right) &= \max_{c,a'}\left\{u\left(c\right)+\beta\mathbb{E}\left[V^{i'=N}\left(a',\varepsilon';\Gamma',p'\right)\mid\varepsilon\right]\right\} \\ \text{subject to} &\quad c+a'=\left(1+r^{w}\right)a+w^{N}\varepsilon \end{aligned}$$

and

$$\begin{aligned} V^{i=N,i'=TH}\left(a,\varepsilon;\Gamma,p\right) &= \max_{c,a'}\left\{u\left(c\right)+\beta V^{i'=TH}\left(a',\varepsilon'=u;\Gamma',p'\right)\right\} \\ \text{subject to} &\quad c+a'+\chi^{N,TH}=\left(1+r^{w}\right)a+w^{N}\varepsilon \\ &\quad \chi^{N,TH}=\chi w^{TH}. \end{aligned}$$

The households' expectation of employment opportunities is governed by the Markov transition matrix

$$\Pi = \begin{pmatrix} \Pr\left(\varepsilon'=1\mid\varepsilon=1\right) & \Pr\left(\varepsilon'=u\mid\varepsilon=1\right) \\ \Pr\left(\varepsilon'=1\mid\varepsilon=u\right) & \Pr\left(\varepsilon'=u\mid\varepsilon=u\right) \end{pmatrix}.$$

The solution to the households' problem gives policy functions for consumption, asset holdings, and sector choices which are

$$c=c\left(a,\varepsilon,i;\Gamma,p\right)\quad,\quad a'=g\left(a,\varepsilon,i;\Gamma,p\right)\quad,\text{ and}\quad i'=\iota\left(a,\varepsilon,i;\Gamma,p\right),\text{ respectively.}$$

### 2.9.2 Aggregate Variables

The economy-wide aggregate consumption, asset holding, and domestic supply capital stock are

$$\begin{aligned}
C &= \int c\left(a,\varepsilon,i;\Gamma,p\right)\mathrm{d}\Gamma\left(a,\varepsilon,i\right)\\
\left(K^{domestic}\right)' &= \int g\left(a,\varepsilon,i;\Gamma,p\right)\mathrm{d}\Gamma\left(a,\varepsilon,i\right)\\
K^{domestic} &= \int a\mathrm{d}\Gamma\left(a,\varepsilon,i\right).
\end{aligned}$$

The households' demand for each of the three types of goods is given by

$$p^{TH}C^{TH}=\nu\psi PC \quad , \quad \left[Ep^{TF}/\left(1-\tau^{TF}\right)\right]C^{TF}=\nu\left(1-\psi\right)PC \quad \text{, and} \quad p^{N}C^{N}=\left(1-\nu\right)PC.$$

The price index is

$$P = \left(\frac{p^{TH}}{\nu\psi}\right)^{\nu\psi}\left[\frac{Ep^{TF}/\left(1-\tau^{TF}\right)}{\nu\left(1-\psi\right)}\right]^{\nu(1-\psi)}\left(\frac{p^{N}}{1-\nu}\right)^{1-\nu}.$$

The price of Foreign Tradable goods is taken as the numeraire, and the price of the Home Tradable good is assumed to be constant due to the assumption of a small open economy.

$$\begin{aligned}
p^{TF} &= 1\\
p^{TH} &= 1
\end{aligned}$$

Labor supply in each sector and total labor supply are

$$\begin{aligned}
L^{TH} &= \int \mathbb{I}\left\{i=TH,\varepsilon=1\right\}\mathrm{d}\Gamma\left(a,\varepsilon,i\right)\\
L^{N} &= \int \mathbb{I}\left\{i=N,\varepsilon=1\right\}\mathrm{d}\Gamma\left(a,\varepsilon,i\right)\\
L^{TH}+L^{N} &= \int \mathbb{I}\left\{\varepsilon=1\right\}\mathrm{d}\Gamma\left(a,\varepsilon,i\right).
\end{aligned}$$

Wage rates and capital demand for sector $i\in\{TH,N\}$ are

$$\begin{aligned}
w^{i} &= \left(\frac{p^{i}}{P}\right)^{\frac{1}{1-\alpha}}\left(1-\alpha\right)A^{i}\left(\frac{\alpha A^{i}}{r^{w}+\delta}\right)^{\frac{\alpha}{1-\alpha}}\\
K^{i} &= \left(\frac{p^{i}}{P}\right)^{\frac{1}{1-\alpha}}\left(\frac{\alpha A^{i}}{r^{w}+\delta}\right)^{\frac{1}{1-\alpha}}L^{i}.
\end{aligned}$$

Output in sector $i \in \{TH, N\}$ is given by

$$Y^i = A^i \left(K^i\right)^{\alpha} \left(L^i\right)^{1-\alpha}.$$

The market clearing condition for Non-tradable good is

$$Y^N = C^N + X^N.$$

The capital market clearing condition is

$$K^{TH} + K^{TN} = \int a \mathrm{d}\Gamma\left(a, \varepsilon, i\right) + K^{foreign}.$$

The capital accumulation equation is

$$X = \left[\left(K^{domestic}\right)' - (1-\delta) K^{domestic}\right] + (1+\delta) EK^{foreign} - EK^{foreign}_{-1}.$$

The input demand functions for the production of the capital good are

$$p^{TH}X^{TH} = \nu\psi PX \quad , \quad \left[Ep^{TF}/\left(1-\tau^{TF}\right)\right] X^{TF} = \nu\left(1-\psi\right) PX \quad \text{, and} \quad p^N X^N = (1-\nu) PX.$$

Net exports, the current account, the capital and financial account, and the balance of payments are given by

$$\begin{aligned}
NX &= \left(1-\tau^{TH}\right)\left[\frac{p^{TH}}{P}\left(Y^{TH} - C^{TH} - X^{TH}\right)\right] - \left[\frac{Ep^{TF}}{P}\left(C^{TF} + X^{TF}\right)\right] \\
CA &= NX - r^w EK^{foreign} \\
KFA &= EK^{foreign} - EK^{foreign}_{-1} \\
CA + KFA &= 0.
\end{aligned}$$

## 2.10 Equilibrium Definition

A stationary competitive equilibrium given the world interest rate and trade barriers $\{r^w, \tau^{TH}, \tau^{TF}\}$ is the list of value functions $\{V^{i=T}, V^{i=N}\}$, policy functions $\{c, a', i'\}$, labor supply and labor demand $\{L^{TH}, L^N\}$, outputs and GDP $\{Y^{TH}, Y^N, Y\}$, wages $\{w^{TH}, w^N\}$, prices and exchange rate $\{p^{TH}, p^{TF}, p^N, E\}$, capital allocation and capital ownership $\left\{K^{TH}, K^{N}, K^{domestic}, K^{foreign}\right\}$, net exports and balance of payments $\{NX, CA, KFA\}$, and stationary distribution $\Gamma\left(a, \varepsilon, i\right)$ such that

1. Given $\left\{r^{w}, \tau^{TH}, \tau^{N}\right\}$,$\left\{p^{N}, p^{TH}, p^{TF}, E\right\}$, $\left\{w^{TH}, w^{N}\right\}$ and $\Gamma\left(a, \varepsilon, i\right)$, the value functions and policy functions solve the households' problems in sector $i = TH, N$.

2. Given $\left\{\tau^{TH}, \tau^{N}\right\}$ and with $p^{TF} = 1$ as numeraire and $p^{TH} = 1$ due to the small open economy assumption, the price of Non-tradable good and the exchange rate $\left\{p^{N}, E\right\}$ clear the markets for the Non-tradable and Home Tradable goods and determines the balance of payments.

3. Wages clear the competitive labor market. The mapping for the stationary distribution and sector choice determine the amount of labor supply in each sector in the following time period.

4. Capital is aggregated from households' current asset holdings and Foreign-owned Home assets, and allocated between sectors according to the world interest rate.

5. The resource constraint is satisfied, and the balance of payments is zero.

6. The mapping for the stationary distribution is the fixed point of

$$\begin{aligned}
\Gamma'\left(a', \varepsilon', i'\right) \quad &= \quad \int \mathbb{I}\left\{a', \varepsilon', i' = i\right\} \Pr\left(\varepsilon' \mid \varepsilon\right) \mathrm{d}\Gamma\left(a, \varepsilon, i\right) \\
&\quad\; + \int \mathbb{I}\left\{a', \varepsilon' = u, i' \neq i\right\} \mathrm{d}\Gamma\left(a, \varepsilon, i\right).
\end{aligned}$$

# 3 Counterfactual Analysis

This section presents the solution algorithm and calibration. Then, I perform counterfactual analyses: first, a bilateral trade liberalization – as defined by the elimination of trade barriers in both directions, and second, a unilateral decrease in trade barriers for imported Foreign Tradable goods.

## 3.1 Algorithm and Calibration

In period $t = 1$, assume that the economy is initially in its stationary steady state with the existing trade barriers for both exported Home Tradable and imported Foreign Tradable goods of $\tau^{TH} = 0.05$ and $\tau^{TF} = 0.05$, respectively. That is, the transportation cost of goods across borders is 5% in both directions. The associated value functions, policy functions, and stationary distribution are obtained using value function iteration. This calibration will be referred to hereafter as the benchmark model.

In period $t = 2$, the economy faces a surprise announcement of an alternative trade policy. In scenario (1), $\hat{\tau}^{TH} = \hat{\tau}^{TF} = 0$. In scenario (2),$\hat{\tau}^{TF} = 0.025$. The algorithm to solve for the transition path and the new steady state is as follows.

1. Since households complete their sector switching after the current period and must enter into a mandatory period of unemployment phase after the switch, the current labor supply in each sector is predetermined according to the law of motion for the stationary distribution and the sector choice decisions from the previous period.

2. With the labor supply determined, solve for the value functions, policy functions for asset holdings and sector choice, and prices that clear the labor, capital and goods markets, and satisfy the balance of payments equation in each period.

3. Given the sector choice decision and the law of motion for the stationary distribution, obtain the labor supply and distribution of households across asset levels, employment status, and sectors in the next period.

4. Repeat for $T$ periods to obtain the transition path. The solution approaches the new steady state as $T$ becomes large.

I use a common parameterization from macroeconomics literature to set the value of four parameters In particular, I set the discount rate $\beta = 0.98$, the coefficient of risk aversion $\sigma = 1.5$, the world interest rate $r^w = 0.02$, and the depreciation rate $\delta = 0.025$.

The Markov transition matrix is calibrated so that (1) the stationary unemployment rate is 6%, and (2) the duration of unemployment is two periods. Thus, $\Pr(\varepsilon' = 1 \mid \varepsilon = 1) = 0.97$, $\Pr(\varepsilon' = u \mid \varepsilon = u) = 0.5$, and $\overline{u} \approx 0.06$. The unemployment benefit is calibrated to $u = 0.5$; that is, unemployed households earn transfer income equal to half the annual sector-specific wage.

The total factor productivity for both sectors is set to $A^T = A^N = 1$, and the capital income share is $\alpha = 0.3$. The wages for both sectors are $w^i \approx 0.04$ in the neighborhood of the initial steady state. The borrowing constraint is calibrated to $\underline{a} = -0.04$. Thus, households can borrow up to approximately one period of income.

The share of Non-tradable goods in the basket of consumption and investment is $1 - \nu = 0.54$, which is common in the existing open-economy macroeconomics literature. Therefore, the share of Tradable goods in the basket is $\nu = 0.46$. I then assume that half of the Tradable goods used in consumption and investment are produced domestically and the other half are imported as Foreign Tradable good; thus, $\psi = 0.5$.

The parameter $\chi$ in the labor switching cost from Section 2.4 is the proportion of the current wage of the sector into which the household is switching. In the U.S. data, the average cost of obtaining four years of college education is roughly equal to three years of average college graduate wage income; thus, I calibrate $\chi = 3$.

In the following subsections, I present the simulation results from both counterfactual analyses.

### 3.2 Trade Liberalization: Bilateral Reduction of Trade Barriers

Figure 3.2.1 – 3.2.10 display the results of the counterfactual experiment when trade barriers for both exporting Home Tradable and importing Foreign Tradable goods are decreased from $\tau^{TH} = \tau^{TF} = 0.05$ to $\hat{\tau}^{TH} = \hat{\tau}^{TF} = 0$ in period $t = 2$.

The bilateral elimination of trade barriers leads to a movement of households from the Home Tradable to the Non-tradable sector. In Figure 3.2.1, immediately after trade liberalization, the unemployed households previously in the Home Tradable sector with sufficient wealth, which accounts for 1.4% of the total population, switch to the Non-tradable sector. In the new steady state, the employed labor supply in the Home Tradable sector ($L^{TH}$) and Non-tradable sector ($L^N$) decreases and increases by 1.3%, respectively. The unemployment rate ($u = 1 - L^{TH} - L^N$) initially rises by 0.7% due to the mandatory unemployment phase of the migrating households before returning to the steady state level $\overline{u}$. Figure 3.2.2 shows that the real wage in the Home Tradable sector ($w^{TH}$) initially falls by 3.6% after trade liberalization before rising 4.8% above the initial steady state, while the real wage in the Non-tradable sector ($w^N$) rises by 2.6% towards the new steady state. Wages are equal before trade liberalization but diverge after the liberalization. The widest wage gap occurs immediately after trade liberalization.

In Figure 3.2.3, the price of the Non-tradable good ($p^N$) initially rises by 6.9% upon trade liberalization, then falls to 1.5% below the initial steady state as sector labor supply ($L^N$) and output ($Y^N$) increase. The Home currency ($E$) initially depreciates by 0.7% immediately after trade liberalization but then appreciates by 5.5% towards the new steady state. The effective price of Foreign Tradable goods with the exchange rate and trade barrier, as measured by $Ep^{TF} / \left(1 - \tau^{TF}\right)$, decreases by 10.2%.

Figure 3.2.4 shows that production in the Home Tradable sector ($Y^{TH}$) falls by 1.4% in the new steady state while the output of the Non-tradable sector ($Y^N$) rises by 3.6%. Real GDP ($Y$) also increases by 3.7% in the steady state, with the largest increase immediately after trade liberalization due to the switching cost. However, Figure 3.2.5 shows that in the steady state after trade liberalization, output per employed worker in both the Home Tradable sector ($Y^{TH}/L^{TH}$) and Non-tradable sector ($Y^N/L^N$) increases by 1.1%

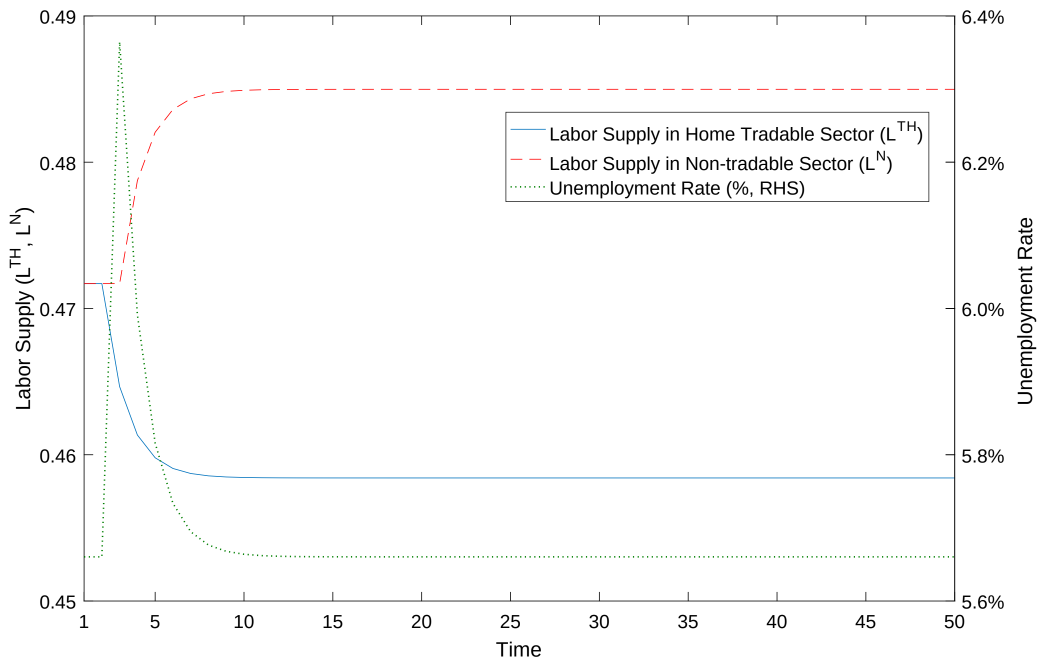


Figure 3.2.1: Labor Supply and Unemployment Rate

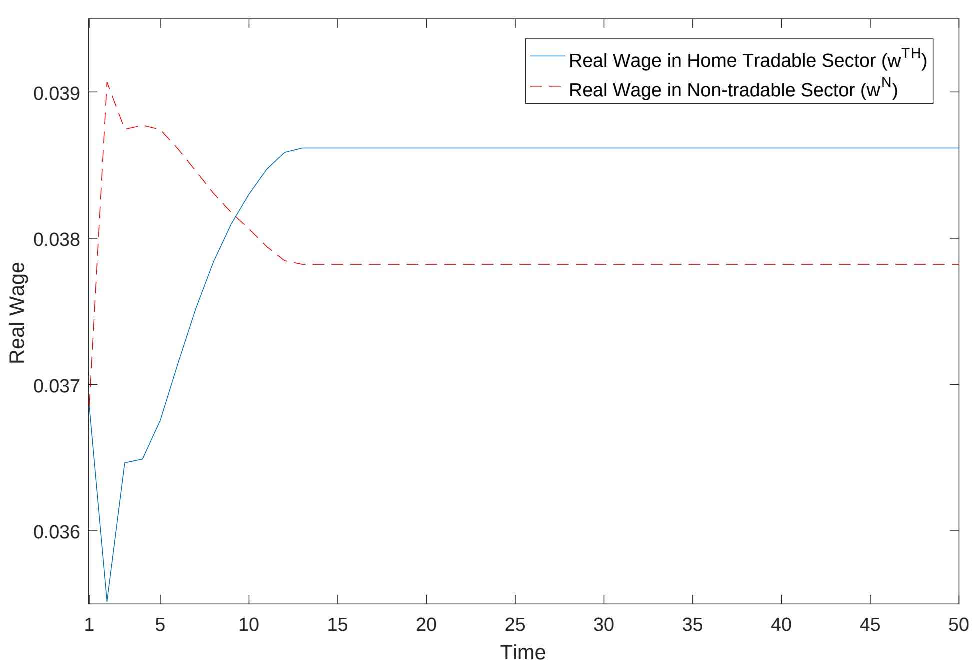


Figure 3.2.2: Sector Wage

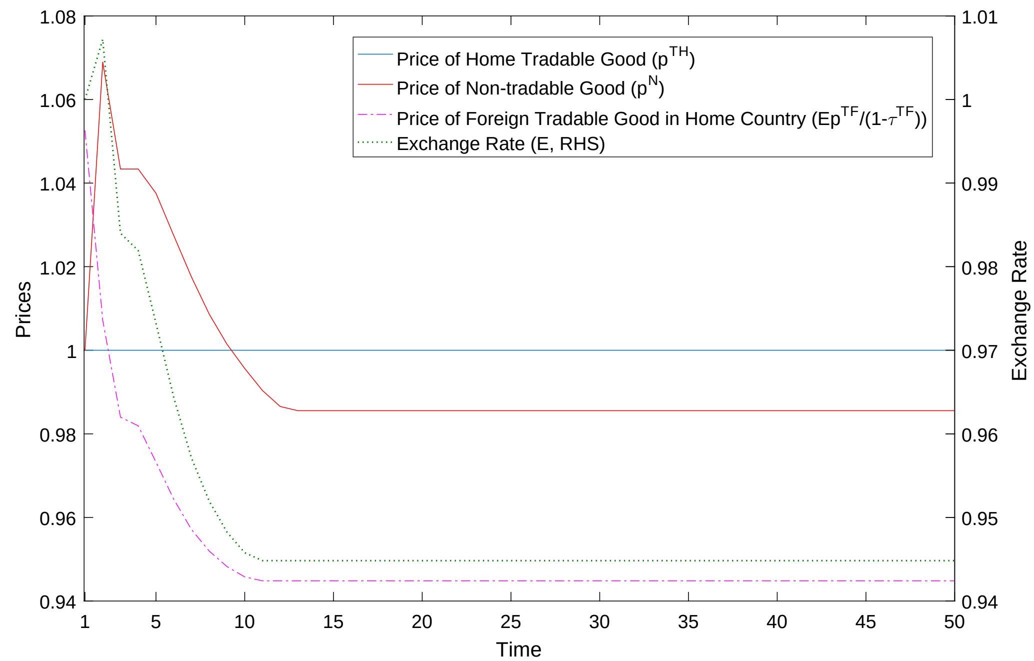


Figure 3.2.3: Prices and Exchange Rate

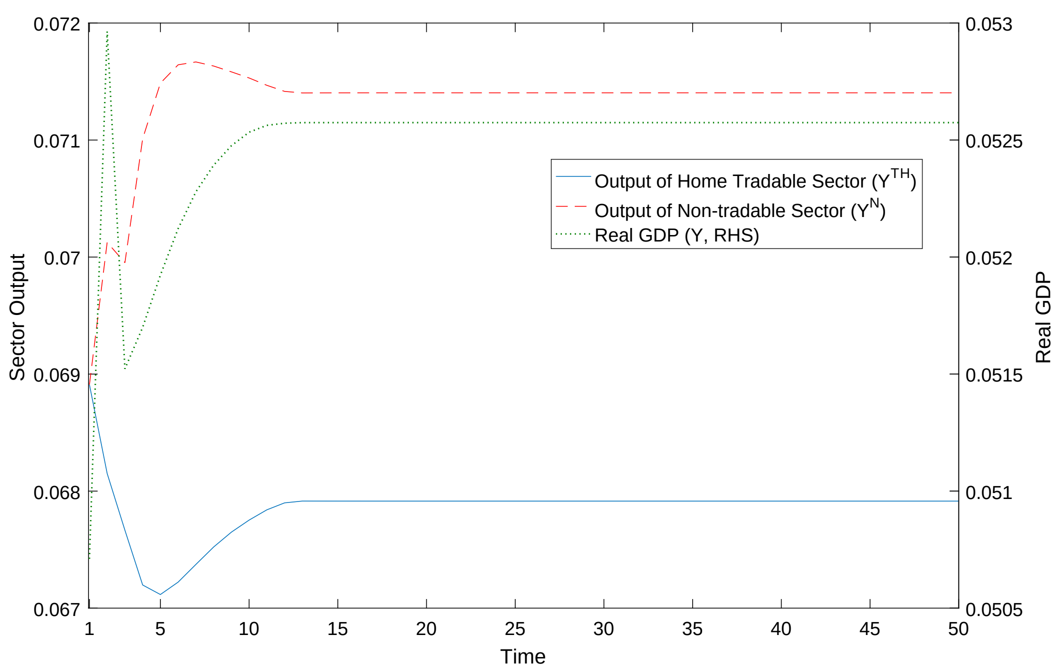


Figure 3.2.4: Sector Output and Real GDP

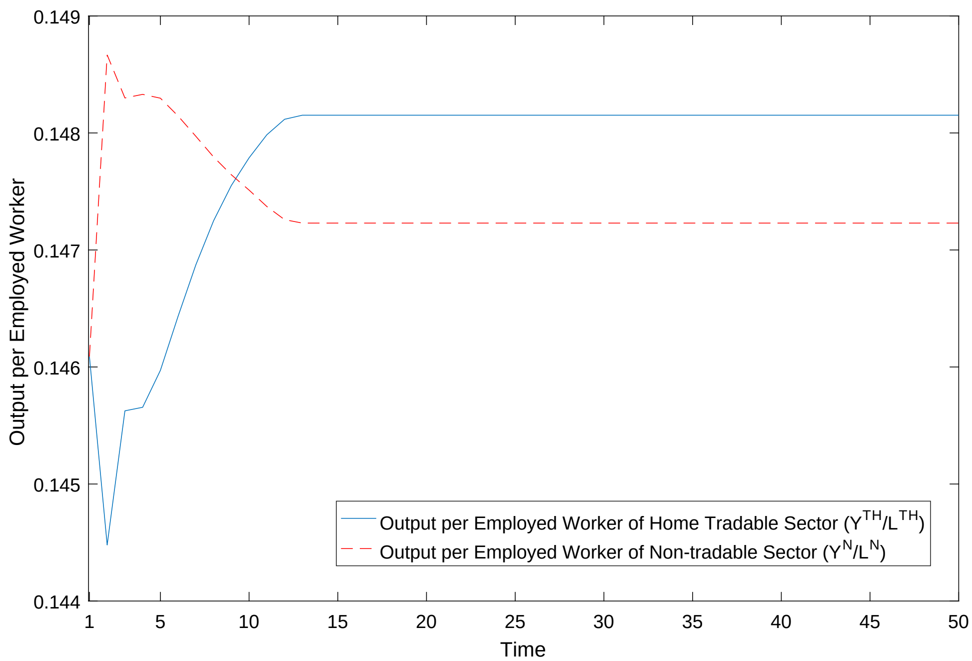


Figure 3.2.5: Output per Employed Worker

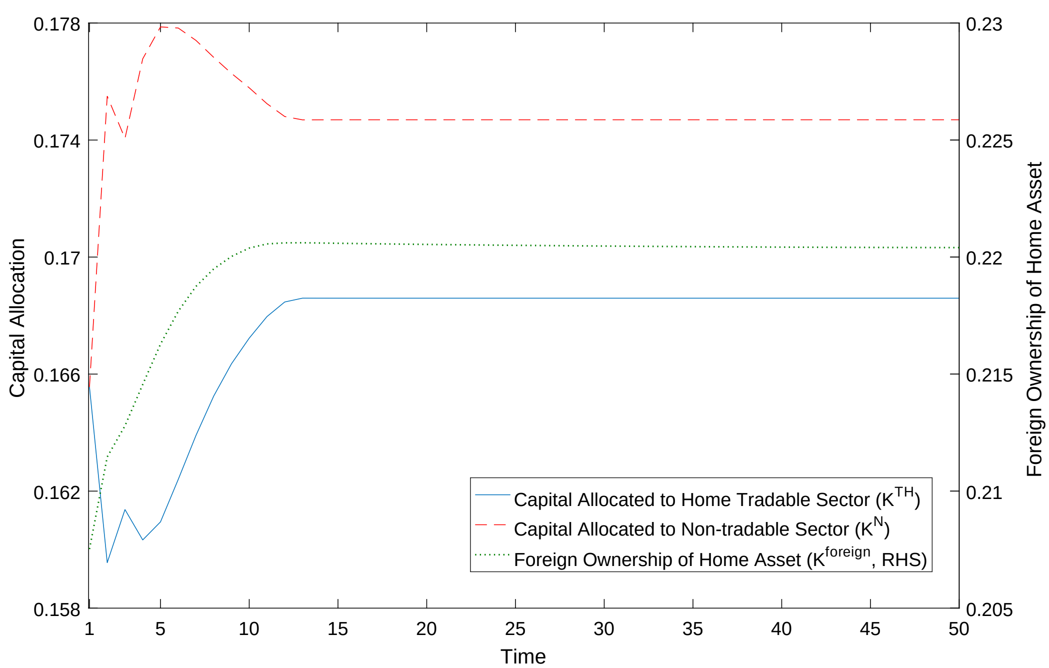


Figure 3.2.6: Capital Allocation and Foreign Ownership of Home Assets

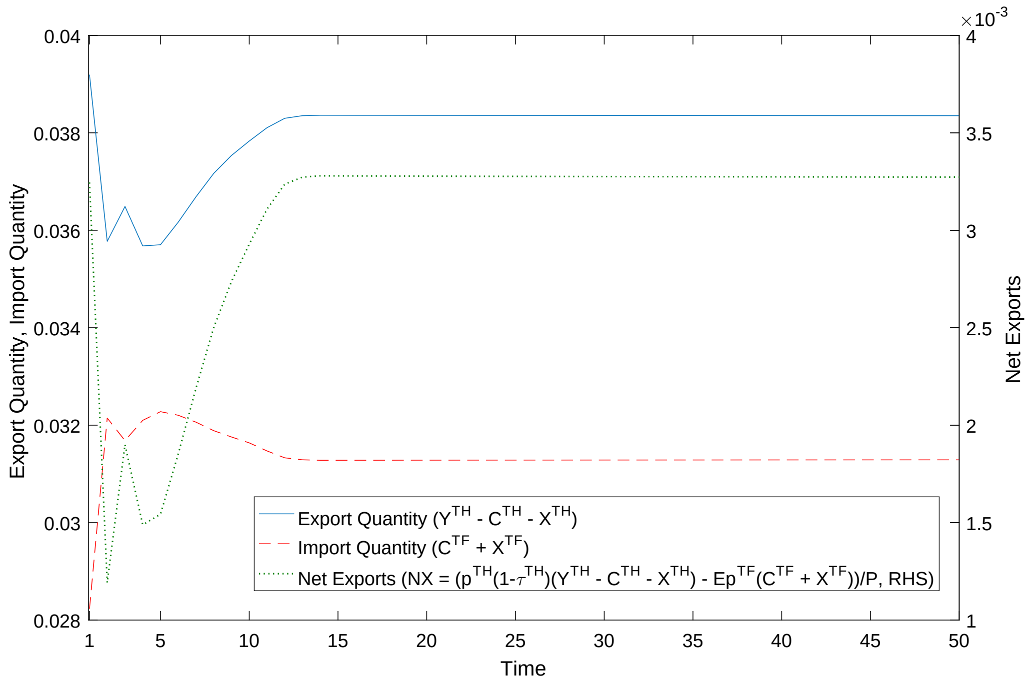


Figure 3.2.7: Export Quantity, Import Quantity, and Net Exports

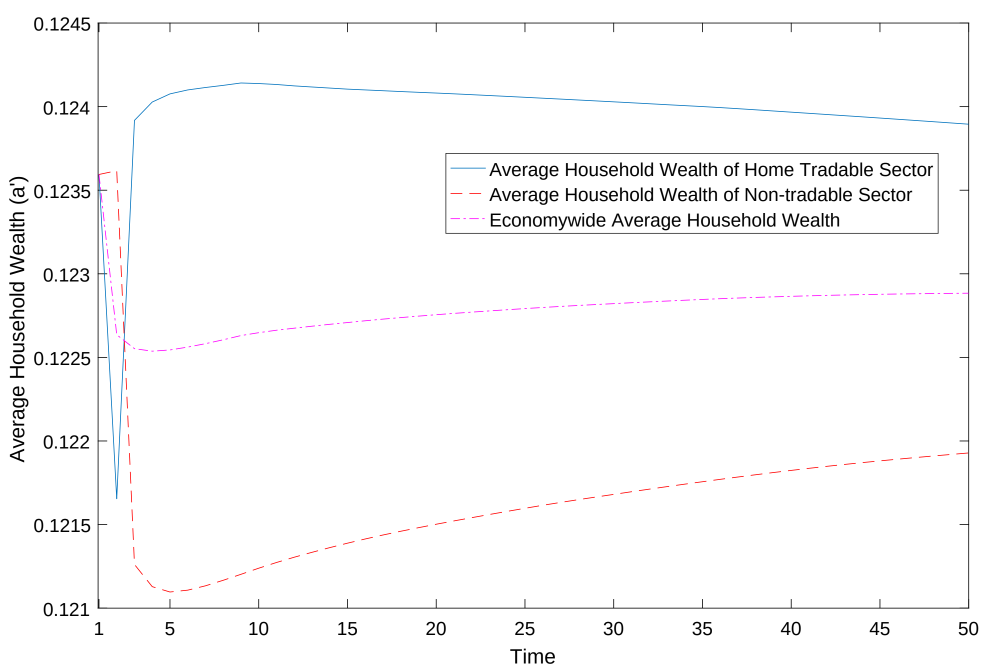


Figure 3.2.8: Average Household Wealth by Sector and Economy-wide

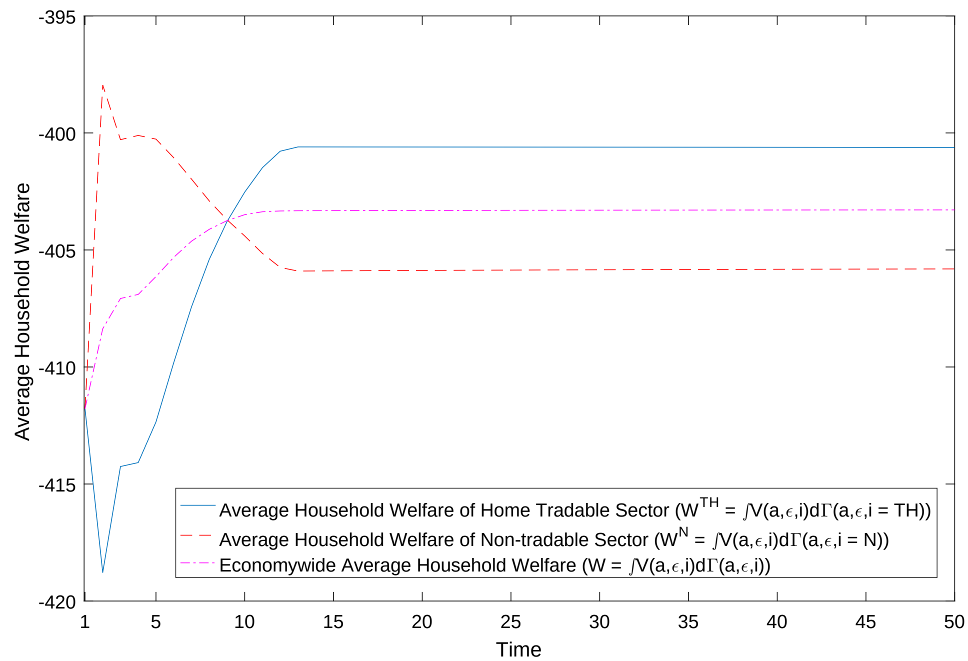


Figure 3.2.9: Average Household Welfare by Sector and Economy-wide

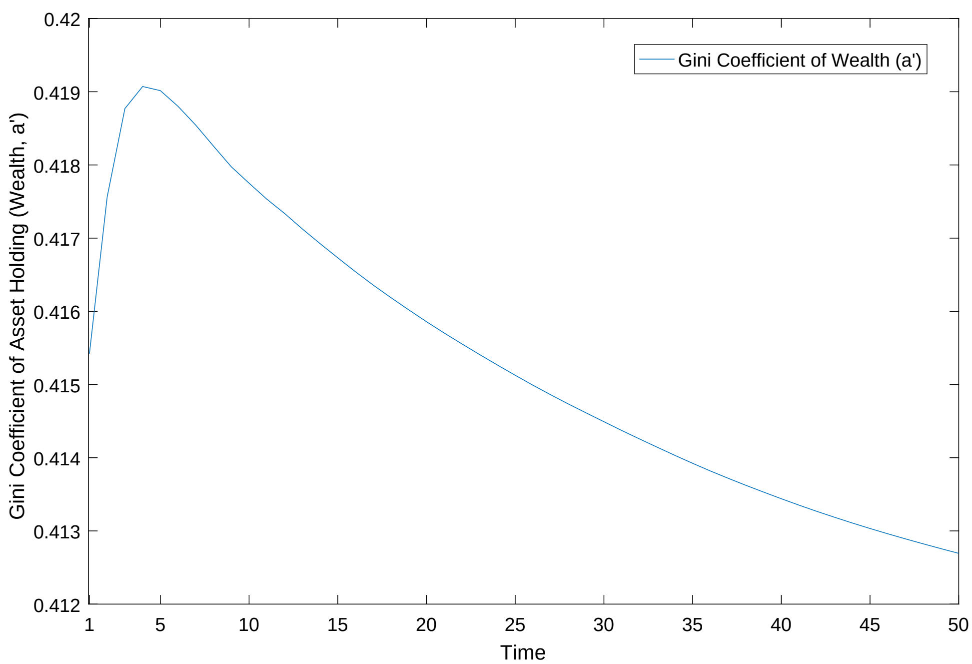


Figure 3.2.10: Gini Coefficient of Wealth

and 0.8%, respectively.

Figure 3.2.6 shows that capital allocated to the Home Tradable sector ($K^{TH}$) and Non-tradable sector ($K^{N}$) increases by 1.8% and 5.5%, respectively, and total capital used in production ($K^{TH} + K^{N}$) increases by 3.7%. Foreign ownership of Home assets ($K^{foreign}$) also increases by 6.2%, indicating capital inflows. The domestic supply of capital ($K^{domestic}$) decreases by 0.6%.

Figure 3.2.7 shows that the real value of net exports ($NX$) initially decreases by 64% immediately after trade liberalization due to the sharp decrease in the export quantity ($Y^{TH} - C^{TH} - X^{TH}$), the increase in the import demand ($C^{TF} + X^{TF}$), and the depreciation of the Home currency. However, the value of net exports increases by 0.9% in the new steady state, with a 2.2% decrease and a 10.8% increase in export and import quantity, respectively.

Figure 3.2.8 details the changes to the aggregate household wealth, as measured by the average wealth ($a'$) held by households in each sector. The average wealth of households in the Home Tradable sector initially decreases due to the lower real wage in Home Tradable sector and the switching cost paid by the migrating households. The average household wealth in the Non-tradable sector decreases as the migrating households are absorbed into the sector. The economy-wide total wealth decreases by 0.5% in the steady state.

Figure 3.2.9 shows that, on average, households in the Home Tradable sector are initially the losers from the policy; however, households in both sectors eventually gain from trade liberalization. The measure of welfare improvement will be discussed in Section 4.

Figure 3.2.10 shows that the Gini coefficient of wealth, as measured with asset holdings $a'$, immediately increases after trade liberalization and then tapers towards a more equitable distribution of wealth. The peak increase in the Gini coefficient of 0.8% occurs three periods after the policy implementation. The Gini coefficient returns to the pre-liberalization level in the following twenty periods then slowly decreases to 0.6% below the initial distribution.

### 3.3 A Decrease in Trade Barrier for Imported Foreign Tradable Good

Figure 3.3.1 – 3.3.10 display the results of the counterfactual experiment when only the trade barrier for importing Foreign Tradable goods is decreased from $\tau^{TF} = 0.05$ to $\hat{\tau}^{TF} = 0.025$. Immediately after the policy is implemented, 0.2% of the total population from unemployed households in the Home Tradable sector switches to the Non-tradable sector. Labor supply in the Home Tradable sector ($L^{TH}$) and Non-tradable sector ($L^{N}$) decreases and increases by 0.2%, respectively. The unemployment rate ($u = 1 - L^{TH} - L^{N}$) initially rises by 0.1%. The real wage in the Home Tradable sector ($w^{TH}$) initially falls by 3.1% after

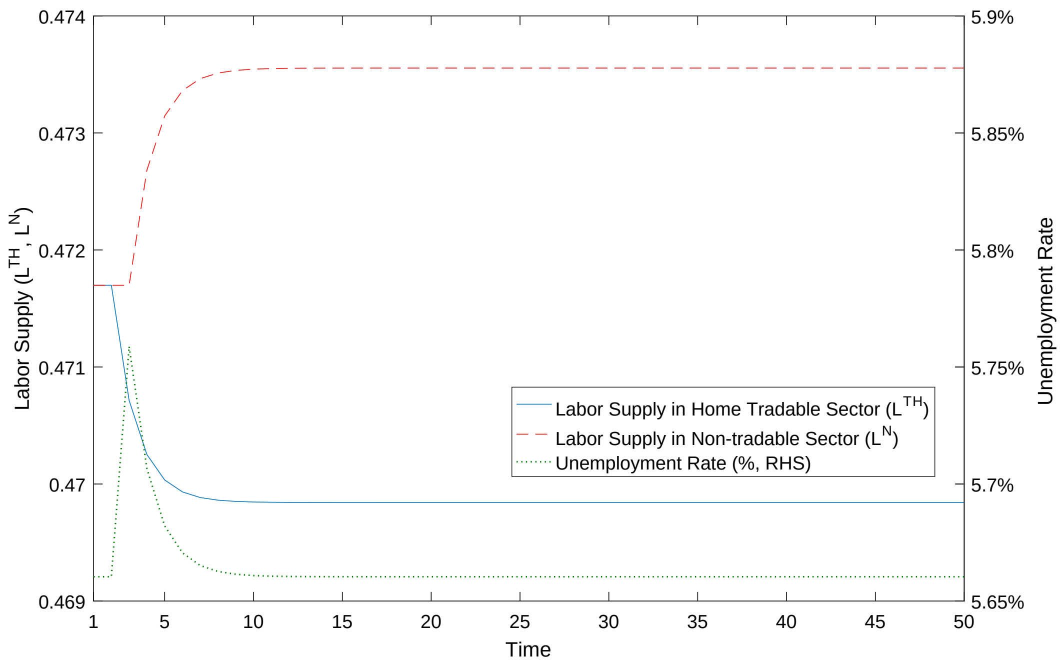


Figure 3.3.1: Labor Supply and Unemployment Rate

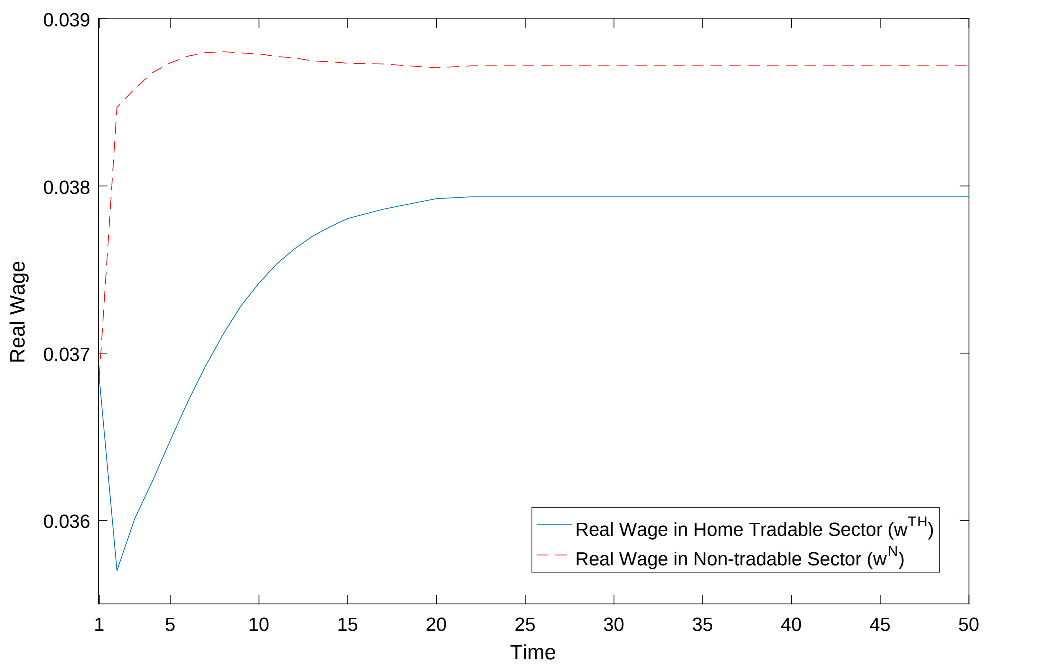


Figure 3.3.2: Sector Wage

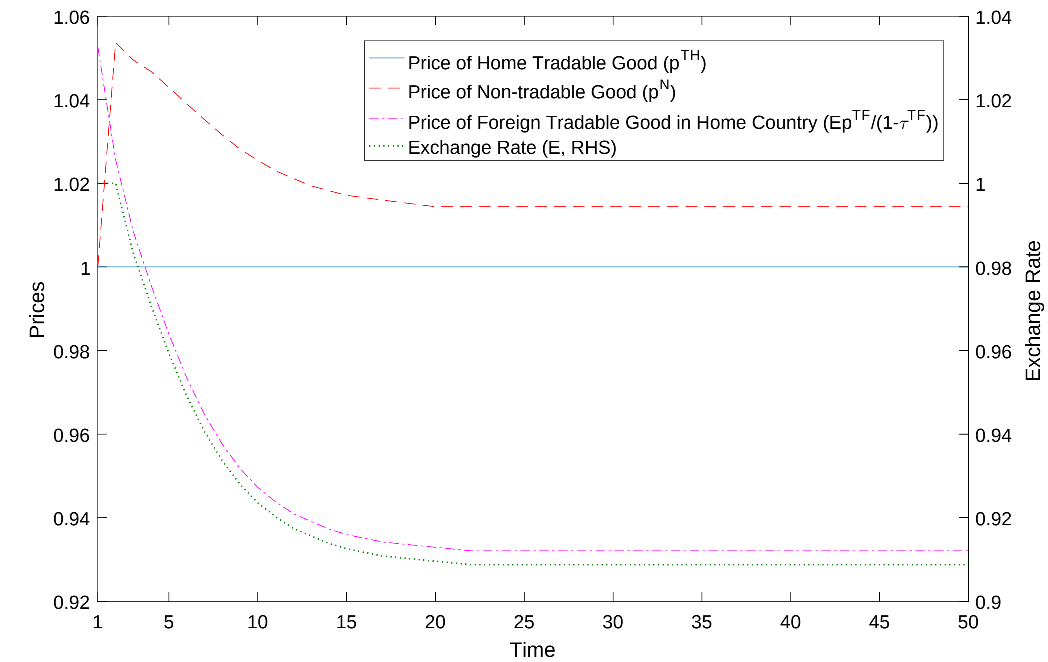


Figure 3.3.3: Prices and Exchange Rate

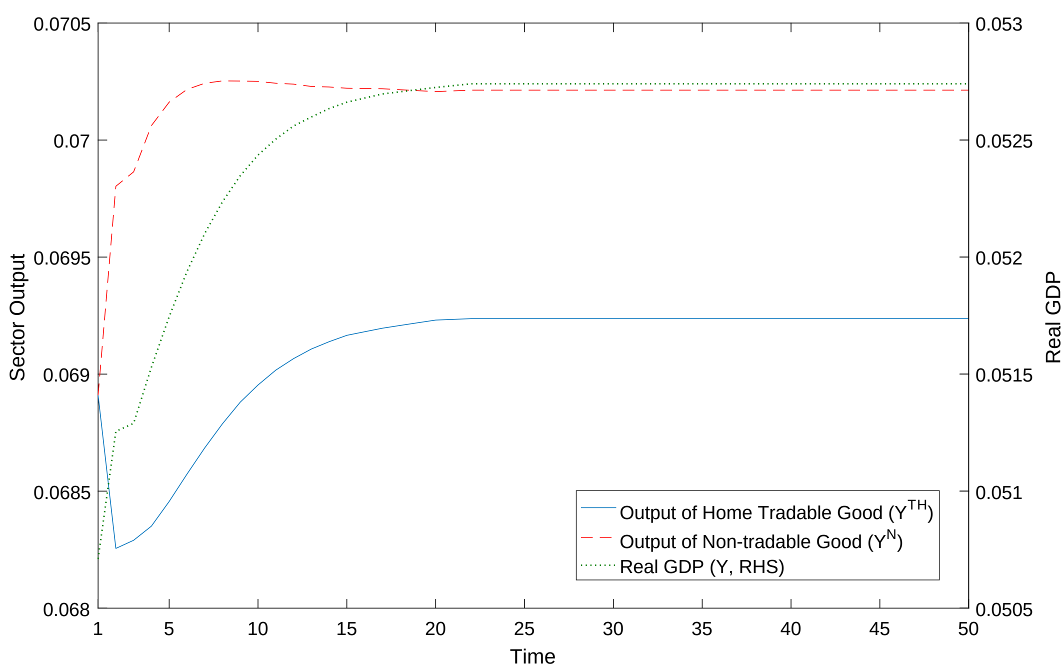


Figure 3.3.4: Sector Output and Real GDP

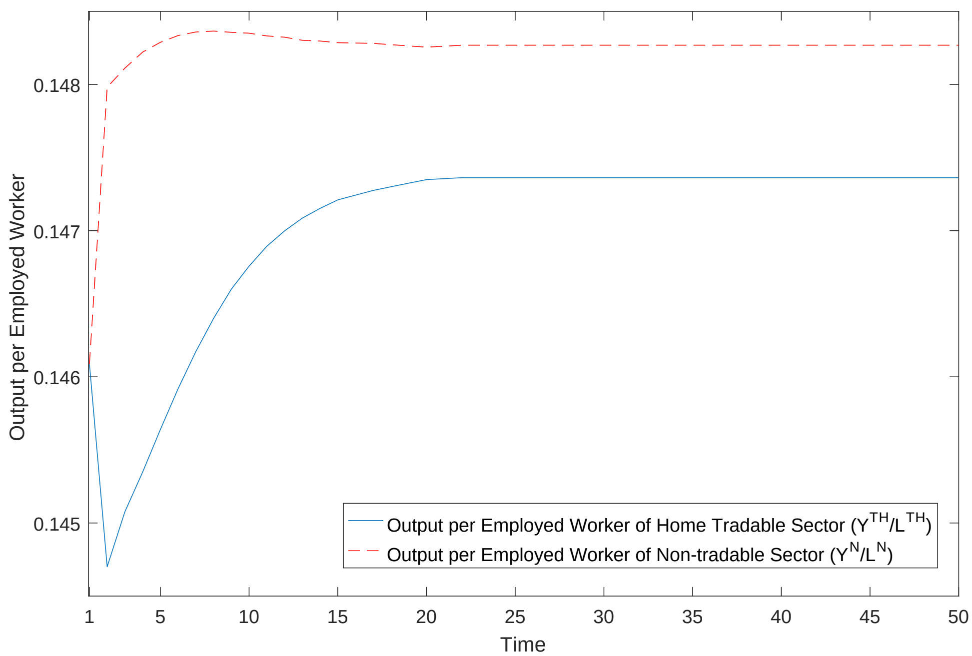


Figure 3.3.5: Output per Employed Worker

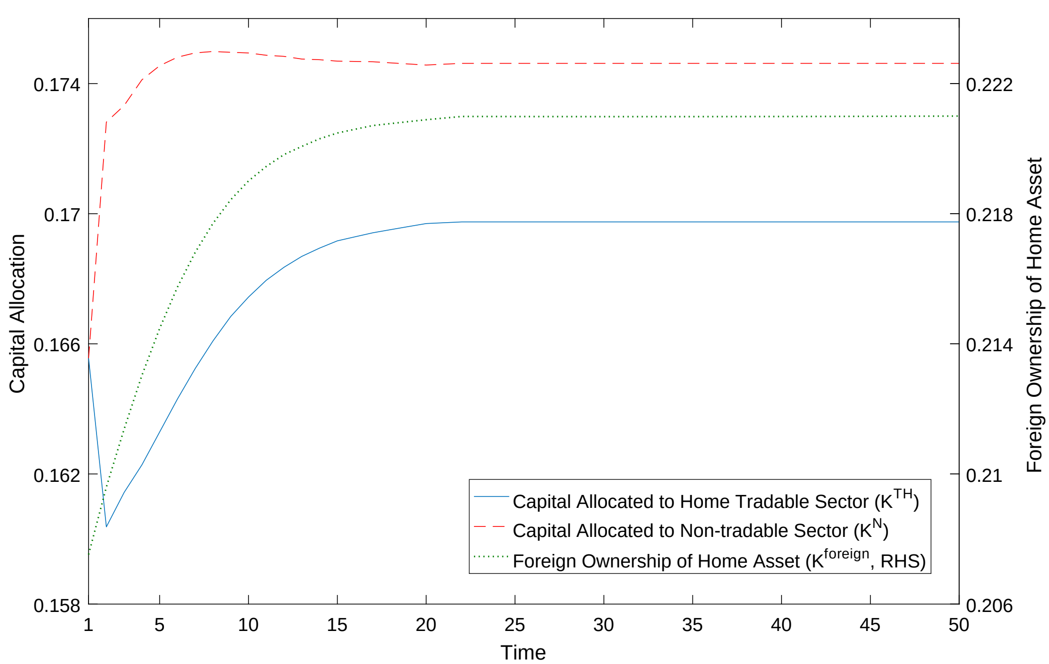


Figure 3.3.6: Capital Allocation and Foreign Ownership of Home Assets

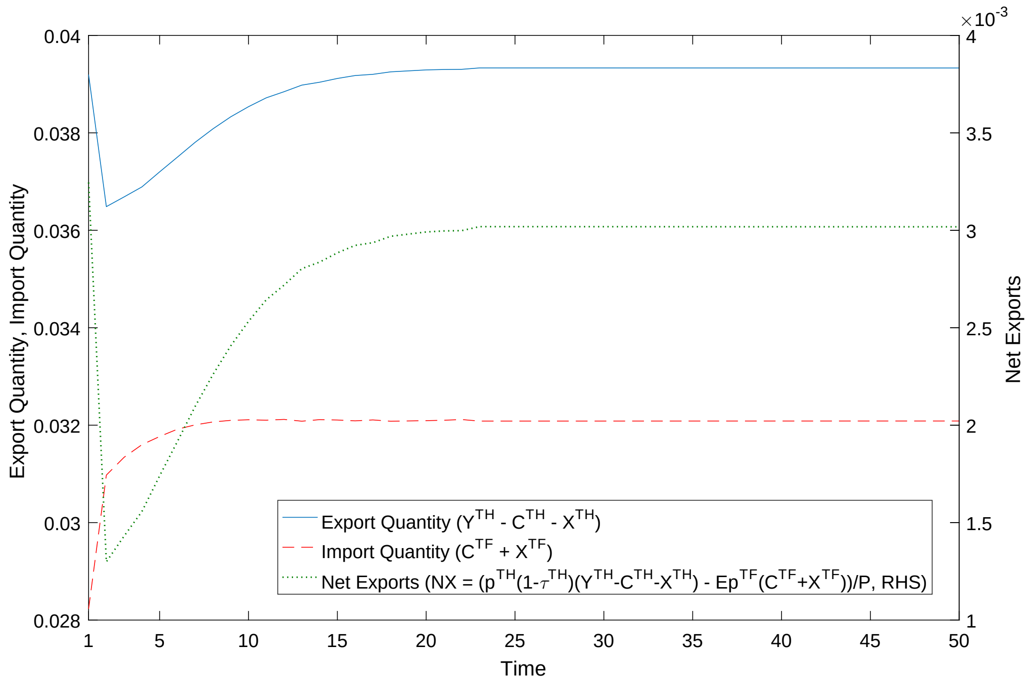


Figure 3.3.7: Export Quantity, Import Quantity, and Net Exports

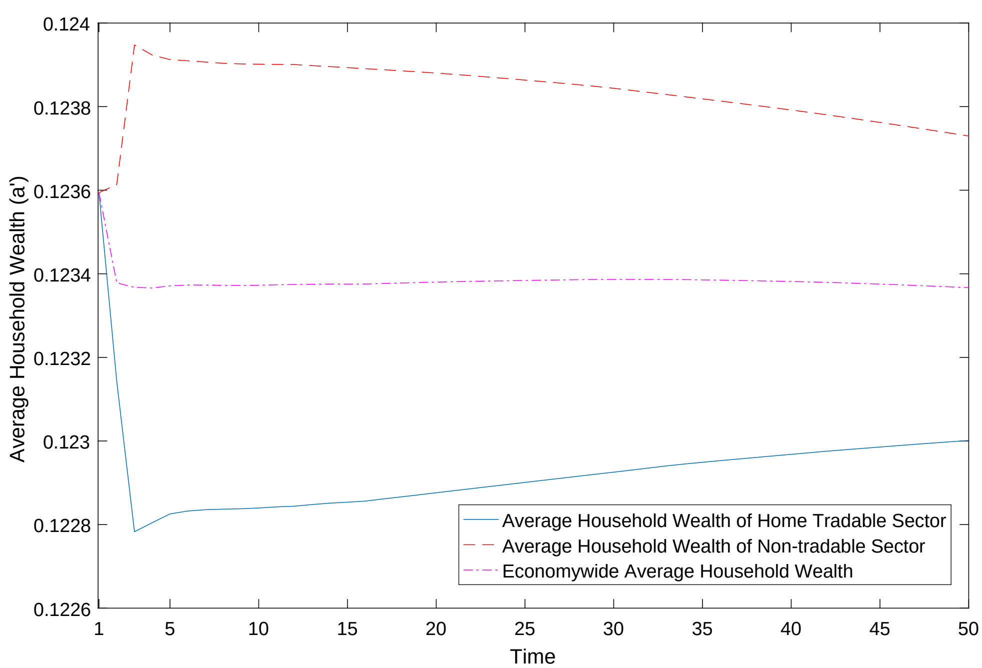


Figure 3.3.8: Average Household Wealth by Sector and Economy-wide

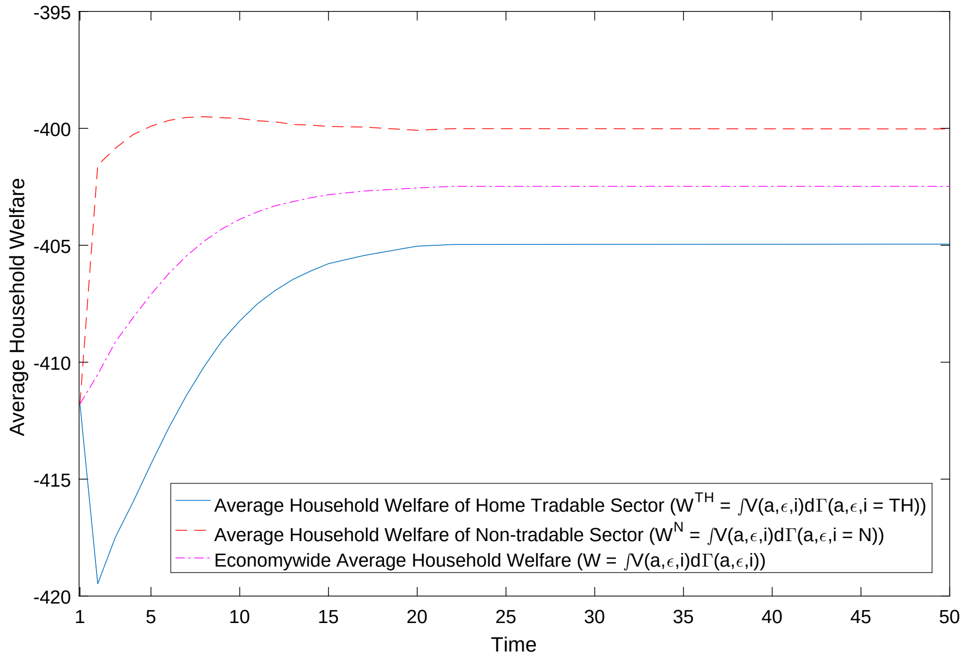


Figure 3.3.9: Average Household Welfare by Sector and Economy-wide

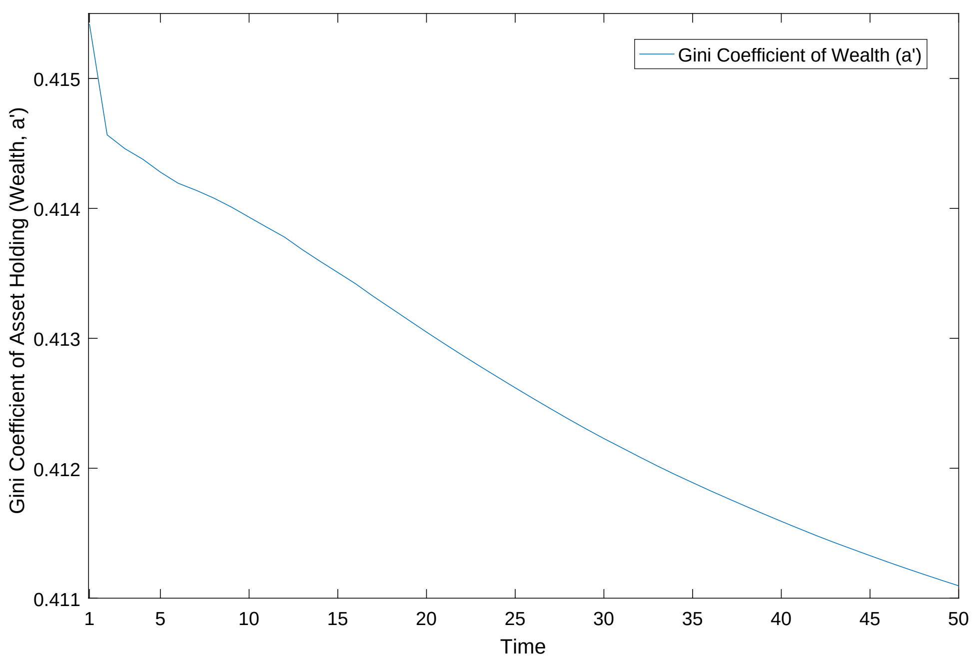


Figure 3.3.10: Gini Coefficient of Wealth

the new policy before rising to 2.9% above the initial steady state, while the real wage in the Non-tradable sector ($w^N$) rises by 5.1% towards the new steady state. Similarly, wage inequality permanently occurs and the gap between the two sectors is largest immediately after trade liberalization.

The price of the Non-tradable good ($p^N$) initially rises by 5.4%, then falls to 1.4% above the initial steady state as sector output ($Y^N$) increases. The Home currency ($E$) gradually appreciates by 9.1% towards the new steady state. The effective price of Foreign Tradable goods with the exchange rate and trade barrier, as measured by $Ep^{TF}/\left(1-\tau^{TF}\right)$, decreases by 11.5%.

The output in the Home Tradable sector ($Y^{TH}$) initially falls by 1.0% before rising to 0.5% above the initial level, while the output of Non-tradable sector ($Y^N$) steadily increases by 1.9%. Real GDP ($Y$) also increases by 4.0% in the steady state. Similarly, output per employed worker in both the Home Tradable sector ($Y^{TH}/L^{TH}$) and Non-tradable sector ($Y^N/L^N$) increases by 0.9% and 1.5%, respectively.

Capital allocated to the Home Tradable sector ($K^{TH}$) and Non-tradable sector ($K^N$) increases by 2.5% and 5.5%, respectively, and total capital used in production ($K^{TH}+K^N$) increases by 4.0%. The Foreign ownership of the Home assets ($K^{foreign}$) also increases by 6.5%, while domestic supply of capital ($K^{domestic}$) decreases by 0.2%. The real value of net exports ($NX$) initially decreases by 60% immediately after the policy and gradually increases to 7.0% below the initial policy, while export and import quantity increase by 0.4% and 13.7%, respectively.

The average household wealth ($a'$) in the Home Tradable sector initially decreases due to the lower real wage in the Home Tradable sector and the switching cost paid by migrating households. The average household wealth in the Non-tradable sector initially increases due to the higher real wage in the Non-tradable sector, but decreases as the real wage gradually decreases and the migrating households are absorbed into the sector. The economy-wide total wealth decreases by 0.2% in the steady state.

Households in the Home Tradable sector are initially the losers; however, households in both sectors eventually gain from the policy. The policy improves wealth inequality as the Gini coefficient of wealth ($a'$) immediately decreases.

# 4 Welfare and Political Economy

In this section, I discuss the welfare effects of the two alternative trade policies – bilateral trade liberalization ($\hat{\tau}^{TH}=\hat{\tau}^{TF}=0$), and the unilateral decrease in the trade barrier of the Foreign Tradable good ($\hat{\tau}^{TF}=0.025$). The change in welfare is measured by the consumption equivalent variation. Using the results from Section 3, the welfare effects are evaluated in two ways – between the two steady states of each policy, and along the transition path when each of the trade policies is implemented. An introductory discussion on the political economy of trade policies is also presented.

## 4.1 Welfare Comparison between Steady States

To compare the households' welfare between the two trade policies at the steady state, we compare the steady-state households' value functions from each policy regime. Define $\lambda\left(a,\varepsilon,i\right)$ as the consumption equivalent variation for a household currently in sector $i$ with current asset level $a$ and employment status $\varepsilon$. For each household with the current state variables $(a,\varepsilon,i)$, I ask the following questions: what percentage of permanent consumption under the current trade policy it would be willing to pay in order to achieve the steady-state utility value associated with the alternative trade policy? In other words, for each household with the same current state variables $(a,\varepsilon,i)$, which of the two steady states would it prefer and how much would it pay to be at the steady state under the alternative policy? If $\lambda\left(a,\varepsilon,i\right) > 0$, such household is willing to pay to move to the steady state under the alternative trade policy. Otherwise, household must be compensated if $\lambda\left(a,\varepsilon,i\right) < 0$.

Let $V\left(a,\varepsilon,i;\tau^{TH},\tau^{TF}\right) = \mathbb{E}\left[\sum_{t=1}^{\infty}\beta^{t-1}u\left(c_t\right)\right]$ and $\hat{V}\left(a,\varepsilon,i;\hat{\tau}^{TH},\hat{\tau}^{TF}\right) = \mathbb{E}\left[\sum_{t=1}^{\infty}\beta^{t-1}u\left(\hat{c}_t\right)\right]$ be the steady-state value functions associated with the benchmark $\left\{\tau^{TH},\tau^{TF}\right\}$ and the alternative $\left\{\hat{\tau}^{TH},\hat{\tau}^{TF}\right\}$ trade policies, respectively. The consumption equivalent variation can be solved from

$$\hat{V}\left(a,\varepsilon,i;\hat{\tau}^{TH},\hat{\tau}^{TF}\right) = \mathbb{E}\left[\sum_{t=1}^{\infty}\beta^{t-1}u\left(\left(1+\lambda\left(a,\varepsilon,i\right)\right)c_t\right)\right]$$

It can be shown that the consumption equivalent variation is

$$\lambda\left(a,\varepsilon,i\right) = \left[\frac{\hat{V}\left(a,\varepsilon,i;\hat{\tau}^{TH},\hat{\tau}^{TF}\right)+\frac{1}{(1-\sigma)(1-\beta)}}{V\left(a,\varepsilon,i;\tau^{TH},\tau^{TF}\right)+\frac{1}{(1-\sigma)(1-\beta)}}\right]^{\frac{1}{1-\sigma}} - 1$$

The steady-state value functions under the benchmark and the alternative trade policies are the value functions at time $t = 1$ and $t = T$, respectively. Since the economy is initially in the steady state under the trade barriers of $\tau^{TH} = \tau^{TF} = 0.05$ at time $t = 1$, and the economy converges to the steady state under the alternative trade policy $\left\{\hat{\tau}^{TH},\hat{\tau}^{TF}\right\}$ as $T$ grows large.

The economy-wide welfare gain is calculated from the average of the consumption equivalent variation over the initial distribution of households across the state variables $(a,\varepsilon,i)$ at time $t = 1$. That is, the average welfare gain as a result of moving all households from the current steady state under the benchmark policy

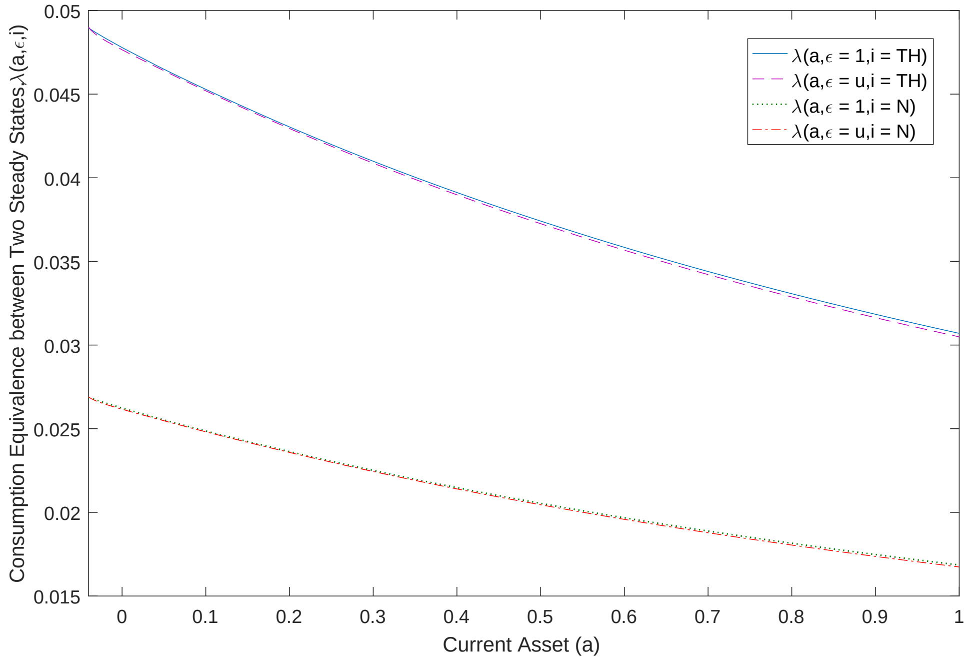


Figure 4.1.1: Consumption Equivalence Function between Two Steady States - Bilateral Trade Liberalization (from $\tau^{TH} = \tau^{TF} = 0.05$ to $\hat{\tau}^{TH} = \hat{\tau}^{TF} = 0$)

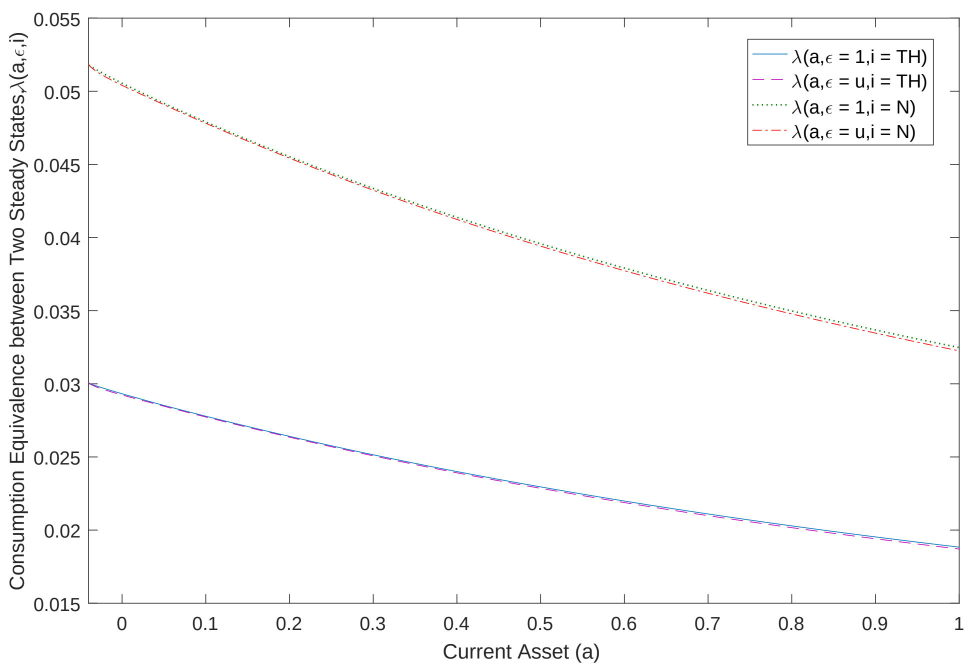


Figure 4.1.2: Consumption Equivalence between Two Steady States - Unilateral Trade Barrier Decrease for Foreign Tradable Good (from $\tau^{TF} = 0.05$ to $\hat{\tau}^{TF} = 0.025$)

to the alternative policy is

$$WG_{ss} = \int \lambda\left(a, \varepsilon, i\right) \mathrm{d}\Gamma_1\left(a, \varepsilon, i\right)$$

Figures 4.1.1 and 4.1.2 exhibit the steady-state consumption equivalent variation for the alternative trade policies of $\hat{\tau}^{TH} = \hat{\tau}^{TF} = 0$ and $\hat{\tau}^{TF} = 0.025$, respectively. In the steady states of both alternative policies, it can be observed that households in the Home Tradable sector have higher welfare gains than those in the Non-tradable sector. Households with lower current assets also have higher welfare gains, measured in percentage of consumption. Furthermore, all households prefer the steady states under both liberalized trade policies since $\lambda\left(a, \varepsilon, i\right) > 0$ in both of the new trade policies. Comparing the steady states, the economy-wide average welfare gain from trade liberalization is 3.5%, while the economy-wide welfare gain from the reduction in the import barrier is 3.8%.

## 4.2 Welfare Comparison along the Transition Paths, Political Economy, and Voting

Despite the welfare improvement for all households in the steady state under more liberalized trade policies, the transition towards new steady states may not be favored by every household. This welfare comparison takes into account the transition after the trade policies are announced and implemented in period $t = 2$. This is measured with the respect to the identical states of each household – with current asset $a_2$, employment status $\varepsilon_2$, and current sector $i_2$. Define $\lambda\left(a_2, \varepsilon_2, i_2\right)$ as the consumption equivalent variation for a household with state variables $\left(a_2, \varepsilon_2, i_2\right)$ in period $t = 2$. I ask the following question: what percentage of consumption stream under the current trade policy it would be willing to pay in order to achieve the utility stream associated with the transition towards the steady state under the new trade policy? In other words, would each household with the state variables $\left(a_2, \varepsilon_2, i_2\right)$ prefer to transition towards the steady state of the new policy, or to remain in the old policy?

Let $W\left(a_2, \varepsilon_2, i_2; \tau^{TH}, \tau^{TF}\right) = \mathbb{E}\left[\sum_{t=2}^{T} \beta^{t-2} u\left(c_t\right)\right]$ and $\hat{W}\left(a_2, \varepsilon_2, i_2; \hat{\tau}^{TH}, \hat{\tau}^{TF}\right) = \mathbb{E}\left[\sum_{t=2}^{T} \beta^{t-2} u\left(\hat{c}_t\right)\right]$ be the household's $T$-period utility streams associated with the benchmark $\left\{\tau^{TH}, \tau^{TF}\right\}$ trade policy and the transition towards the steady state of the alternative $\left\{\hat{\tau}^{TH}, \hat{\tau}^{TF}\right\}$ trade policy, respectively. The consumption equivalent variation can be solved from

$$\hat{W}\left(a_2, \varepsilon_2, i_2; \hat{\tau}^{TH}, \hat{\tau}^{TF}\right) = \mathbb{E}\left[\sum_{t=2}^{T} \beta^{t-2} u\left(\left(1 + \lambda\left(a_2, \varepsilon_2, i_2\right)\right) c_t\right)\right]$$

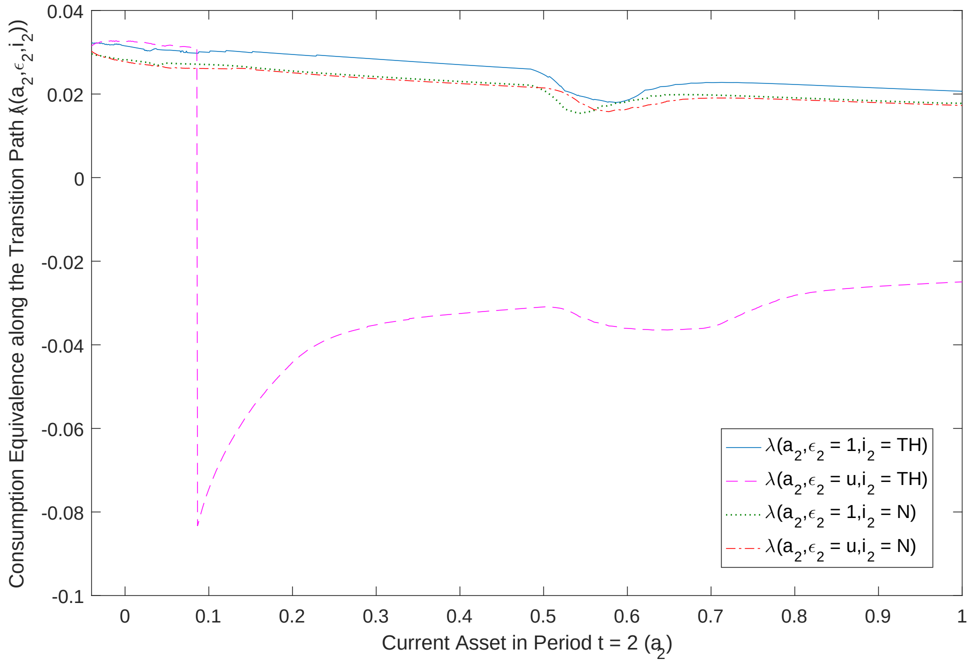


Figure 4.2.1: Consumption Equivalence Function along the Transition Path - Bilateral Trade Liberalization (from $\tau^{TH} = \tau^{TF} = 0.05$ to $\tau^{TH} = \tau^{TF} = 0$)

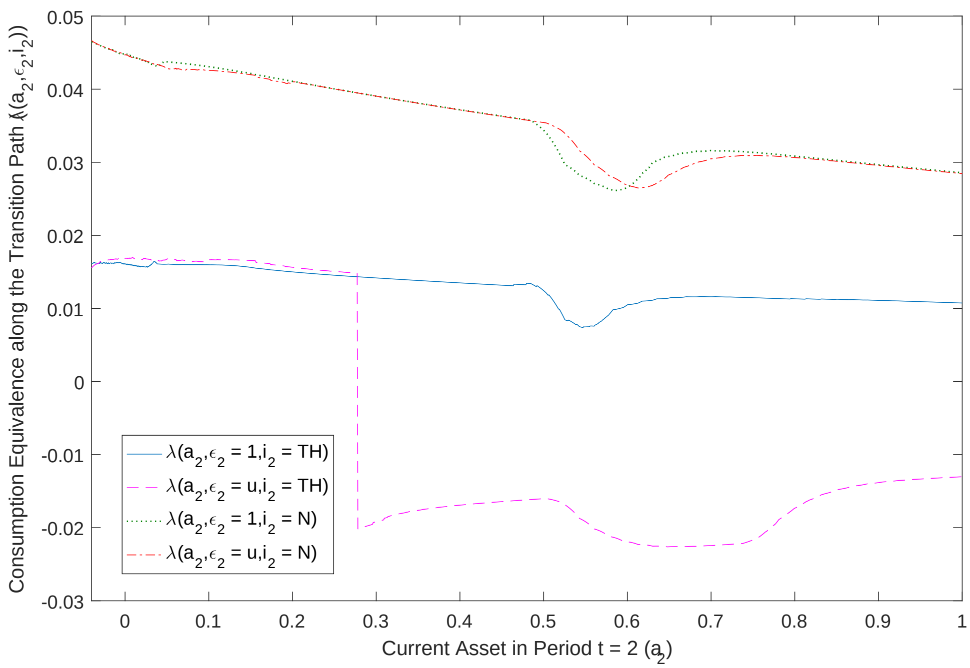


Figure 4.2.2: Consumption Equivalence along the Transition Path - Unilateral Trade Barrier Decrease for Foreign Tradable Good (from $\tau^{TF} = 0.05$ to $\tau^{TF} = 0.025$)

The consumption equivalent variation is given by

$$\lambda\left(a_2,\varepsilon_2,i_2\right)=\left[\frac{\hat{W}\left(a_2,\varepsilon_2,i_2;\hat{\tau}^{TH},\hat{\tau}^{TF}\right)+\frac{1}{(1-\sigma)(1-\beta)}}{W\left(a_2,\varepsilon_2,i_2;\tau^{TH},\tau^{TF}\right)+\frac{1}{(1-\sigma)(1-\beta)}}\right]^{\frac{1}{1-\sigma}}-1$$

In order to compute $W\left(a_2,\varepsilon_2,i_2;\tau^{TH},\tau^{TF}\right)$ and $\hat{W}\left(a_2,\varepsilon_2,i_2;\hat{\tau}^{TH},\hat{\tau}^{TF}\right)$, the sequences of consumption, saving and sector decision rules, $\{c_t,a_{t+1},i_{t+1}\}_{t=2}^{T}$ and $\left\{\hat{c}_t,\hat{a}_{t+1},\hat{i}_{t+1}\right\}_{t=2}^{T}$, associated with the two trade policies, $\left\{\tau^{TH},\tau^{TF}\right\}$ and $\left\{\hat{\tau}^{TH},\hat{\tau}^{TF}\right\}$, are obtained. Note that when $T\to\infty$, the transition path is complete, that is, households take into account the full horizon of transition processes towards the new steady state.

The economy-wide welfare gain along the transition towards the new steady state can also be computed from the average of the consumption equivalent variation over the distribution of households in period $t=2$ as

$$WG_{transition}=\int\lambda\left(a_2,\varepsilon_2,i_2\right)\mathrm{d}\Gamma_2\left(a_2,\varepsilon_2,i_2\right)$$

Furthermore, the fraction of the population who are in favor of transitioning to the new steady state can be calculated from the fraction of households with $\lambda\left(a_2,\varepsilon_2,i_2\right)\geq 0$. The mass of households in period $t=2$ who are voting in favor of transitioning is the fraction given by

$$\int\mathbb{I}\left\{\lambda\left(a_2,\varepsilon_2,i_2\right)\geq 0\right\}\mathrm{d}\Gamma_2\left(a_2,\varepsilon_2,i_2\right)$$

Figures 4.2.1 and 4.2.2 show the consumption equivalent variation along the transition paths after the implementation of the alternative trade policies of $\hat{\tau}^{TH}=\hat{\tau}^{TF}=0$ and $\hat{\tau}^{TF}=0.025$, respectively. Taking into account the transition path towards the new steady states, the economy-wide average welfare gains are 2.7% and 2.9% for the trade liberalization and the reduction in import barrier, respectively. Furthermore, almost all households experience welfare gains from transitioning towards either of the more liberalized trade policies, except the unemployed households in the Home Tradable sector with the higher level of current asset, who suffer from the switching costs and mandatory unemployment after switching. The fraction of households who vote in favor of transitioning to the new policies is 98.6% for the trade liberalization and 99.8% for the decrease in import barrier, respectively.

## 4.3 Political Economy, Myopia and Voting

In Section 4.2, households compare the $T$-period utility streams of transitioning towards the steady state under the new trade policy to remaining in the initial trade policy. Households have complete information of the consumption, saving and sector choices along the transition path as $T \to \infty$ and vote in favor of the new trade policy when $\lambda\left(a_2, \varepsilon_2, i_2\right) \geq 0$. Suppose instead that all households are myopic, that is, let $T < \infty$ so that households do not take into account the full horizon of transitioning. The consumption equivalent variation with $T$-period forward-looking horizon is similarly defined as

$$\lambda_T\left(a_2, \varepsilon_2, i_2\right) = \left[\frac{\hat{W}_T\left(a_2, \varepsilon_2, i_2; \hat{\tau}^{TH}, \hat{\tau}^{TF}\right) + \frac{1}{(1-\sigma)(1-\beta)}}{W_T\left(a_2, \varepsilon_2, i_2; \tau^{TH}, \tau^{TF}\right) + \frac{1}{(1-\sigma)(1-\beta)}}\right]^{\frac{1}{1-\sigma}} - 1$$

where $W_T\left(a_2, \varepsilon_2, i_2; \tau^{TH}, \tau^{TF}\right) = \mathbb{E}\left[\sum_{t=2}^{T} \beta^{t-2} u\left(c_t\right)\right]$ and $\hat{W}_T\left(a_2, \varepsilon_2, i_2; \hat{\tau}^{TH}, \hat{\tau}^{TF}\right) = \mathbb{E}\left[\sum_{t=2}^{T} \beta^{t-2} u\left(\hat{c}_t\right)\right]$, $T = 3, \ldots < \infty$. For instance, if $T = 3$, households compare the utility streams of only two periods – immediately following ($t = 2$), and one period after ($t = 3$) the new trade policy is implemented. Given $T$-period forward-looking horizon by all households, the fraction of population who are in favor of transition towards the new trade policy is given by

$$\int \mathbb{I}\left\{\lambda_T\left(a_2, \varepsilon_2, i_2\right) \geq 0\right\} \mathrm{d}\Gamma_2\left(a_2, \varepsilon_2, i_2\right)$$

The calculated votes given the $T$-period horizon as illustrated in Figure 4.3.1 and 4.3.2 show that, in both of the alternative trade policies, households are less likely to vote in favor of the transition towards the new steady state if they are myopic. That is, as low as only 50% of the population are in favor of transitioning to the welfare-improving trade policies as $T$ is small.

# 5 Conclusion

This paper analyzed the effects of trade liberalization on inequality and welfare in a dynamic macroeconomic setting. I revisit the empirical results from the existing literature on wage and income inequality. Many studies agree that, while improving welfare, wage inequality rises as a result of trade liberalization. However, these results are largely based on comparative statics or steady-state analyses. Most recent examinations show that trade liberalization leads to non-monotonic effects of the increasing wage inequality that initially overshoots.

By taking an alternative approach to the existing international trade literature, I construct a dynamic general equilibrium macroeconomic model. The standard heterogeneous agent model with infinitely-lived households is taken as the point of departure. Various features from sparse branches of the literature are added to explain the effects of trade liberalization. These include a small open economy with two pro-

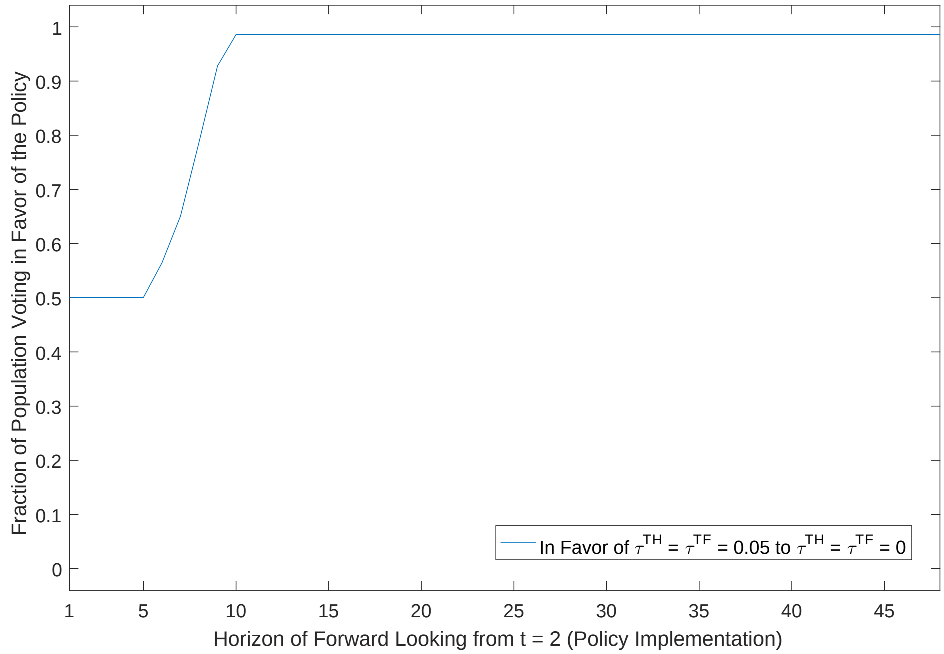


Figure 4.3.1: Consumption Equivalence Function between Two Steady States - Bilateral Trade Liberalization (from $\tau^{TH} = \tau^{TF} = 0.05$ to $\hat{\tau}^{TH} = \hat{\tau}^{TF} = 0$)

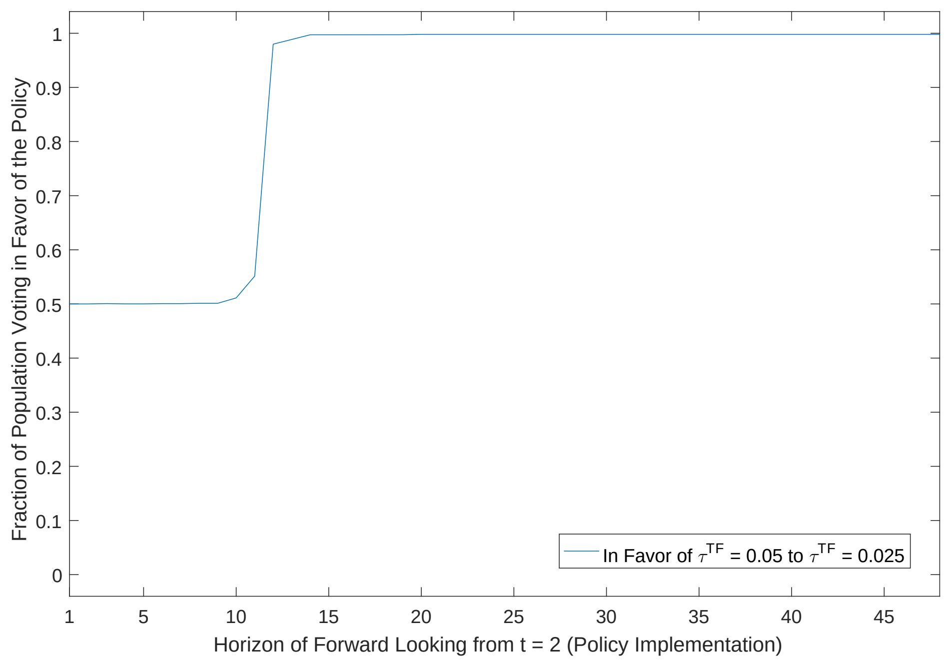


Figure 4.3.2: Consumption Equivalence between Two Steady States - Unilateral Trade Barrier Decrease for Foreign Tradable Good (from $\tau^{TF} = 0.05$ to $\hat{\tau}^{TF} = 0.025$)

duction sectors – Home Tradable and Non-tradable, three types of consumption and investment good, incomplete Home asset market with capital accumulation, iceberg cost of trading, and specific-factor trade model with costly-switching labor supply and freely mobile capital across sectors and borders. The metrics of interest are the Gini coefficient of wealth and the consumption equivalent variation, as measures of wealth inequality and welfare changes, respectively. Furthermore, these rich features not only allow for the analysis of inequality and welfare but also other macroeconomic aggregate variables. I use a common parameterization from macroeconomics literature.

The results from the counterfactual analysis show that trade liberalization, which is defined as the elimination of trade barriers on both exported and imported goods, leads to an initial increase in wealth inequality, attaining the peak increase of 0.8% at 3 years post-liberalization, before returning to the initial level in 20 years and then tapering towards a more equitable distribution. Wealth inequality decreases by 0.6% in the long run. Furthermore, wages diverge permanently, with the largest gap in periods immediately after trade liberalization; thus, the model provides results on wage inequality that are consistent with previous literature. Real GDP increases by 3.7% in the long run. Both sectors also experience an increase in productivity as output per worker rises in both industries. Home currency appreciates in the long run, along with capital inflows from abroad. Comparing the steady states, trade liberalization leads to the economy-wide average of 3.5% increase in households' welfare, as measured by consumption equivalent variation, with households in the Home Tradable sector achieving the higher welfare gain from the policy. The average welfare gain taking into account the transition path is 2.7%. However, not all households, particularly households in the Home Tradable sector, prefer transitioning to the new welfare-improving steady state under trade liberalization. Households are also less likely to vote in favor of trade liberalization when they do not take into account the complete transition path, that is, when households are myopic. This finding may also explain the voting outcomes and the voting behavior of different demographic groups in the recent "Brexit" referendum.

Similar results are also observed from the counterfactual analysis with the reduction in trade barriers for importing Foreign Tradable goods. Wealth inequality immediately and permanently decreases, while wage inequality rises with the largest gap in periods after the impact of the policy. Despite the average welfare gain of 3.8% and 2.9% for the steady state and the transition path of the new policy, respectively, not all households are in favor of the policy.

As this paper is the first attempt in modeling trade liberalization in the great flexibility of dynamic general equilibrium macroeconomics setting, the possible extensions to the model are left for future work.

In the subject of human capital attainment and sector choices, the model can be modified to incorporate overlapping generations of households to study such effects of trade liberalization. Moreover, since trade barriers are both protective to Home Tradable households and destructive to economic growth and capital accumulation, the question of the most preferred trade barriers in the context of political economy is yet to be examined.

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