Quantitative Easing Spillovers

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Abstract

This paper studies the spillover effects of US quantitative easing on emerging market economies. I estimate the spillover effects using Bayesian VAR models for the US economy and a set of emerging market economies. A 1% increase in the Federal Reserves securities held outright has positive and statistically significant effects on real GDP, real Investment, the price level, and asset prices in the US economy. Emerging market economies experience positive statistically significant effects on real GDP, real investment, inflation, and stock market indices, along with currency appreciation, current account deterioration, and increase in their long-term bond yields. Then I build a two-country Heterogeneous-Agents New Keynesian model with QE shocks and dollarized bank balance sheets in the EME. The model is estimated to match the empirical movements. Bank balance sheets are at the heart of the international transmission mechanism. The choice between HANK vs. RANK matters for the magnitude of the impulse responses since without heterogeneity aggregate demand is lower in both countries. The model predicts that QE decreases inequality in the US economy in the medium run, but in the short run wealth inequality rises, whereas in the emerging market economy wealth inequality increases and remains elevated over time. Finally, policies aiming to reduce the flow of capital between countries, such as capital controls, have significant adverse effects on economic activity and welfare.

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Any views expressed herein are the views of the author and do not represent the views of the organization he works for.

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1 Introduction

Financial globalization has been rising over the last decades and changing financial conditions in an economy usually transmit to other economies swiftly. Switches in financial conditions often result from monetary and fiscal policy interventions in relatively big economies. These interventions can have sizeable spillover effects on small open economies through capital flow changes affecting asset prices and exchange rates, which transmit to the rest of the economy through the interaction of bank balance sheets with financial frictions, and through changes in net exports, leading to adjustments in aggregate demand and production. These changes create distributional effects across households in small open economies since their income and wealth depend on asset prices and production decisions. The debate on how conventional monetary policies of big countries affect inequality in small open economies is recent and heated. However, it is still unknown how unconventional monetary policies of big economies affect inequality in small open economies.

In this paper, I try to provide insights into the above issue by focusing on the effects of US quantitative easing programs on the US economy and a set of emerging market economies. First, I use a Bayesian structural VAR model to identify the US QE shocks over the period 2008-2021, and I document the effects of QE on the US economy. The aim is to capture the *stock effect* of QE, as discussed in Gambacorta et al. (2014). The results show positive statistically significant effects of QE on real GDP, real investment, the price level, and the stock market, and negative statistically significant effects on long-term government bond yields. With the structural shocks at hand, I use a panel Bayesian VAR model to study the effects of US QE on emerging market economies. The results for the emerging markets show positive statistically significant effects on real GDP, real investment, inflation, and the stock markets. In addition, long-term government bond yields tend to increase over time, while currencies appreciate in real terms and current accounts deteriorate.

I develop a two-country heterogeneous agents New Keynesian model to address the question of the distributional effects of QE in the US economy and the emerging market economies. The model is estimated to match the empirical responses derived in the empirical exercises, and is calibrated to match key distributional moments in both countries. The domestic country is assumed to be a small open economy that plays the role of an emerging market economy, such as Mexico, and the foreign country represents the US economy. In each country, households differ along two dimensions: labor income and exposure to financial assets. Labor earnings differ across households due to differences in idiosyncratic productivity which cannot be fully diversified away. Given that households start as identical ex-ante, this also leads to differences in asset holdings over time.

In the emerging market economy, households can build wealth by holding liquid deposits in domestic commercial banks and illiquid deposits in domestic investment banks. The commercial banks hold only the reserves issued by the domestic central bank, so the households who hold liquid deposits are only exposed to local currency assets. The investment banks, on the other hand, feature balance sheet currency mismatch since they can invest in domestic and foreign assets, and hold domestic and foreign liabilities, in line with the evidence on partially dollarized bank balance sheets in emerging market economies.[1] In this way, the wealthier households who can afford the illiquid asset are indirectly exposed to domestic and foreign assets. The model is calibrated to match the evidence on deposit dollarization in emerging markets.

In the foreign economy, households can also invest in liquid and illiquid assets. The liquid foreign asset is deposit holdings in a bank that invests in securities issued by entities of the foreign economy, such as government bonds and stocks. In contrast, the illiquid asset is deposits in a bank that holds deposits in the investment bank of the emerging market economy. In this way, foreign households who can invest in the illiquid asset get indirectly exposed to emerging market assets. This element is added to account for the capital inflows in emerging markets after expansionary QE shocks, as documented in Bhattarai et al. (2021).

The model is also enriched with financial frictions in asset intermediation similar to those in Gertler and Karadi (2011) in both countries. Financial frictions make quantitative easing effective in the US economy and provide amplification through the financial accelerator mechanism in both countries. Without such frictions, the asset pricing behavior of the banks in the US economy would be such that expected long-term and short-term interest rates would be equalized in equilibrium, and there would be no role for QE. In contrast, financial frictions generate spreads between short-term and long-term rates. The central bank's asset purchases, which take the form of long-term government bonds purchases, can reduce the spread on government bonds, leading the private banks to increase their investment in stocks. Stock prices increase and boost bank net worth even more. Higher capital investment propagates to the rest of the economy through the production sector. In addition, standard New Keynesian frictions, such as price and wage stickiness and investment adjustment costs, are added in both countries to account for the slow adjustment of prices, GDP, and investment.

The model aims first to highlight the international transmission mechanism at play after expansionary quantitative easing policies in the US economy. Second, the model aims to show how different households are affected in both countries and what the implied inequality effects are. Third, the model aims to show how the existence of constrained households with high marginal propensities to consume interacts with financial frictions and what the implications are for the transmission mechanism. The fourth and last aim of the model is to evaluate policies that would reduce the leverage in the banking sector in EMEs after a US expansionary QE shock.

First, I argue that the balance sheets of financial intermediaries in both countries are at the heart of the international transmission mechanism. Specifically, government bond prices and realized bond returns increase after a positive shock in central bank bond holdings in the US economy. Bank net worth rises,

[1] As an example see Hahm et al. (2013).

and the banks invest in stocks to substitute the more expensive bonds. The price of capital and the realized return on capital increase, boosting bank net worth even more. Then, as banks increase their capital holdings, investment increases, and output, inflation, and labor demand follow. In addition, higher asset prices and lower expected returns in the US economy incentivize households to increase initially their deposits in Mexican investment banks which pay higher interest rates.

The interest rate differentials between the two countries lead to a real currency appreciation. The appreciation of the currency, in turn, boosts the net worth of the Mexican banks since they have to pay less Mexican currency to US households for a given amount of dollars. In addition, Mexican banks hold bonds of the US government and earn higher realized returns at the time of the shock. Then they substitute these expensive bonds with domestic capital claims, leading to a higher stock market valuation, higher realized returns on capital, and higher net worth. Through a similar argument as in the US economy, aggregate demand and inflation rise. However, currency appreciation also deteriorates the current account-to-GDP ratio since it encourages imports and discourages exports.

Second, I examine how household heterogeneity in each country affects the previous results. I start by analyzing how the QE shock affects both economies, assuming that one economy has a representative agent and the other has heterogeneous agents. Then I also consider the pure representative agent model. The findings show that shutting off heterogeneity in either of the two countries can affect significantly the impulse response functions of both countries, and not only the country with a representative agent, because of the lower aggregate demand. Specifically, if any of the two countries have a representative agent instead of heterogeneous agents, then due to the absence of constrained households with high marginal propensities to consume, the increase in aggregate demand is weaker. A smaller increase in aggregate demand leads to a smaller increase in production and income. Also, the consumption of goods from the second country increases by a lower amount. This leads to lower aggregate demand, lower production, and lower consumption in the second country, which then negatively affects the first country by a similar argument.

If both countries have a represenative agent, then the negative aggregate demand effects created by the absence of constrained households are combined, resulting in the lowest positive effects in aggregate variables from QE, among all the cases examined. The pure RANK model, can produce qualitatively similar movements in aggregate variables to those found in the empirical exercise, except for the trade balance-to-GDP ratio, but these movements differ significantly in magnitude from the pure HANK model. Moreover, the pure RANK model cannot provide answers to distributional issues.

Third, I compute the distributional effects of QE in both economies. Regarding consumption inequality, the model predicts lower consumption inequality in both countries after a positive QE shock. However, the way this result is achieved is not symmetric across the two countries, since in Mexico, the share of the top

10% in the consumption distribution increases while in the US, it falls. The model also predicts an increase in wealth inequality in the short run for the US economy, but a decrease in the medium run, while in Mexico wealth inequality increases and remains elevated over time. More specifically, in the US economy, wealthier households initially accumulate more illiquid assets due to their higher returns and since they can afford the transaction costs associated with these assets. However, over time as the poorer households earn higher labor income, they start accumulating liquid assets aggressively since they need to start substituting consumption intertemporally. This behavior closes the wealth gap in the medium run. In the Mexican economy, liquid wealth inequality follows a very similar behavior, and falls over time as poorer households accumulate more liquid assets, even if both the richer and the poorer households are incentivized to accumulate due to the higher real returns on these assets, which results from the aggressive interest rate hikes of the central bank as inflation rises. However, wealthier households accumulate more illiquid assets due to the higher profits which increase the illiquid asset returns. The rise in illiquid asset holdings inequality increases the wealth inequality gap.

Lastly, I investigate the issue of over-levered banks in EMEs following a QE shock, which policymakers[2] worldwide have highlighted. Specifically, I introduce a capital controls tax on the foreign interest payments made by investment banks in Mexico. The tax follows a feedback rule which considers the current account-to-GDP ratio. I show that under a plausible parameterization, the adverse effects of this tax can be significant since it can lead to lower capital flows and lower economic activity in both countries because the tax rate reduces the net worth of the banks in Mexico, which leads to lower capital investment, lower output and lower demand for goods of the US economy. As a result, economic activity in the US economy is also reduced, which then affects negatively the Mexican economy and so on. In addition, I find that the regulated economy is not preferred by the households at the top and the bottom of the wealth distribution in Mexico, but it is preferred by the households in the respective wealth deciles in the US economy.

Related Literature: This paper is related to many different parts of the literature. Specifically, several papers study the effects of US QE shocks on EMEs in the empirical literature. Lavigne et al. (2014) is a comprehensive summarization of these studies. The EME methodology of this paper is closely related to the work of Bhattarai et al. (2021). However, I use a different identification method, a slightly different set of EMEs, and I also expand the dataset to include the QE response of the Federal Reserve during the pandemic period.

This paper is related to papers studying open economies using New Keynesian models, such as Corsetti and Pesenti (2001), Gali and Monacelli (2005), and Farhi and Werning (2014). These papers use models with frictionless financial markets and representative households, building on the earlier work of Obstfeld and Rogoff (1995). I depart from these papers by introducing frictions in financial intermediation and heterogeneous agents in both countries who cannot completely insure against their idiosyncratic shocks.

[2] See for instance Rajan (2014).

This paper is also related to papers using New Keynesian models with a banking sector, and financial frictions to explore the effects of quantitative easing policies on the economy, such as Gertler and Karadi (2011), Gertler and Karadi (2013), Dedola et al. (2013) and Sims et al. (2021). The first main difference in this paper is that I use this framework in a two-country HANK model and try to provide insights into how financial frictions and heterogeneity affect the determination of exchange rates and asset prices in small open economies. The second main difference is the concentration of this study on the distributional effects on residents of each of the two countries.

The focus of this paper is also related to the papers by Gourinchas (2018), Akinci and Queralto (2018), and Ahmed et al. (2021). Under different frameworks, these authors study the spillover effects of US conventional monetary policy on emerging markets economies. This study departs from this literature by concentrating on the spillover effects of unconventional monetary policy shocks and introducing heterogeneous households.

Finally, this study is related to the more general and growing HANK literature that combines incomplete market models with models that include nominal rigidities. Some indicative papers are Ravn and Sterk (2017), Kaplan et al. (2018), Auclert and Rognlie (2018), Auclert et al. (2018), Hagedorn et al. (2019), Auclert et al. (2021a), Auclert et al. (2020), and Dávila and Schaab (2022). However, these papers do not incorporate unconventional monetary policy and study closed economies. Other HANK models incorporating QE policies are Lee (2020), Cui and Sterk (2021), Kyriazis (2022), and Sims et al. (2022), but these papers also focus on a single closed economy. The last category of related models are the open economy HANK models recently developed by Guo et al. (2020), Auclert et al. (2021c), Oskolkov (2021), Zhou (2021), and Ferrante and Gornemann (2022). These papers focus on a single small open economy subject to external shocks, making specific assumptions for aggregate demand from abroad. Aggarwal et al. (2022) in a contemporaneous work, introduce a multi-country model with heterogeneous agents, but focus on fiscal policy and do not consider QE. To my knowledge, this paper studies the first two-country model with full heterogeneity in both countries and quantitative easing policies.

Paper Organization: The rest of the paper is organized in the following way. Section 2 contains the empirical analysis where US QE shocks are identified and then used to examine the spillover effects of QE on emerging market economies. Section 3 contains the two-country HANK model. Section 4 includes the calibration and estimation of the HANK model. Section 5 contains the quantitative analysis of the model where the international transmission mechanism, the role of household heterogeneity, and the distributional effects of QE are analyzed. Section 6 contains a capital controls counterfactual experiment which examines also the welfare effects of this policy. Section 7 concludes.

2 Empirical Results

In this section, I present a Bayesian structural VAR model for the US economy to examine the empirical responses of macro aggregate variables and asset prices to a pure quantitative easing shock. Then I use the identified structural shocks in a Bayesian panel VAR model for a group of emerging markets and examine the empirical responses of macro aggregate variables and asset prices to shocks in US QE.

2.1 Data

The data used in this section are quarterly data covering the period from the first quarter of 2008 until the fourth quarter of 2021. The series are seasonally adjusted using the X-11 method if not seasonally adjusted by the provider. The US data were collected from the FRED database and Refinitiv. The data for the emerging markets were collected from Refinitiv, the FRED database, and the IMF database. All the data used are expressed in natural logarithms, except for interest and inflation rates. The countries considered in the panel BVAR satisfy the following criteria: i) they are classified as emerging markets by the IMF for the decade 2010-2020, as documented in Duttagupta and Pazarbasioglu (2021), ii) they are small open economies and cannot affect international prices, iii) they did not experience sovereign debt or currency crises during the period of interest, iv) there are time series available for all the variables of interest covering the whole period of interest so that the panel dataset is perfectly balanced. The countries satisfying all four criteria are the following: Brazil, Chile, Colombia, Hungary, India, Indonesia, Malaysia, Mexico, Philippines, Poland, South Africa, Thailand, and Turkey.

2.2 US Structural BVAR

The model considered for the US is a structural Bayesian VAR with the following form

$$\mathbf{A}\mathbf{y_t} = \mathbf{B_0} + \mathbf{B_1}\mathbf{y_{t-1}} + ... + \mathbf{B_p}\mathbf{y_{t-p}} + \mathbf{u_t}, \tag{2.1}$$

where $\mathbf{y_t} = \left[Y_t,\ I_t,\ P_t,\ QE_t,\ i_t^B,\ Q_t\right]'$ is the vector containing the variables of the SVAR model, which in the baseline case are the real GDP denoted as Y_t, the amount of real investment denoted as I_t, the PCE index denoted as P_t,[3] the yield on 10-year inflation-indexed treasuries,[4] denoted as i_t^B, the securities held outright

[3]Using the PCE inflation rate does not alter the results in a significant way. However, later in the model is slightly more convenient to match the movements of the price level.

[4]The nominal 10-year yield on government bonds is not robust to changes in the hyperparameters of the model, and its response after a QE shock can be insignificant or even positive in some rare cases. The TIPS 10-year yield is robust to changes

on the balance sheet of the Federal Reserve denoted as QE_t, the S&P500 index denoted as Q_t. The federal funds rate is not included in the BVAR model since it has been pegged to zero for most periods under examination.[5]

The matrix A allows for simultaneous effects among the variables in vector $\mathbf{y_t}$. Moreover, $\mathbf{B_0}$ is a vector of constants and $\mathbf{B_j}$ for $j = 1, 2, ..., p$ is a matrix with the effects of the pth lag of the variables on current variables. Finally, $\mathbf{u_t}$ is a vector of orthogonal shocks with the following properties: $\mathbb{E}\left(\mathbf{u_t}\right) = 0$ and $\mathbb{E}\left(\mathbf{u_t}\mathbf{u_t}'\right) = \Gamma$, where Γ is a diagonal matrix. The identification method used is the triangular decomposition method, which imposes two sets of restrictions: i) the matrix of contemporaneous effects is lower triangular so that the variables preceding a shocked variable cannot respond immediately to the shock. In contrast, the variables following the shocked one can respond immediately to the shock, and ii) the matrix of contemporaneous effects has ones in its main diagonal, so that any shocked variable changes by one unit. In this experiment, the variables are put in the order they appear in vector $\mathbf{y_t}$. Macroeconomic aggregates such as real GDP, real investment, and the price level go first, assuming they cannot respond contemporaneously to a QE shock. Then, the 10-year nominal yield follows as it can respond to shocks on macro variables and monetary policy aggregates within the same period. The last variable is the stock market index, assuming it can respond to shocks in all previous variables.

The prior distribution used is the dummy observations prior, which allows the expression of a prior belief that variables contain a unit root and might be cointegrated. The values of the basic hyperparameters are the following: $\lambda_0 = 0.6$, $\lambda_1 = 0.03$, $\lambda_2 = 0.5$, $\lambda_3 = 1$, and the values of the hyperparameters for unit roots and cointegration are set equal to $\lambda_6 = \lambda_7 = 0.1$. These values are within the range of values suggested in Dieppe et al. (2016). The number of lags is set equal to $p = 2$ after comparing the DIC for different values of p. Given that the dataset starts in the first quarter of 2008, the series of extracted structural shocks starts in the third quarter of 2008. The draws from the posterior distribution are made using the Gibbs sampler: 50.000 draws are generated, and 20.000 are discarded. The model is estimated with the BEAR Toolbox as in Dieppe et al. (2016).

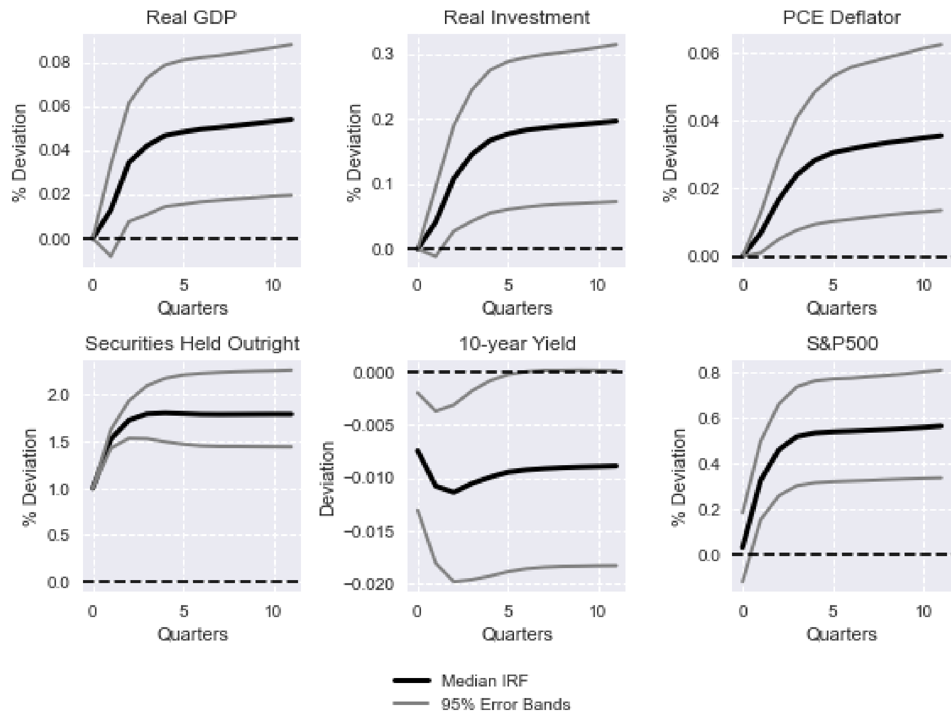
2.3 US Results

Figure 1 contains the median IRFs corresponding to a positive shock in QE_t, together with the 95% error bands. An increase in the securities held outright by the Federal Reserve by 1%, which translates to an increase of roughly 31.6 billion dollars on average for the period of interest, leads to an increase in GDP,

in hyperparameters and is used instead. In addition, ultimately, it is the real interest rate that matters for the response of the economy after the shock.

[5] Even if the federal funds rate or a proxy for the federal funds rate is used in the model, such as the shadow rate, as measured by Wu and Xia (2016), the results are not altered in a significant way.

Figure 1: Impulse Responses to 1% QE Shock in the Baseline Specification



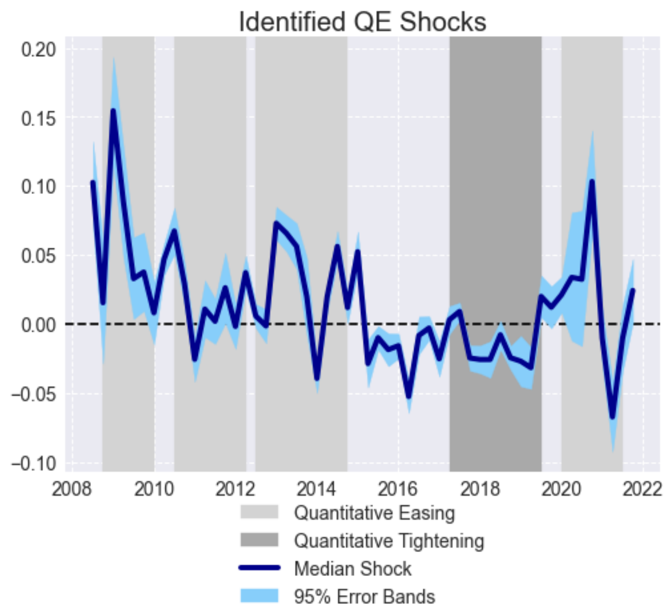
Notes: The above panels show the median IRFs and the corresponding 95% error bands of aggregate variables to a 1% positive QE shock. The identification method used to identify the structural shocks is the triangular decomposition method.

an increase in real investment, and an increase in the PCE index. Specifically, following the QE shock, the median increase in GDP is around 0.013% after one quarter. The positive effect on GDP is persistent, increasing over time because of the persistence in the response of the QE measure. Regarding real investment, one quarter after the shock, the positive effect is close to 0.042%. Investment continues to rise at a higher rate for two more quarters, and then the rate of increase falls. The positive effect is persistent. On the other hand, the PCE index increases by around 0.007% one quarter after the shock. The positive effect is persistent and increases slowly over time.

Turning to asset prices and asset returns, the QE shock leads to a decrease in the yields of 10-year bonds and a rise in the stock market index at the time of the shock. Specifically, the initial effect on the yield of the 10-year TIPS is a decline of around 0.7 percentage points. The maximum effect occurs after six quarters and is a decline of about 1.14 percentage points. Then, government bond yields slowly revert to their mean. On the stock market side, the S&P500 increases at the time of the shock by about 0.033%. The stock market index continues to increase over time and the positive effects take values close to 0.55%.

Figure 2 presents the identified QE shocks for the period of interest and the 95% error bands. The periods during which the various QE programs were announced and implemented are also included, with light grey

Figure 2: Identified QE Shocks to Securities Held Outright



Notes: The above graph shows the median identified structural QE shock in any period and the corresponding 95% error bands. The bars in light grey represent the expansionary QE programs of the Federal Reserve from the moment announced until the moment ended. The bar in darker grey represents QT.

for the periods where the Federal Reserve balance sheet was expanding and dark grey for the periods where the balance sheet was shrinking. Figure 2 shows significant positive QE shocks clearly distinguished from the rest for the period of interest during every QE program adopted by the Federal Reserve. The first shock occurred in Q1 of 2009, at the heart of the Great Financial Crisis. The second occurred in Q3 of 2010. Then there is a series of positive shock between Q1 of 2013 and Q1 2015. The last positive QE shock occured in Q4 of 2020, at the heart of the Great Lockdown Recession. There are also negative QE shock identified during the Quantitative Tightening period Q2 2017 and Q3 2019. The identified QE shocks reflect exogenous deviations in the securities held outright by the Federal Reserve to the linear rule assumed in the VAR model. The most considerable shock is the one associated with the first QE program when the Federal Reserve introduced big-scale long-term asset purchases. It is also worth noting that the shocks are estimated with a high level of precision since the error bands are tight.

2.4 Emerging Markets Panel BVAR

With the US quantitative easing structural shocks at hand, we can examine the effects of QE on emerging markets by introducing the shocks in a panel BVAR of the following form:

$$\mathbf{w_{i,t}} = \sum_{j=1}^{q} \mathbf{C_{i,j}} \mathbf{w_{i,t-j}} + \sum_{j=0}^{q} \mathbf{D_{i,j}} \mathbf{u_{QE,t-j}} + \mathbf{F_i} \mathbf{x_t} + \mathbf{v_{i,t}}, \tag{2.2}$$

where $\mathbf{w_{i,t}} = \left[Y_{i,t},\ I_{i,t},\ \pi_{i,t},\ CA_{i,t},\ M_{i,t},\ i^B_{i,t},\ E_{i,t},\ Q_{i,t} \right]$ is the vector of endogenous variables for country i, which includes the real GDP $Y_{i,t}$, real investment $I_{i,t}$, the CPI inflation rate $\pi_{i,t}$, the current account-to-GDP ratio $CA_{i,t}$, the M2 money supply $M_{i,t}$, the nominal yield on the 10-year government bonds[6] $i^B_{i,t}$, the real exchange rate $\mathcal{E}_{i,t}$, and the MSCI stock market index $Q_{i,t}$ expressed in local currency. The other regressors are the median identified US QE shocks $\mathbf{u_{QE,t-j}}$, and a vector $\mathbf{x_t}$ containing exogenous variables such as the global price index of commodities, which accounts for the fact that some countries in the panel are commodity exporters, indicator variables for European countries during the European debt crisis period, and the total production of OECD countries. Finally $\mathbf{v_{i,t}}$ is the shock with zero mean and a covariance matrix $\mathbf{\Sigma}$.

The identification method used is triangular decomposition. The variables are put in the order they are included in vector $\mathbf{w_{i,t}}$. Again, macroeconomic variables such as the GDP, investment, the inflation rate, and the current account-to-GDP ratio go first. It is also assumed that the central banks of emerging countries can respond to shocks in output and inflation within the period, so the money supply variable is next in order.[7] Then, the nominal yield on government bonds follows as it can respond to shocks on all previous variables. The real exchange rate, in turn, can respond to shocks in all previous variables and is the next variable in order. However, changing the order of the yields on government bonds and the real exchange rate does not alter the results in a significant way. The last variable is the MSCI stock market index, assuming that the stock market can respond to shocks in all previous variables.

A pooled estimator is used for the panel BVAR in the baseline case. Later, the results on a specific country based on a random effects estimator are also discussed. The values of the hyperparameters are $\lambda_0 = 0.6$, $\lambda_1 = 0.15$, $\lambda_2 = 0.5$, and $\lambda_3 = 1.25$. The number of lags is set equal to $p = 2$, given that the number of endogenous variables is relatively large. The draws from the posterior distribution are made using the Gibbs sampler: 50.000 draws are generated, and 20.000 are discarded.

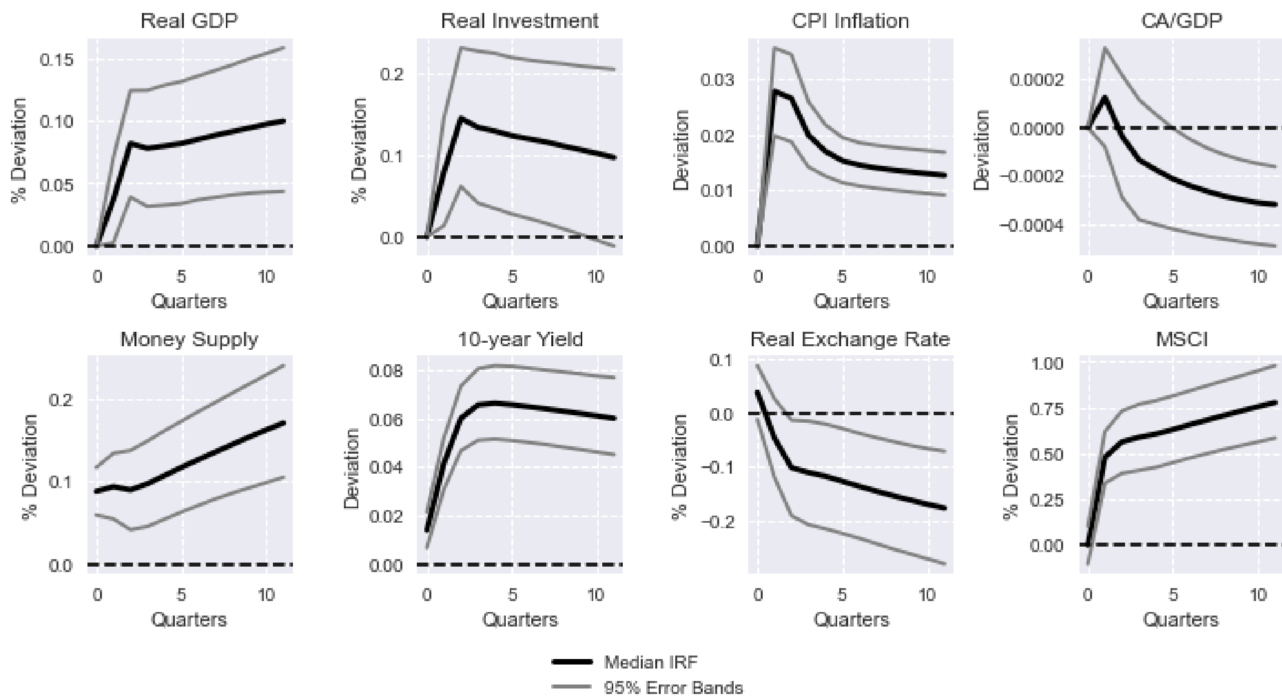
2.5 Emerging Markets Results

Figure 3 contains the IRFs corresponding to a positive QE shock. The shock leads to a statistically significant increase in the GDP of emerging market economies since the median response is close to 0.037% after one

[6]Here the nominal yield is used since for many of the emerging markets there was no data availability on inflation indexed bonds. Also, the time series of the 10-year yield for Turkey did not cover the whole period of interest, and for that reason the yield on the 5-year bond is used instead.

[7]The money supply variable is also used as a proxy for the QE measures that some emerging market countries implemented during the Great Lockdown Recession, given that QE is financed by reserve creation, which increases the money supply.

Figure 3: Panel response to 1% structural shock in US QE



Notes: The above panels show the median IRFs and the corresponding 95% error bands of aggregate variables in emerging markets to a 1% positive US QE shock.

quarter. The effects on GDP are persistent and keep increasing. The positive QE shock leads to an increase in real investment by 0.079% after one quarter. The maximum effect occurs two quarters after the QE shock with a magnitude of 0.145%. The QE shock also leads to an increase in CPI inflation. One quarter after the shock in QE, CPI inflation increases by around 2.8 percentage points, which is also the maximum effect. The response of inflation remains positive for several quarters after the QE shock, but over time it reverts to its mean value. The current account-to-GDP ratio declines over time, although the initial response is ambiguous. The decline could result from the currency appreciation as implied by the real exchange rate response.

On the other hand, QE leads to a persistent increase in the money supply. This could be a countermeasure from the side of emerging market economies to the QE shock that leads to an appreciation of foreign currencies. As for government bond yields, the QE shock leads to an initial increase in the 10-year yields, which implies lower bond prices. This result contrasts the previous empirical literature that reports a negative movement in long-term bond yields after a US QE shock. However, it is robust to changes in the number of lags, or the ordering of endogenous variables. This movement could result from higher inflation expectations induced by higher inflation. The previous literature has reported that inflation expectations are not well-anchored in the EMEs, so an increase in inflation could trigger expectations for higher inflation in the future, which could lead to an adjustment of the government bond yields to higher levels. The maximum effect on long-term yields occurs four quarters after the shock.

The response of the real exchange rates at the time of the QE shock is statistically insignificant. Nevertheless, the real exchange rates decline over time, implying a real appreciation. A simple UIP-style argument could explain this effect. Given that nominal yields on long-term government debt increase in the emerging markets and decrease in the US, investors choose to hold more securities of the emerging market economies, increasing the demand for emerging market currencies, which results in nominal appreciation. As long as the price levels between the EMEs and the US economy do not offset the nominal appreciation, there is also real appreciation. The effect on the real exchange rate is persistent and maximized after the 12 quarters, equaling 0.178%.

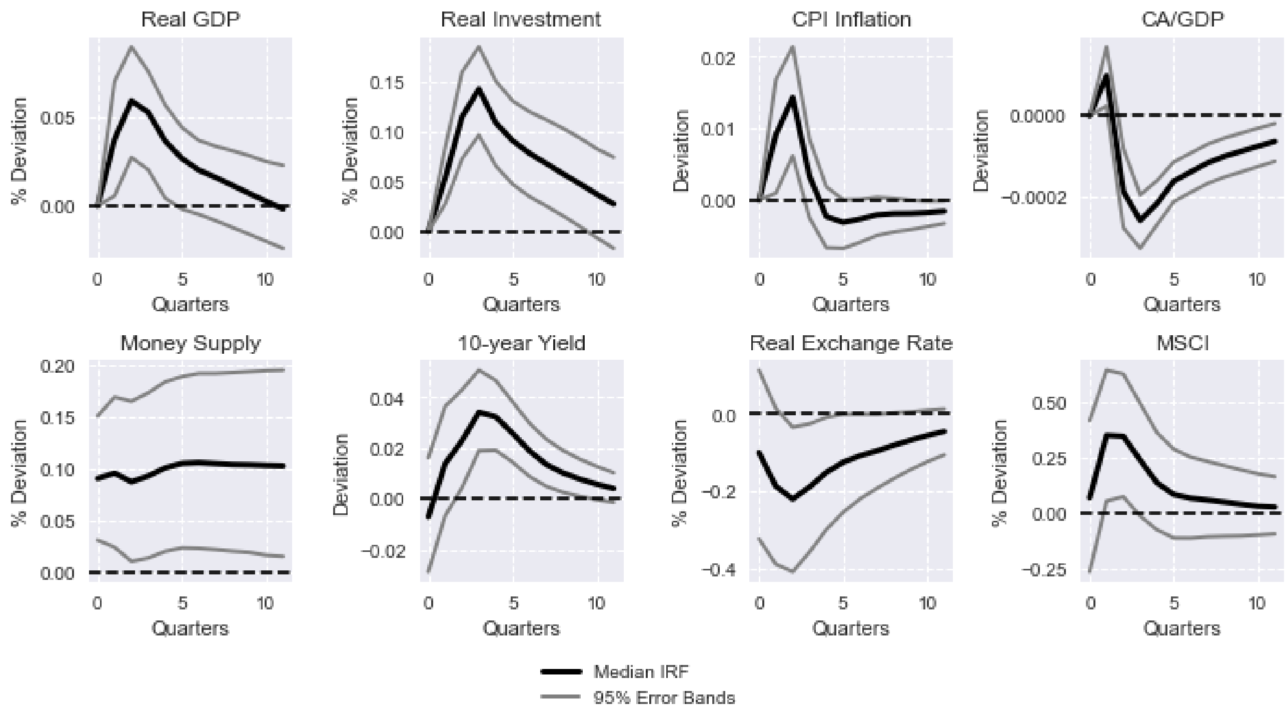
Finally, on the stock market side, the MSCI index movement at the time of the shock is statistically insignificant. However, the effect strengthens and becomes positive over time. After twelve quarters, the index remains elevated by 0.777%. The stock market movements could result from US investors searching for higher yields, given that bond prices in the US increase and expected returns fall.

2.6 The Case of Mexico

This subsection contains the results of the panel BVAR based on a hierarchical random effects estimator for the country of Mexico, which is the country that will be used later for the calibration and the estimation of the two-country model. The random effect estimator estimates a BVAR model for every country in the model, implying that the vector of endogenous variables contains too many variables for an individual VAR model. For that reason I follow the methodology of Bhattarai et al. (2021) and consider a baseline case in each country where the vector of endogenous variables contains five variables: $\tilde{\mathbf{w}}_{\mathbf{i,t}} = [Y_{i,t}, \pi_{i,t}, M_{i,t}, E_{i,t}, Q_{i,t}]$. Then, I re-estimate the individual models by adding one of the remaining variables from (2.2) at a time, in the same order considered in the previous subsection. In this part I use three lags for the variables of the BVAR model.

Figure 4 contains the IRFs for the Mexican economy after the shock in US QE. The QE shock in the US leads to a statistically significant increase in the GDP of Mexico. The median response of Mexican GDP is close to 0.038% after one quarter, while the maximum effect takes place after two quarters with a magnitude close to 0.059%. The effects on GDP decline and revert to zero over time. The QE shock also leads to an increase in real investment, which follows a similar path to real GDP. One quarter after the shock, investment increases by around 0.054%, and the maximum effect occurs after two quarters with a magnitude of around 0.143%. Next, CPI inflation increases by around 0.01 percentage points one quarter after the shock. The maximum effect occurs in the next quarter when CPI inflation increases by around 1.4 percentage points.

Figure 4: Aggregate responses in Mexico to 1% structural shock in US QE



Notes: The above panels show the median IRFs and the corresponding 95% error bands of aggregate variables in Mexico to a 1% positive US QE shock.

Inflation then quickly returns to values that are close to zero.

Regarding the current account-to-GDP ratio, this ratio falls, and the response remains negative over time. The maximum effect occurs three quarters after the QE shock. This could result from currency appreciation. In addition, the money supply increases over time and this could be a countermeasure to currency appreciation, in order to minimize the deterioration of the current account-to-GDP ratio.

Regarding asset prices and returns, the QE shock leads to an increase in the 10-year yields. This movement is similar to the one reported in the case of the pooled estimator. The maximum effect on the long-term yields occurs two quarters after the shock. On the other hand, the QE shock leads to a real appreciation of the Mexican peso. The initial effect on the real exchange rate is a change of -0.076%, although the initial movement is not statistically significant, while the maximum effect takes place after two quarters and is equal to -0.219%. On the stock market side, the MSCI index increases at the time of the shock by about 0.07%, but again this movement is not statistically significant. The effect is maximized in the next period, taking a value of around 0.353%. Over time the stock market index falls and reverts to its steady state value.

3 A Two-Country HANK Model

In this part I present a two-country HANK model which produces similar movements in macro aggregates and asset prices to those found in the empirical part for both the US economy and a typical emerging market economy. The goal of this model is to examine the distributional effects of a US QE shock in both countries, when the variables of interest follow similar paths to those implied by the previous BVAR models, and important distributional moments are matched. The model contains typical New-Keynesian frictions, such as nominal rigidities in prices and wages, and investment adjustment costs, to account for the slow adjustments in GDP investment and prices. However, the model is also enhanced with financial frictions in both countries, in order to generate differences in the returns of various assets and make QE effective.

3.1 Domestic Households

The demand side of the economy consists of infinitely-lived households indexed by $i \in [0,1]$. Households are assumed to be ex-ante identical but ex-post heterogeneous due to the evolution of their idiosyncratic productivity shock e_i, and their different holdings of illiquid and liquid assets, a_i and d_i. Each individual i derives utility from consumption c_i and disutility from labor supply l_i. In each period individuals choose consumption, labor supply and savings to maximize lifetime utility

$$\max_{\{c_{it}, l_{it}, a_{it}, d_{it}\}_{t=0}^{\infty}} U_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u\left(c_{it}\right) - v\left(l_{it}\right) \right] \tag{3.1}$$

subject to

$$c_{it} + d_{it} + a_{it} + \Xi\left(a_{it}, a_{it-1}\right) + \mathcal{T}_t = \left(1 - \tau^L\right) w_t l_{it} e_{it} + \frac{1 + i_{t-1}^D}{\Pi_t} d_{it-1} + \left(1 + r_t^A\right) a_{it-1} \tag{3.2}$$

$$\Xi\left(a_{it}, a_{it-1}\right) = \frac{\chi_1}{\chi_2} \left| \frac{a_{it} - \left(1 + r_t^A\right) a_{it-1}}{\left(1 + r_t^A\right) a_{it-1} + \chi_0} \right|^{\chi_2} \left[\left(1 + r_t^A\right) a_{it-1} + \chi_0 \right] \tag{3.3}$$

$$a_{it} \geq 0, \;\; d_{it} \geq \underline{d}. \tag{3.4}$$

Equation (3.1) is the period budget constraint written in real terms. Household i spends c_{it} for consumption goods, d_{it} for liquid assets, a_{it} for illiquid assets and $\mathcal{T}_t$ for lump-sum taxes. The saving decisions are constrained by the liquidity constraints given in (3.4). The decision for the illiquid asset is subject to a cost of adjustment which takes the form given in equation (3.3) with χ_0, $\chi_1 > 0$ and $\chi_2 > 1$.

Individuals finance the expenditures for consumption and savings with income earned from various sources. The first source is after-tax labor income $\left(1 - \tau^L\right) w_t l_{it} e_{it}$, where τ^L denotes a linear labor income tax, w_t denotes the real wage, l_{it} denotes the amount of labor supplied which is decided by a labor union for each individual, and e_{it} denotes the productivity shock received by household i. The latter is modeled as a Markov process with transition probability matrix $\Omega\left(e_{t+1}|e_t\right)$. Other sources of income are interest payments on previous liquid savings $\frac{1+i^D_{t-1}}{\Pi_t}d_{it-1}$, and previous illiquid savings $\left(1+r^A_t\right)a_{it-1}$. The interest rates in the previous terms are determined in equilibrium by the behavior of financial intermediaries. The tax rate τ^L as well as the lump-sum tax $\mathcal{T}_t$ are taken as given by the households. All households share the same utility per period utility function, which has the following form

$$u\left(c_t\right) - v\left(l_t\right) = \frac{c_t^{1-\sigma}-1}{1-\sigma} - \mu_L \frac{l_t^{1+\nu}}{1+\nu} \tag{3.5}$$

where c_t is a consumption basket of domestic and foreign goods[8] given as

$$c_t = \left[(1-\mu)^{\frac{1}{\eta}} c_{Ht}^{\frac{\eta-1}{\eta}} + \mu^{\frac{1}{\eta}} c_{Ft}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{3.6}$$

In the utility expression, σ is the coefficient of relative risk aversion, ν is the inverse Frisch elasticity of labor supply. In the definition of the consumption aggregator μ is the familiar measure of the openness of the economy, and η is the elasticity of substitution between domestic and foreign goods. It is well known that the demand functions for domestic and foreign goods satisfy the optimality conditions

$$c_{Ft} = \mu\left(\frac{P_{Ft}}{P_t}\right)^{-\eta} c_t \tag{3.7}$$

$$c_{Ht} = (1-\mu)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta} c_t, \tag{3.8}$$

where in the previous expressions P_{Ft} is the price level of foreign goods in domestic currency units, P_{Ht} is the price level of domestic goods, and P_t is the general price level. This index, in turn, is defined by

$$P_t \equiv \left[(1-\mu)P_{Ht}^{1-\eta} + \mu P_{Ft}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{3.9}$$

The law of one price is assumed to hold at the good level: producer currency pricing holds, so there is full pass-through of exchange rates to foreign currency prices. Hence,

$$P_{Ft} = \mathcal{E}_t P^*_{Ft} \tag{3.10}$$

$$P^*_{Ht} = \frac{P_{Ht}}{\mathcal{E}_t}, \tag{3.11}$$

[8] At this point the subscript i is dropped to facilitate exposition. However the expressions still refer to any household i.

where $\mathcal{E}_t$ is the nominal exchange rate. The real exchange rate is defined by

$$E_t = \frac{\mathcal{E}_t P_t^*}{P_t}. \tag{3.12}$$

Moreover, the terms of trade for the domestic country are given by

$$S_t = \frac{P_{Ft}}{P_{Ht}} \tag{3.13}$$

Using the law of one price and the definitions of the terms of trade and the real exchange rate, the terms of trade can be expressed as a function of the real exchange rate as follows

$$S_t = \left[\frac{\mu^* - (1-\mu) E_t^{1-\eta}}{\mu E_t^{1-\eta} - (1-\mu^*)} \right]^{\frac{1}{1-\eta}}. \tag{3.14}$$

3.2 Labor Unions

Labor unions are introduced as a way to allow for sticky wages in the model economy. Each household i provides differentiated labor services $l_{it}e_{it}$ to a labor union and then the union sells these labor services to a representative and competitive labor recruiting firm. The labor recruiter demands the same amount of differentiated labor as the intermediate goods producers. The problem of the labor recruiter is to minimize the cost of producing a given amount of aggregate labor:

$$\min_{l_{it}} \mathcal{C}_t^{LR} = \int_0^1 W_{it} l_{it} e_{it} di \tag{3.15}$$

subject to the technology constraint

$$L_t = \left[\int_0^1 (l_{it})^{\frac{\varepsilon_w - 1}{\varepsilon_w}} e_{it} \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}}, \tag{3.16}$$

where ε_w is the elasticity of substitution between differentiated labor services. The demand of the labor recruiter for each differentiated labor service is

$$l_{it} = \left(\frac{W_{it}}{W_t} \right)^{-\varepsilon_w} L_t, \tag{3.17}$$

where in the last equation $W_t = \left[\int_0^1 e_{it} W_{it}^{1-\varepsilon_w} \right]^{\frac{1}{1-\varepsilon_w}}$ is the equilibrium nominal wage. The labor union picks the same nominal wage $W_{it} = \hat{W}_t$ for all households to maximize profits, subject to a wage adjustment cost à la Rotemberg (1982). The cost is proportional to the amount of total effective labor L_t and is denoted as $\Xi^w\left(W_t, W_{t-1}, L_t\right)$. The problem of the union can be expressed as

$$V_t^w\left(\hat{W}_{t-1}\right) \equiv \max_{\hat{W}_t}\left\{\int \frac{e_{it}\left(1-\tau^L\right)\hat{W}_t}{P_t} l\left(\hat{W}_t; W_t, L_t\right) di - \frac{v\left(l\left(\hat{W}_t; W_t, L_t\right)\right)}{u'\left(C_t\right)}\right.$$
$$\left. - \int \frac{\xi_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - 1\right)^2 L_t e_{it} di + \frac{V_{t+1}^w\left(\hat{W}_t\right)}{1+r_{t+1}}\right\}. \tag{3.18}$$

In the previous equation $V_t^w(.)$ is the value function of the union, r_{t+1} is the real interest rate[9] in period $t+1$ and ξ_w is a parameter that determines the magnitude of the cost of adjusting wages. In the special case that $\xi_w = 0$, wages are fully flexible. In equilibrium $\hat{W}_t = W_t$ and $l_{it} = L_t$. The optimality condition for the union's problem is a Phillips curve relation for wages:

$$\left(1-\tau^L\right)\left(1-\varepsilon_w\right) w_t + \varepsilon_w \frac{v'\left(l\left(W_t, L_t\right)\right)}{u'\left(C_t\right)} + \frac{1}{1+r_{t+1}} \xi_w\left(\Pi_{t+1}^w - 1\right)\Pi_{t+1}^w \frac{L_{t+1}}{L_t} = \xi_w\left(\Pi_t^w - 1\right)\Pi_t^w. \tag{3.19}$$

where in equation (3.19) nominal wage inflation can be written as

$$\Pi_t^w = \Pi_t \frac{w_t}{w_{t-1}}. \tag{3.20}$$

3.3 Commercial Banks

The first type of financial intermediaries in the economy is commercial banks. There is a continuum of commercial banks indexed by $b \in [0,1]$. Each bank collects part of the liquid savings D_{bt} of households and issues deposits that pay a nominal return $\left(1+i_t^D\right)$ subject to an exogenous cost of financial intermediation that lowers in equilibrium the real return on the liquid asset. These deposits are invested in nominal reserves controlled by the central bank. The balance sheet constraint of a commercial bank in real terms is

$$M_{bt} = D_{bt} + N_{bt}, \tag{3.21}$$

where N_{bt} is the real net worth of commercial bank b. The budget constraint of a commerical bank is

$$M_{bt} + \left(\frac{1+i_{t-1}^D}{\Pi_t} + \xi_D\right) D_{bt-1} = \left(\frac{1+i_{t-1}^M}{\Pi_t}\right) M_{bt-1} + D_{bt} \tag{3.22}$$

[9]Since the experiments studied here are perfect foresight experiments after one-time MIT-type aggregate shocks in period $t=0$, the real interest rate can be used as the global discount factor for every agent different than households.

The combination of the balance sheet constraint with the budget constraint gives the net worth evolution equation which expresses net worth as the difference between interest rate payments received on previous central bank reserves and the interest paid on households' previous deposits

$$N_{bt} = \left(\frac{1+i^M_{t-1}}{\Pi_t}\right) M_{bt-1} - \left(\frac{1+i^D_{t-1}}{\Pi_t} + \xi_D\right) D_{bt-1}. \tag{3.23}$$

The real return on any asset j is defined by the Fisher equation

$$1 + r^j_t = \frac{1+i^j_{t-1}}{\Pi_t}. \tag{3.24}$$

The problem of a commercial bank is to pick optimally the amount of real reserves M_{bt} to hold, and the amount of real deposits D_{bt} to issue so as to maximize the present discounted value of the weighted average of net worth in the next period and the continuation value in the next period, where the weighting scheme consists of the corresponding probabilities of exiting the market and continuing operating in the market for one more period:

$$V_{bt}\left(N_{bt}\right) = \max_{M_{bt}, D_{bt}} \left\{\frac{1}{1+r_{t+1}}\left[\left(1-\theta_b\right) N_{bt+1} + \theta_b V_{bt+1}\left(N_{bt+1}\right)\right]\right\} \tag{3.25}$$

subject to equations (3.21), (3.23).

Proposition 1: *The commercial bank's value function is linear in net worth and satisfies*

$$V_{bt}\left(N_{bt}\right) = \Sigma_t N_{bt} \text{ with } \Sigma_t = 1. \tag{3.26}$$

Proof: See Appendix B.1. ■

Using the two constraints (3.21) and (3.23) in equation (3.25), and the definition in (3.24), the optimality condition for the commercial bank is

$$r_{t+1} = r^D_{t+1} + \xi_D. \tag{3.27}$$

Equation (3.27) says that the financial intermediaries will accumulate reserves until the expected real return on reserves equals the expected real cost of deposits. Due to the financial intermediation cost the real return on deposits is lower in equilibrium than the real interest rate. Finally we can aggregate the individual net worth evolution equation (3.23) over b by taking into account the survival rate θ_b together with the fact that new banks, when entering the market, get a transfer $\omega_b M_{t-1}$. In this way we get the equation for total net worth evolution written at the end of period t as:

$$N_t = \theta_b \left[(1 + r_t) M_{t-1} - \left(1 + r_t^D + \xi_D \right) D_{t-1} \right] + \omega_b M_{t-1}. \tag{3.28}$$

The profits of the commercial banking sector are given by

$$\Pi_{bt} = (1 - \theta_b) \left[(1 + r_t) M_{t-1} - \left(1 + r_t^D + \xi_D \right) D_{t-1} \right] - \omega_b M_{t-1}. \tag{3.29}$$

The above expression is just the total net worth of exiting banks minus the resources given to new banks. Part of the profits of the commercial banks is taxed by the government at a rate τ^D. The remaining part is given to the mutual fund which owns the commercial banks.

3.4 Investment Fund

In the economy there is a hypothetical investment fund which collects the illiquid savings of households A_t and invests these resources in deposits issued by investment banks. The investment fund is the owner of all firms and collects the profits. In equilibrium it pays a real return to households r_t^A subject to a cost of intermediation ξ_A. The balance sheet of the investment fund is

$$A_t = F_t, \tag{3.30}$$

where F_t is the real deposits of the investment fund in the investment banks. The budget constraint is

$$F_t + \left(1 + r_t^A + \xi_A \right) A_{t-1} = \left(1 - \tau^D \right) \mathcal{D}_t + A_t + \left(1 + r_t^F \right) F_{t-1}, \tag{3.31}$$

where $\mathcal{D}_t$ is the aggregate profits of all firms in the economy taxed at the rate τ^D. The mutual fund is assumed to operate under a no-retained earnings rule. This, together with the balance sheet constraint imply that in equilibrium the real return paid to households is

$$r_t^A = \frac{\left(1 - \tau^D \right) \mathcal{D}_t}{A_{t-1}} + r_t^F - \xi_A. \tag{3.32}$$

3.5 Investment Banks

The second type of financial intermediary in the home country is investment banks. This is modeled in a way similar to Gertler and Karadi (2011) and Gertler and Karadi (2013). There is a continuum of financial intermediaries indexed by $n \in [0,1]$. Each bank collects part of the investment fund's deposits $\mathcal{F}_{nt}^{MF}$ and pays a nominal return on these savings in the next period equal to $(1+i_t^F)$. It also collects deposits from the banks of the foreign economy $\mathcal{H}_t^* \mathcal{E}_t$ and pays a nominal return $\left(1+i_t^{H^*}\right)\mathcal{E}_{t+1}$ in the next period. With these funds available, the investment bank invests in domestic government bonds $\mathcal{B}_{nt}^{MF}$ with price q_t that pay a nominal return $(1+i_t^B)$, capital claims issued by the intermediate goods firms $P_t K_{nt+1}^{MF}$ with price Q_t, and foreign government bonds $\mathcal{B}_{nt}^{*MF}$ with price q_t^* that pay a nominal return $\left(1+i_t^{B^*}\right)$. The balance sheet constraint of each financial intermediary in real terms is

$$Q_t K_{nt}^{MF} + q_t B_{nt}^{MF} + q_t^* B_{nt}^{*MF} E_t = F_{nt}^{MF} + H_{nt}^* E_t + N_{nt}^{MF}. \tag{3.33}$$

The budget cosntraint in real terms has the following form

$$\begin{aligned} Q_t K_{nt}^{MF} + q_t B_{nt}^{MF} + q_t^* B_{nt}^{*MF} E_t + \left(1+r_t^F\right) F_{nt-1}^{MF} + \left(1+r_t^{H^*}\right) H_{nt-1}^* E_t \\ = \left(1+r_t^K\right) Q_{t-1} K_{nt-1}^{MF} + \left(1+r_t^B\right) q_{t-1} B_{nt-1}^{MF} + \left(1+r_t^{B^*}\right) q_{t-1}^* B_{nt-1}^{*MF} E_t + F_{nt}^{MF} + H_{nt}^* E_t \end{aligned} \tag{3.34}$$

The combination of the previous two equations gives the evolution of net worth in every period, which is described by the difference on interest rate payments received on assets with the interest paid on liabilities

$$\begin{aligned} N_{nt}^{MF} = \left[\left(1+r_t^K\right) - \left(1+r_t^F\right)\right] Q_{t-1} K_{nt-1}^{MF} + \left[\left(1+r_t^B\right) - \left(1+r_t^F\right)\right] q_{t-1} B_{nt-1}^{MF} + \left(1+r_t^F\right) N_{nt-1}^{MF} \\ + \left[\left(1+r_t^{B^*}\right)\frac{E_t}{E_{t-1}} - \left(1+r_t^F\right)\right] q_{t-1}^* B_{nt-1}^{*MF} E_{t-1} + \left[\left(1+r_t^F\right) - \left(1+r_t^{H^*}\right)\frac{E_t}{E_{t-1}}\right] H_{nt-1}^* E_{t-1}. \end{aligned} \tag{3.35}$$

In each period a fraction of banks θ^{MF} continues to operate, while the remaining fraction $1-\theta^{MF}$ exits the market. The banking sector is characterized also by a moral hazard problem. In each period a bank can declare bankruptcy and get away with part of the assets. A banker will avoid diverting the assets when the value from continuing operating in financial intermediation and investment V_{nt}^{MF} is greater or equal than the value obtained from diverting the assets. Putting all the previous together, we can express the problem of a bank as follows:

$$V_{nt}^{MF}\left(N_{nt}^{MF}\right) = \max_{K_{nt}^{MF}, B_{nt}^{MF}, B_{nt}^{*MF}, H_{nt}^*} \left\{\frac{1}{1+r_{t+1}}\left[\left(1-\theta^{MF}\right) N_{nt+1}^{MF} + \theta^{MF} V_{nt+1}^{MF}\left(N_{nt+1}^{MF}\right)\right]\right\} \tag{3.36}$$

subject to equations (3.33) and (3.35), and the incentive constraint

$$V_{nt}^{MF}\left(N_{nt}^{MF}\right) \geq \lambda_K Q_t K_{nt}^{MF} + \lambda_B q_t B_{nt}^{MF} + \lambda_{B^*} q_t^* B_{nt}^{*MF} E_t \left(1 + \frac{\xi_{B^*}}{2} \frac{q_t^* B_{nt}^{*MF} E_t}{Q_t K_t^{MF}}\right) \tag{3.37}$$

The last term in the right-hand side of (3.37) is quadratic. This formulation induces an interior solution for the bank's choice of B_{nt}^{*MF}, without affecting the qualitative insights obtained from the linear case.

Proposition 2: *The investment bank's value function is linear in net worth and satisfies*

$$V_{nt}^{MF}\left(N_{nt}^{MF}\right) = \Sigma_t^{MF} N_{nt}^{MF} \tag{3.38}$$

$$\Sigma_t^{MF} = \frac{\lambda_B}{\lambda_B - \frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)\left(r_{t+1}^B - r_{t+1}^F\right)} \frac{1+r_{t+1}^F}{1+r_{t+1}} \left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right). \tag{3.39}$$

Proof: See Appendix B.2. ■

The optimality conditions corresponding to the bank's problem consist of the bank budget constraint and:

$$(1+\Theta_t)\frac{1}{1+r_{t+1}}\left(1-\theta_b+\theta_b\Sigma_{t+1}^{MF}\right)\left(r_{t+1}^K - r_{t+1}^F\right) = \Theta_t\left[\lambda_K - \lambda_{B^*}\frac{\xi_{B^*}}{2}\left(\frac{q_t^* B_{nt}^{*MF} E_t}{Q_t K_t^{MF}}\right)^2\right] \tag{3.40}$$

$$(1+\Theta_t)\frac{1}{1+r_{t+1}}\left(1-\theta_b+\theta_b\Sigma_{t+1}^{MF}\right)\left(r_{t+1}^B - r_{t+1}^F\right) = \Theta_t\lambda_B \tag{3.41}$$

$$(1+\Theta_t)\frac{1}{1+r_{t+1}}\left(1-\theta_b+\theta_b\Sigma_{t+1}^{MF}\right)\left[\left(1+r_{t+1}^{B^*}\right)\frac{E_{t+1}}{E_t} - \left(1+r_{t+1}^F\right)\right] = \Theta_t\lambda_{B^*}\left(1+\xi_{B^*}\frac{q_t^* B_{nt}^{*MF} E_t}{Q_t K_t^{MF}}\right) \tag{3.42}$$

$$(1+\Theta_t)\frac{1}{1+r_{t+1}}\left(1-\theta_b+\theta_b\Sigma_{t+1}^{MF}\right)\left[\left(1+r_{t+1}^F\right) - \left(1+r_{t+1}^{H^*}\right)\frac{E_{t+1}}{E_t}\right] = 0 \tag{3.43}$$

From the above equations it can be deduced that if the incentive constraint binds then the expected returns among various assets will be different in equilibrium. The amount of capital claims held by the banks is determined by the aggregate incentive constraint

$$K_t^{MF} = \frac{1}{\lambda_K Q_t}\left[\Sigma_t^{MF} N_t^{MF} - \lambda_B q_t B_t^{MF} - \lambda_{B^*} q_t^* B_{nt}^{*MF} E_t \left(1 + \frac{\xi_{B^*}}{2}\frac{q_t^* B_{nt}^{*MF} E_t}{Q_t K_t^{MF}}\right)\right] \tag{3.44}$$

Finally we can aggregate the individual net worth evolution equation (3.35) over n, and take into account the survival rate θ^{MF} and the fact that new banks get a transfer $\omega^{MF}\left(Q_{t-1}K_{t-1}^{MF}+q_{t-1}B_{t-1}^{MF}+q_{t-1}^{*}B_{t-1}^{*MF}E_{t-1}\right)$ which is a fraction of the total assets held by banks in the previous period. Then, total net worth evolution written at the end of period t is

$$
\begin{aligned}
N_t^{MF} = \theta^{MF}\Big\{ & \left[\left(1+r_t^K\right)-\left(1+r_t^F\right)\right]Q_{t-1}K_{t-1}^{MF}+\left[\left(1+r_t^B\right)-\left(1+r_t^F\right)\right]q_{t-1}B_{t-1}^{MF}+\left(1+r_t^F\right)N_{t-1}^{MF} \\
& +\left[\left(1+r_t^{B^*}\right)\frac{E_t}{E_{t-1}}-\left(1+r_t^F\right)\right]q_{t-1}^{*}B_{t-1}^{*MF}E_{t-1}+\left[\left(1+r_t^F\right)-\left(1+r_t^{H^*}\right)\frac{E_t}{E_{t-1}}\right]H_{t-1}^{*MF}E_{t-1}\Big\} \\
& +\omega^{MF}\left(Q_{t-1}K_{t-1}^{MF}+q_{t-1}B_{t-1}^{MF}+q_{t-1}^{*}B_{t-1}^{*MF}E_{t-1}\right)
\end{aligned}
\tag{3.45}
$$

The profits of the investment banks are given by

$$
\mathcal{D}_t^{MF}=\frac{1-\theta^{MF}}{\theta^{MF}}N_t^{MF}-\frac{\omega^{MF}}{\theta^{MF}}\left(Q_{t-1}K_{t-1}^{MF}+q_{t-1}B_{t-1}^{MF}+q_{t-1}^{*}B_{t-1}^{*MF}E_{t-1}\right). \tag{3.46}
$$

The above expression is just the total net worth of existing banks minus the funds given to new banks. Part of the profits of the financial sector is taxed at a rate τ^D. The remaining part is given to the investment fund.

3.6 Final Goods Producers

Perfectly competitive firms in the final good sector produce the final good Y_{Ht} using as inputs a continuum of intermediate goods Y_{Ht}^j with $j\in[0,1]$. They take as given the input prices and choose the quantities of intermediate goods to maximize profits

$$
\max_{Y_{Ht}^j}\ \mathcal{D}_t^F=P_{Ht}Y_{Ht}-\int_0^1 P_{Ht}^jY_{Ht}^j dj \tag{3.47}
$$

subject to

$$
Y_{Ht}=\left[\int_0^1\left(Y_{Ht}^j\right)^{\frac{\varepsilon_p-1}{\varepsilon_p}}dj\right]^{\frac{\varepsilon_p}{\varepsilon_p-1}}, \tag{3.48}
$$

where P_{Ht}^j is the price of intermediate good j. The solution to the above problem is standard

$$
Y_{Ht}^j=\left(\frac{P_{Ht}^j}{P_{Ht}}\right)^{-\varepsilon_p}Y_{Ht}. \tag{3.49}
$$

3.7 Intermediate Goods Producers

There is a continuum of firms in the intermediate goods sector indexed by $j \in [0,1]$. Each firm j has access to the same CRS production technology which combines labor L_t^j, capital K_{t-1}^j, and total factor productivity Z_t to produce output Y_{Ht}^j:

$$Y_{Ht}^j = Z_t \left(K_{t-1}^j\right)^{\alpha} \left(L_t^j\right)^{1-\alpha} \tag{3.50}$$

Intermediate goods producers hire capital and labor in perfectly competitive markets in a way that minimizes the cost of production

$$\min_{K_{t-1}^j, L_t^j} \mathcal{C}_t^j = w_t L_t^j + \left(1 + r_t^K\right) Q_{t-1} K_{t-1}^j - \left(Q_t - \delta\right) K_{t-1}^j \tag{3.51}$$

The cost minimization is subject to the production function (3.50). The optimality conditions are

$$r_t^K = \frac{1}{Q_{t-1}} \left(\alpha \frac{Y_{Ht}^j}{K_{t-1}^j} \mathrm{MC}_t + Q_t - \delta\right) - 1 \tag{3.52}$$

$$w_t = (1-\alpha) \frac{Y_{Ht}^j}{L_t^j} \mathrm{MC}_t \tag{3.53}$$

$$\mathrm{MC}_t = \left(\frac{r_t^K}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}. \tag{3.54}$$

In the previous equations MC_t is the real marginal cost of production. Total cost is then

$$\mathcal{C}_t^j = \left(1 + r_t^K\right) Q_{t-1} K_{t-1}^j - \left(Q_t - \delta\right) K_{t-1}^j + w_t L_t^j = \mathrm{MC}_t Y_{Ht}^j. \tag{3.55}$$

Intermediate goods producers also pick the price of their products subject to the demand for intermediate inputs from the side of the final good producers as given in (3.49). However, every time they adjust their prices they have to undertake a price adjustment cost à la Rotemberg (1982), which is denoted here as $\Xi_t^P \left(P_{Ht}^j, P_{Ht-1}^j, \Pi_{Ht-1}, Y_{Ht}\right)$. This cost is proportional to the final good. The optimal pricing problem is

$$V_t^j \left(P_{Ht-1}^j\right) = \max_{P_{Ht}^j} \left\{ \left(\frac{P_{Ht}^j}{P_t} - \mathrm{MC}_t\right) \left(\frac{P_{Ht}^j}{P_{Ht}}\right)^{-\varepsilon_p} Y_{Ht} - \frac{\xi_p}{2} \left(\frac{P_{Ht}^j}{P_{Ht-1}^j} - \Pi_{Ht-1}^{\zeta} \Pi_H^{1-\zeta}\right)^2 \frac{P_{Ht}}{P_t} Y_{Ht} + \frac{V_{t+1}^j \left(P_{Ht}^j\right)}{1 + r_{t+1}} \right\} \tag{3.56}$$

In the previous equation $\Pi_H = 1$ is the steady state gross inflation rate. Also, ζ measures how strong the backward looking behavior of the firms is when setting prices in an equivalent Calvo price-setting setup. In equilibrium $P^j_{Ht} = P_{Ht}$, so the optimality condition for the optimal pricing problem gives rise to a New Keynesian Phillips Curve augmented with a backward looking inflation term

$$(1-\varepsilon_p)\frac{P_{Ht}}{P_t}+\varepsilon_p \mathrm{MC}_t+\frac{1}{1+r_{t+1}}\xi_p\left(\Pi_{Ht+1}-\Pi^{\zeta}_{Ht}\Pi^{1-\zeta}_{H}\right)\Pi_{Ht+1}\frac{Y_{Ht+1}}{Y_{Ht}}\frac{P_{Ht+1}}{P_{t+1}}=\xi_p\left(\Pi_{Ht}-\Pi^{\zeta}_{Ht-1}\Pi^{1-\zeta}_{H}\right)\Pi_{Ht}\frac{P_{Ht}}{P_t}. \tag{3.57}$$

In the special case $\xi_p = 0$ prices are flexible and real marginal cost is $\mathrm{MC}_t = \frac{\varepsilon_p - 1}{\varepsilon_p}\frac{P_{Ht}}{P_t}$. The dividend paid is

$$\mathcal{D}^{IG}_t = Y_{Ht}\left[\frac{P_{Ht}}{P_t} - \mathrm{MC}_t - \frac{\xi_p}{2}\left(\frac{P_{Ht}}{P_{Ht-1}} - \Pi^{\zeta}_{Ht-1}\Pi^{1-\zeta}_{H}\right)^2\frac{P_{Ht}}{P_t}\right] \tag{3.58}$$

Part of the dividends is taxed at rate τ^D. The remaining part is given to the investment fund.

3.8 Capital Producers

A representative firm buys the capital stock at the end of any period t, builds new capital to replenish the depreciated capital, and then sells the total amount of capital to the intermediate goods producers for a price Q_t. New capital is built in each period t by undertaking investment I_{nt} subject to increasing and convex investment adjustment costs denoted as $\Xi^I_t\left(I_{nt}, I_{nt-1}\right)$. The objective of the capital producing firm is

$$\max_{I_{nt}}\sum_{s=t}^{\infty}\left(\prod_{k=1}^{j|_{j\geq 1}}\frac{1}{1+r_{t+k}}\right)\left[\left(Q_s-1\right)I_{ns}-\frac{P_{Ht}}{P_t}\frac{\xi_I}{2}\left(\frac{I_{ns}+I}{I_{ns-1}+I}-1\right)^2\left(I_{ns}+I\right)\right] \tag{3.59}$$

where new and total investment satisfy the law of motions

$$I_{nt} = I_t - \delta K_{t-1} \tag{3.60}$$

$$I_t = K_t - (1-\delta)K_{t-1}. \tag{3.61}$$

The optimality condition is

$$Q_t+\frac{1}{1+r_{t+1}}\frac{P_{Ht+1}}{P_{t+1}}\xi_I\left(\frac{I_{nt+1}+I}{I_{nt}+I}-1\right)\left(\frac{I_{nt+1}+I}{I_{nt}+I}\right)^2 = 1+\frac{P_{Ht}}{P_t}\left[\xi_I\left(\frac{I_{nt}+I}{I_{nt-1}+I}-1\right)\frac{I_{nt}+I}{I_{nt-1}+I}+\frac{\xi_I}{2}\left(\frac{I_{nt}+I}{I_{nt-1}+I}-1\right)^2\right]. \tag{3.62}$$

Also, I_t is a basket of domestic and foreign investment goods given as

$$I_t = \left[(1-\mu)^{\frac{1}{\eta}} I_{Ht}^{\frac{\eta-1}{\eta}} + \mu^{\frac{1}{\eta}} I_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \tag{3.63}$$

The demand functions for domestic and foreign investment goods satisfy the optimality conditions

$$I_{Ft} = \mu \left(\frac{P_{Ft}}{P_t} \right)^{-\eta} I_t \tag{3.64}$$

$$I_{Ht} = (1-\mu) \left(\frac{P_{Ht}}{P_t} \right)^{-\eta} I_t, \tag{3.65}$$

Part of the dividends of the capital producers is taxed at rate τ^D. The rest is given to the investment fund.

3.9 Monetary Authority

The central bank is conducting monetary policy by changing the nominal interest rate on reserves i_t^M and by purchasing government debt $q_t \mathcal{B}_t^{CB}$, and firms equity claims $P_t Q_t K_t^{CB}$. The central bank balance sheet in real terms takes the following form

$$q_t B_t^{CB} + Q_t K_t^{CB} + (1+r_t) M_{t-1} + T_t^{CB} = \left(1 + r_t^B\right) q_{t-1} B_{t-1}^{CB} + \left(1 + r_t^K\right) Q_{t-1} K_{t-1}^{CB} + M_t, \tag{3.66}$$

where T_t^{CB} is the real lump-sum transfer between the monetary authority and the fiscal authority. The central bank behavior is described by policy rules. The nominal rate on reserves is given by a Taylor rule

$$1 + i_t^M = \max \left\{ (1+r)^{1-\rho} \left(1 + i_{t-1}^M\right)^{\rho} \left(\frac{\Pi_t}{\Pi} \right)^{(1-\rho)\phi_\Pi} \left(\frac{Y_{Ht}}{Y_H} \right)^{(1-\rho)\phi_{Y_H}} \left(\frac{\mathcal{E}_t}{\mathcal{E}} \right)^{(1-\rho)\phi_{\mathcal{E}}}, 1 \right\}. \tag{3.67}$$

In equation (3.67), r is the steady state real interest rate and ρ is a parameter that measures the inertia in the Taylor rule. The central bank's asset purchases are given by

$$Q_t K_t^{CB} = QK^{CB} \left[\frac{\left(1 + r_{t+1}^K\right) / \left(1 + r^K\right)}{\left(1 + r_{t+1}\right) / \left(1 + r\right)} \right]^{\psi_K} \frac{Q_t K_t}{QK} \tag{3.68}$$

$$q_t B_t^{CB} = qB^{CB} \left[\frac{\left(1 + r_{t+1}^B\right) / \left(1 + r^B\right)}{\left(1 + r_{t+1}\right) / \left(1 + r\right)} \right]^{\psi_B} \frac{q_t B_t}{qB}. \tag{3.69}$$

Equations (3.68) and (3.69) imply that the central bank increases the amount of asset purchases when the expected spreads on private assets and government bonds increase.

The last rule is about the lump-sum transfer of the central bank. By assumption, the central bank operates under a balanced budget rule, so that $T_t^{CB} = 0$ in every period. Then, the amount of reserves adjusts

$$M_t = q_t B_t^{CB} + Q_t K_t^{CB} + (1 + r_t) M_{t-1} - \left(1 + r_t^B\right) q_{t-1} B_{t-1}^{CB} - \left(1 + r_t^K\right) Q_{t-1} K_{t-1}^{CB}. \tag{3.70}$$

3.10 Fiscal Authority

The fiscal authority obtains revenues from household lump-sum taxes and labor income taxes, and also from taxes on the dividends of all firms. It also issues new long-term debt and receives a transfer from the monetary authority. These revenues are used to finance an exogenous path of real government expenditures G_t, and pay the interest on previous debt. The government budget constraint in real terms is therefore

$$q_t B_t + \mathcal{T}_t + \tau^L w_t L_t + \tau^D \mathcal{D}_t + T_t^{CB} = \left(1 + r_t^B\right) q_{t-1} B_{t-1} + \frac{P_{Ht}}{P_t} G_t. \tag{3.71}$$

where the real return on government bonds is given by

$$1 + r_t^B = \frac{1 + \gamma q_t}{q_{t-1}} \frac{1}{\Pi_t}. \tag{3.72}$$

The fiscal rule behind the lump-sum tax follows the tradition of Leeper (1991) and specifies the lump-sum tax as a constant amount plus a varying amount depending on the difference of previous government debt-to-GDP ratio from its steady state level counterpart

$$\mathcal{T}_t = T + \phi_B \left(\frac{q_{t-1} B_{t-1}}{Y_{Ht-1}} - \frac{qB}{Y_H} \right). \tag{3.73}$$

Given the rule for lump-sum taxes, everything on the right-hand side of (3.71) is determined either exogenously or by optimality conditions of other agents or by policy rules. So, new debt adjusts.

3.11 Domestic Market Clearing

There are several market clearing conditions in the model economy reflecting the various markets. They are all summarized by the following equations:

$$L_t = \int L_t^j dj = \int l_{it} di \tag{3.74}$$

$$M_t = \int M_{bt} db \tag{3.75}$$

$$D_t = \int d_{it} di = \int D_{bt} db \tag{3.76}$$

$$K_t = K_t^{MF} + K_t^{CB} \tag{3.77}$$

$$B_t = B_t^{MF} + B_t^{CB} \tag{3.78}$$

$$Y_{Ht} = C_{Ht} + I_{Ht} + G_t + \frac{\varsigma^*}{\varsigma} \left(C_{Ht}^* + I_{Ht}^*\right) + \Xi_t^I \left(I_{nt}, I_{nt-1}\right) + \Xi_t^P \left(\Pi_{Ht}, \Pi_{Ht-1}, Y_{Ht}\right) \tag{3.79}$$

The set of equations (3.74) are the labor market clearing conditions saying that the total amount of labor supplied is equal to the total demand for labor from the production side. Equation (3.75) is the market clearing condition for reserves stating that the total amount of reserves offered by the central bank must be equal in equilibrium to the amount of reserves held by commercial banks. Equation (3.76) is the market clearing condition for liquid savings stating that the total amout of liquid savings offered by the households must be equal to the amout of deposits offered by commercial banks.

Equation (3.77) is the capital market clearing condition. The capital claims held by financial intermediaries and the central bank must be equal to the total amount of capital claims issued by the firms.[10] Equation (3.78) is the market clearing condition for government debt. The amount of bonds supplied by the government must equal the amount of bonds demanded by the private banks and the central bank. Finally, (3.79) is the goods market clearing condition which says that the total supply of goods must be equal to the goods demanded by domestic agents for private consumption, private investment, government consumption, and adjustment costs, plus the demand for domestic goods coming from abroad for consumption and investment purposes weighted by the relative population size of the foreign economy $\frac{\varsigma^*}{\varsigma}$. The combination of budget constraints and market clearing conditions gives the balance of payments

$$\begin{aligned}\frac{P_{Ht}}{P_t} \left(C_{Ht}^* + I_{Ht}^*\right) - \frac{P_{Ft}}{P_t} \left(C_{Ft} + I_{Ft}\right) = q_t^* B_t^{*MF} E_t - \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{t-1}^* E_t + \left(1 + r_t^{H^*}\right) H_{t-1}^* E_t - H_t^* E_t \\ + \int \Xi \left(a_{it}, a_{it-1}\right) d\Gamma_t + \xi_D D_{t-1} + \xi_A A_{t-1}.\end{aligned} \tag{3.80}$$

3.12 Foreign Economy and Equilibrium Definition

The foreign economy, the calibration details for the foreign economy and the equilibrium definition are all presented in Appendix A.

[10] The total amount of capital claims is always equal to the total amount of capital.

4 Calibration and Estimation

The domestic economy is assumed to be the Mexican economy. The model is calibrated over 2008-2021 using quarterly data, in line with the empirical part.

4.1 Calibration - Domestic Economy

Households: The households are split into two categories: those with a high discount factor and those with a low discount factor. Discount factor heterogeneity is used to hit the following calibration targets: i) the high discount factor is set equal to $\beta^H = 0.9925$ so that households hold wealth in the form of liquid assets equal to 73% of GDP as in Auclert et al. (2021c), and ii) the low discount factor is set equal to $\beta^L = 0.9743$ to match the size of the hand-to-mouth households in the tradable sector, which is equal to 23%, as reported in Cugat et al. (2019). The parameter measuring the relative weight of labor disutility is set equal to $\mu_L = 2.141$ to satisfy the steady-state version of the WNKPC (3.19). The pivot adjustment cost parameter is free and is set equal to $\chi_0 = 0.01$. The scale adjustment cost parameter is set equal to $\chi_1 = 31.438$ to match the mean illiquid assets ratio over quarterly GDP of 2.77, as implied by Auclert et al. (2021c). The curvature adjustment cost parameter is set equal to $\chi_2 = 2$. The trade openness parameter is set equal to $\mu = 0.323$ as in Auclert et al. (2021c). The elasticity of substitution between domestic and foreign goods is set equal to $\eta = 0.75$ which is a value among those used in the literature. The labor productivity process e_t is assumed to follow an $AR(1)$ process with persistence $\rho_e = 0.968$ and standard deviation of the shocks equal to $\sigma_e = 0.487$ as in Hong (2020). The labor productivity process is discretized as a Markov chain with nine nodes. Finally, the grid upper bounds for the households' liquid and illiquid savings choice are set equal to $\bar{a} = 6.571$ and $\bar{b} = 3.644$ to match the average wealth share of the top 10% and the top 1% given by the WID for 2008-2021.[11].

Labor Union: The elasticity of substitution between different types of labor is set equal to $\varepsilon_w = \varepsilon_p = 10$. The steady-state amount of labor is normalized to $L = 1$.

Commercial Bank: The unit cost of intermediation is set equal to $\xi_D = 0.0085$ to make the liquid deposit rate at the steady state equal to $r^D = 0.6\%$ per quarter, which is close to the value provided by the World Bank for the Mexican economy for the period of interest. The commercial bank survival rate is set equal to $\theta_b = 0.97$ which is a standard value in the literature. Then, the parameter controlling the magnitude of the transfer received by new banks entering the economy is set equal to $\omega = 0.002$, a common value.

Investment Fund: The unit cost of intermediation is set equal to $\xi_A = 0.0886$ to achieve a steady state real return on illiquid savings equal to 2% per annum.

[11]See https://wid.world/data/

Investment Bank: The divertible fraction of domestic capital claims is set equal to $\lambda_K = 0.4$, which is a standard value in the literature. Then, the divertible fraction of domestic government bonds is set equal to $\lambda_B = 0.369$ to satisfy the steady-state version of (3.41). The steady-state real interest rate on government bonds is equal to $r^B = 6\%$ per annum using the average real return for the period 2008-2021 on 10-year Udibonos as provided by the website of the Bank of Mexico. The real deposit rate earned by the mutual fund is set equal to $r^F = 0.6\%$ per quarter. The divertible fraction of foreign government bonds is set equal to $\lambda_{B^*} = 0.013$ to satisfy the steady-state version of equation (3.42). The bank survival rate is $\theta^{MF} = 0.97$ and the parameter for the magnitude of the transfer received by new banks is calibrated to be $\omega = 0.0012$. The home bias in bank funding parameter is set equal to $\xi_{B^*} = 450$, a value that helps with model estimation.

Intermediate Goods Producers: Steady state output is normalized to $Y_H = 1$, and the steady-state capital-to-output ratio is set equal to $\frac{K}{Y_H} = 18.305$ as implied by the Penn World Tables 10.0.[12] The labor share is $1 - \alpha = 0.37$, the average for the period of interest in the same dataset. The capital share is $\alpha = 0.63$. Since $L = 1$, then $Z = K^{-\alpha} = 0.16$. The elasticity of substitution between intermediate goods is set equal to $\varepsilon_p = 10$, implying a steady-state markup of 11%.

Capital Producers: The depreciation rate is set equal to $\delta = 0.015$, which is also a common value.

Monetary Authority: The inflation coefficient in the Taylor rule is set equal to $\phi_{\Pi_H} = 1.5$. The exchange rate coefficient is set equal to $\phi_E = 0$. The steady-state holdings of private and government securities are equal to $QK^{CB}/Y_H = 0.000678$ and $qB^{CB}/Y_H = 0.04047$, the average values for 2008-2021, according to the website of the Bank of Mexico on "Debt Outstanding".

Fiscal Authority: Given that $r^B = 6\%$ per annum, the parameter that controls for the duration of long-term government bonds is set equal to $\gamma = 0.9896$ so as to match an average duration of 10 years / 40 quarters.[13] The tax rate on labor is set equal to $\tau^L = 0.25$ which is a standard value, while the tax rates on dividends of intermediate goods producers and capital producing firms are set equal to $\tau^D = 0.3$. The ratio of government debt over GDP is set equal to $qB/Y_H = 128.69\%$, which is the average value for the federal government debt held by the public during 2008-2021. The average government spending-to-GDP ratio G/Y_H was 12.17% during the same period. The parameter controlling the adjustment speed of lump-sum taxes to public debt changes is set equal to $\phi^B = 0.1$, implying a strong reaction of taxes to government debt given the parameter values in the Taylor rule for the nominal interest rate. Finally, the constant part of the lump-sum tax is determined at the steady state to satisfy the government budget constraint and is equal to $T = -0.061$.

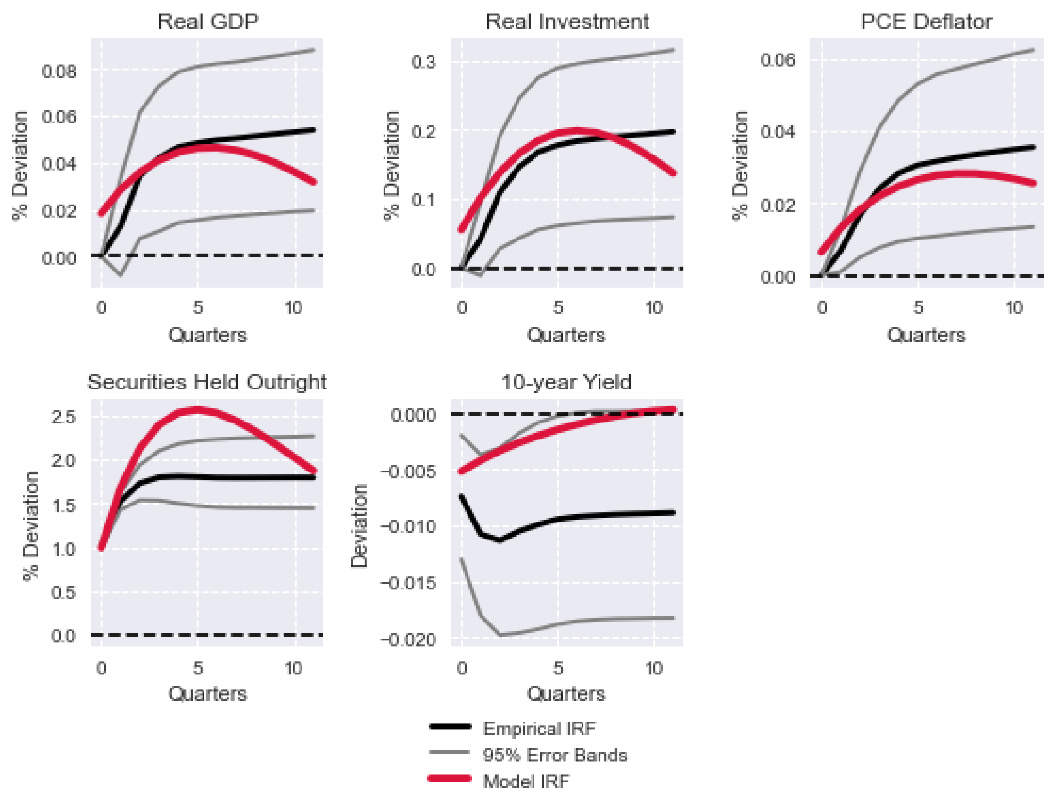
[12] See Feenstra et al. (2015)

[13] It can be shown that the modified duration of government bonds is $md = \frac{1+r^B}{1+r^B-\gamma}$. Setting $md = 40$ gives $\gamma = \left(1 + r^B\right)\left(1 - \frac{1}{40}\right)$.

Table 1: Baseline Calibration of Parameter Values - Domestic Economy

Parameter	Description	Value	Target/Source
Households			
β^H	Household High Discount Factor	0.9925	$D/Y_H = 0.73$
β^L	Household Low Discount Factor	0.9743	HtM Households Size = 23%
σ	Relative Risk Aversion Coefficient	2	Standard Value
ν	Inverse Frisch Elasticity	2	Standard Value
μ_L	Relative Weight of Labor Disutility	2.141	Internally Calibrated
χ_0	Portfolio Adjustment Cost Pivot	0.01	Baseline Scenario
χ_1	Portfolio Adjustment Cost Scale	31.438	$A/Y_H = 2.77$
χ_2	Portfolio Adjustment Cost Curvature	2	Baseline Scenario
μ	Trade Openess	0.323	Auclert et al. (2021c)
η	Elasticity of Substitution Domestic/Foreign Goods	0.75	Baseline Scenario
ρ_e	Autocorrelation of Earnings	0.968	Hong (2020)
σ_e	St. Dev. of Log-Earnings	0.487	Hong (2020)
$\bar{a}$	Upper Bound on a-grid	6.571	Top 10% Wealth Share = 79.5%
$\bar{b}$	Upper Bound on b-grid	3.644	Top 1% Wealth Share = 48.03%
Labor Union			
ε_w	Elasticity of Substitution in Labor	10	Standard Value
Commercial Banks			
ξ_D	Intermediation Cost	0.0085	$r^D = 0.6\%$ per annum
θ_b	Commercial Bank Survival Rate	0.97	Baseline Scenario
ω	Entering Banks Transfer Magnitude	0.002	Baseline Scenario
Investment Fund			
ξ_A	Intermediation Cost	0.0886	$r^A = 2\%$ per annum
Investment Banks			
λ_K	Divertible Fraction - Domestic Capital	0.4	Baseline Scenario
λ_B	Divertible Fraction - Foreign Government Debt	0.369	Internally Calibrated
λ_{B*}	Divertible Fraction - Foreign Government Debt	0.013	Internally Calibrated
θ^{MF}	Investment Bank Survival Rate	0.97	Baseline Scenario
ω^{MF}	Entering Banks Transfer Magnitude	0.0012	Baseline Scenario
ξ_{B*}	Home Bias in Bank Funding	450	Baseline Scenario
Intermediate Goods Producers			
α	Capital Share of Income	0.63	Avg. Value 2008-2021
ε_p	Elasticity of Substitution Interm. Goods	10	Baseline Scenario
Z	TFP	0.16	$Y_H = 1$
Capital Producers			
δ	Capital Depreciation Rate	0.015	Baseline Scenario
Monetary Authority			
ϕ_Π	Inflation Coefficient - Interest Rate Rule	1.5	Baseline Scenario
ϕ_E	Exchange Rate Coefficient - Interest Rate Rule	0	Baseline Scenario
QK^{CB}/Y_H	CB-Held Equity	0.000678	Bank of Mexico Equity Holdings 2008-2021
qB^{CB}/Y_H	CB-Held Debt	0.04047	Bank of Mexico Government Debt Holdings 2008-2021
Fiscal Authority			
γ	Duration Parameter	0.9896	Avg. Duration of 40 Quarters
τ^L	Labor Income Tax Rate	0.25	National Accounts
τ^D	Corporate Income Tax Rate	0.3	National Accounts
ϕ_B	Lump-sum Tax Adjustment Speed	0.1	Baseline Scenario
G	Government Spending-to-Output Ratio	12.17%	Average Value 2008-2021
qB/Y_H	Debt-to-GDP ratio	128.69%	Avg. Value 2008-2021

Figure 5: Impulse Responses to 1% QE Shock in the Baseline Specification



Notes: The above panels show the model IRFs, the median empirical IRFs and the corresponding 95% error bands of aggregate variables in the US after a 1% positive US QE shock.

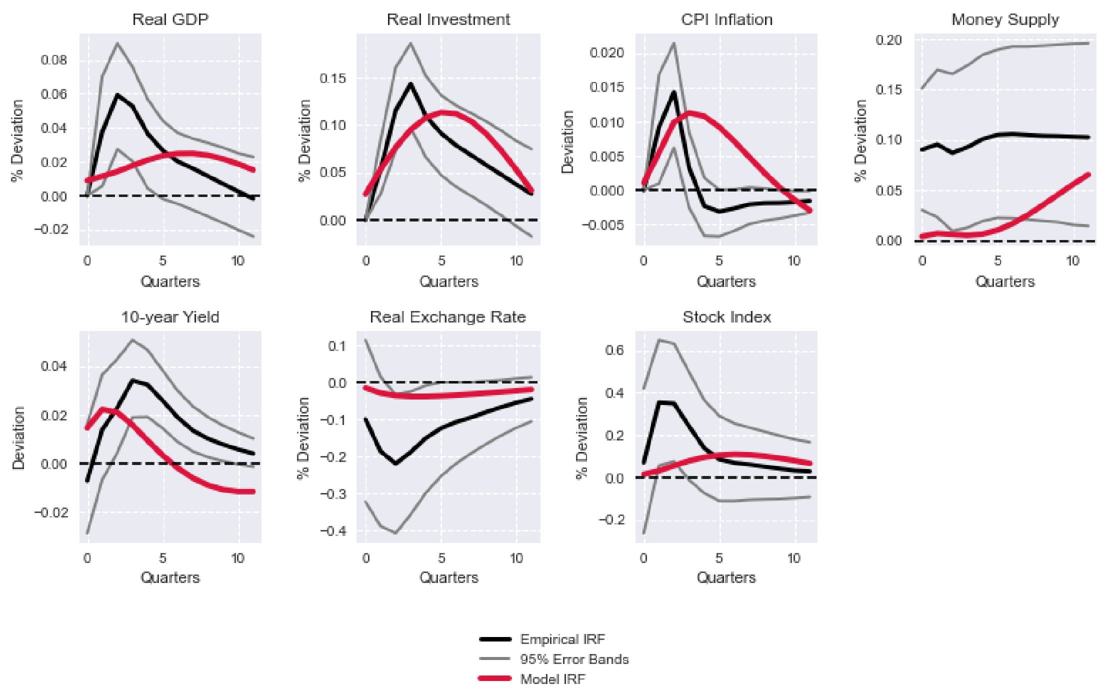
4.2 Estimation

Some of the parameters are estimated by matching the median impulse response functions of aggregate variables in Mexico, and in the US economy presented in section 2, following the methodology of Christiano et al. (2005). I assume that the structural shocks in QE from the US BVAR model in section 2 correspond to iid innovations in the Taylor-type rule for real asset purchases for the foreign economy $u_t^{B^*}$.

The estimated parameters for the domestic economy are the following seven: the degree of price stickiness, ξ_p, the curvature of the investment adjustment cost function, ξ_I, the elasticity of the central bank's government bond purchases, ψ_B,[14], the elasticity of the central bank's interest rate policy with respect to output ϕ_{Y_H}, the degree of wage stickiness, ξ_w, the price indexation parameter, ζ, and the inertia parameter in the rule for the nominal interest rate, ρ. The estimated parameters for the foreign economy are the following five: the elasticities of the foreign central bank's government bond purchases with respect to inflation and output, $\psi_{\Pi_F^*}$

[14]The elasticity of the central bank's private asset purchases, ψ_K, is by assumption set equal to the estimated value of ψ_B.

Figure 6: Aggregate responses in Mexico to 1% structural shock in US QE



Notes: The above panels show the model IRFs on top of the median IRFs and the corresponding 95% error bands of aggregate variables in Mexico to a 1% positive US QE shock.

and $\psi_{Y_F^*}$, the foreign degree of price stickiness, ξ_p^*, the foreign degree of wage stickiness, ξ_w^*, and the curvature of the foreign adjustment cost function, ξ_I^*. Letting $\theta \equiv \left[\xi_p, \xi_w, \xi_I, \zeta, \psi_B, \phi_{Y_H}, \rho, \xi_p^*, \xi_w^*, \xi_I^*, \psi_{\Pi_F^*}, \psi_{Y_F^*}\right]'$ and if $\mathcal{G}(\theta)$ denotes the vector of impulse reponse functions generated by the model, then, the parameters in θ are estimated by solving

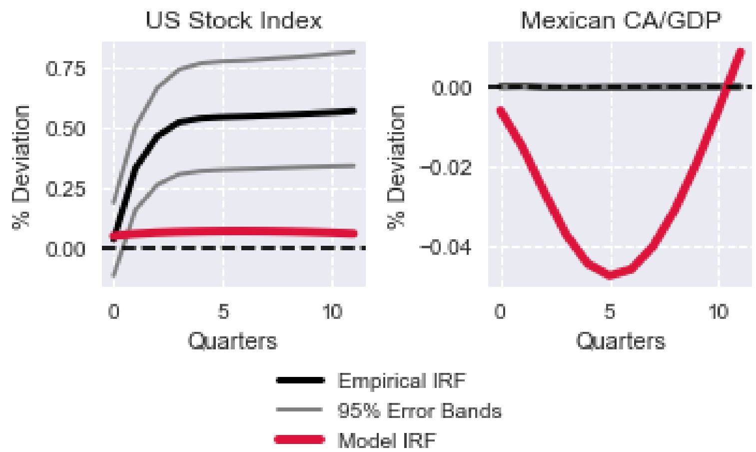
$$\min_{\theta} \left[\mathcal{G}(\theta) - \hat{\mathcal{G}}\right]' \left[\mathcal{G}(\theta) - \hat{\mathcal{G}}\right], \tag{4.1}$$

where $\hat{\mathcal{G}}$ is a vector containing the median empirical impulse response functions for aggregate variables from section 2. This vector contains 12 impulse response functions from both countries corresponding to the 12 parameters. The two impulse response functions not included in the estimation are the stock market index IRF in the US economy, and the IRF for the current account-to-GDP ratio in Mexico.

4.3 Model Fit

The model IRFs for the US and Mexican economies are depicted in solid red lines in Figures 5 and 6, respectively. Overall, the model produces impulse responses for macro aggregates that match those found

Figure 7: Non-targeted aggregate responses to 1% structural shock in US QE



Notes: The above panels show the non-targeted model IRFs on top of the median IRFs and the corresponding 95% error bands of aggregate variables in the US and Mexico to a 1% positive US QE shock.

in the empirical part. Regarding the US economy, the parameters related to the Phillips curve of prices and wages imply a significant degree of price stickiness since $\xi_p^* = 395.65$ and $\xi_w^* = 1486.77$. In contrast, the investment adjustment cost parameter takes the value $\xi_I^* = 4$. In addition, the parameters governing the Taylor rule for central bank asset purchases take the values $\psi_{\Pi_F^*} = 11.48$ and $\psi_{Y_F^*} = 5$. As for the Mexican economy the price and wage adjustment costs takes the values $\xi_p = 122.41$ and $\xi_w = 251.82$. The investment adjustment cost parameter takes the value $\xi_I = 7.3$, the price indexation parameter takes the value $\zeta = 0.507$ and the central bank asset purchases parameter takes the value $\psi_B = \psi_K = 0.55$. The elasticity of the central bank's interest rate policy with respect to output takes the value $\phi_{Y_H} = 0.0197$ Also, the inertia parameter in the rule for the nominal interest rate is set equal to $\rho = 0.73$.

Figure 7 contains the IRFs produced by the model for variables that are not targeted in the estimation, including the US stock market index, and the Mexican current account-to-GDP ratio. Although the model produces an increase in the US stock market index, this is relatively small when compared to the median IRF produced in the empirical part. On the other hand, the deterioration in the current account-to-GDP ratio is stronger than the empirical part. The model can be further modified to match these IRFs. For instance, introducing adjustment costs in imports, as in Erceg et al. (2005), could help in reducing the strong negative response of the CA/GDP ratio.

In addition, the model produces empirically plausible annualized marginal propensities to consume. For the country of Mexico the *MPC* is equal to 0.667, which very close to the number reported by Auclert et al. (2021c), and for the US economy the annualized MPC^* is equal to 0.347, a value which is almost in the middle of the values that have been reported in Johnson et al. (2006) and Auclert et al. (2020).

5 Transmission Mechanism, Heterogeneity, and Inequality

In this part, the model presented in the previous sections is put to work, and the model results are discussed and explained. The main object of interest is the transmission mechanism in both countries after a US expansionary quantitative easing shock. Then, the movements in inequality variables are discussed.

5.1 International Transmission Mechanism

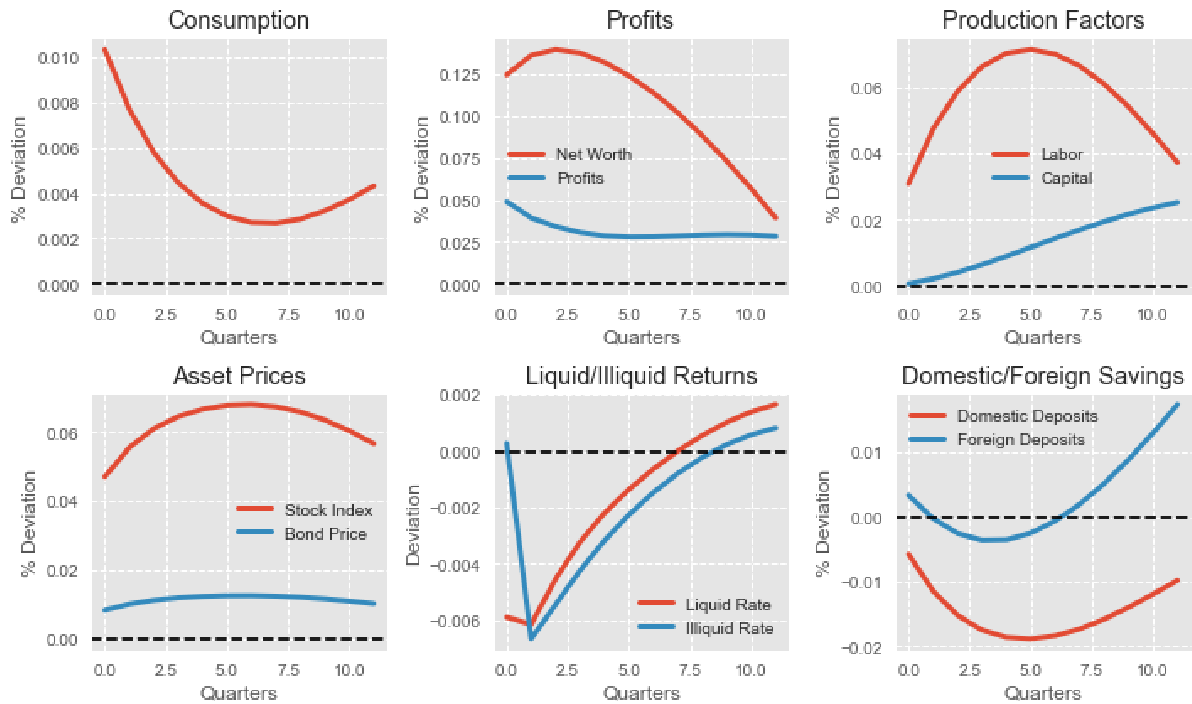
In this part, I focus on how the positive QE shock gets transmitted to both economies, starting from the US economy, where the shock originates. The shock is assumed to occur in period $t = 0$ and has a persistence of 0.85.[15] As shown in Figure 8, an increase in the central bank's government bond holdings first leads to an increase in the price of the bonds because of the higher demand for bonds. Higher bond prices increase the realized returns in period $t = 0$. The financial intermediaries decrease their holdings of government bonds due to higher prices and substitute these holdings with capital claims issued by the intermediate goods firms, as implied by their incentive constraint, leading to an increase in the stock market value. The increase in Tobin's Q leads to a further increase in the net worth of financial intermediaries, which can then invest more, triggering the financial accelerator mechanism. Capital accumulation and investment lead to an increase in output. This, in turn, leads to an increase in the demand for labor. In addition, higher aggregate demand leads to an increase in the aggregate price level.

As for the other US aggregate variables, consumption increases since constrained households increase their consumption due to higher labor income and unconstrained households tend to decrease domestic savings. The decrease in domestic savings takes place because the increase in inflation leads to a fall in the real interest rate, given that the US economy is assumed to be at the ZLB, which lowers the rate that banks pay to the investment fund, which in turn lowers the rate that the investment fund pays to the households. The lower return on US assets incentivizes US households to increase their foreign savings initially, leading to capital inflows to the Mexican economy. However, foreign savings also fall over time because the higher asset prices in the Mexican economy also lower the expected returns on the Mexican assets, which in turn determine the bank rate paid by the Mexican investment banks.

The Mexican economy is not affected by the QE shock only through the higher demand for savings from US households. There is also a direct effect working through the balance sheet channel of investment banks. The initial increase in the price of government bonds and the realized bond returns in the US economy leads to an increase in the net worth of the Mexican investment banks. Then, through a similar mechanism to the

[15] This persistence rate has been used in other studies for conventional monetary policy shocks. See for instance Ferrante and Gornemann (2022).

Figure 8: US Economy IRFs to 1% QE Shock

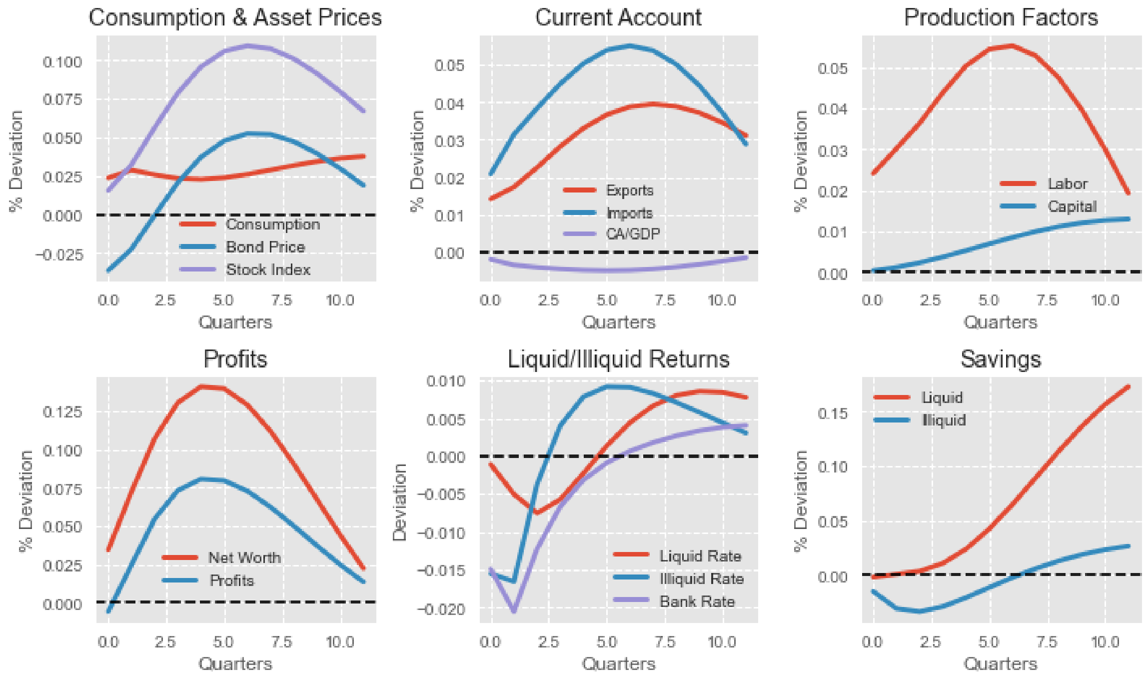


Notes: The above graphs depict the impulse response functions of various US variables after a positive 1% shock in the government bond holdings of the US central bank.

one described for the US economy, the banks increase their capital claims investments and decrease their holdings of the more expensive US government bonds. The banks also reduce their holdings of the Mexican debt because the monetary authority buys more bonds in the initial period due to the positive spread between the government bond yield and the real interest rate.

Nonetheless, the net worth of the banks is now affected also by the exchange rate movements. The initial appreciation of the assets at the time of the shock allows the investment banks to pay a higher interest rate on their deposits, domestic or foreign, leading to an appreciation of the Mexican currency. Then, through the net worth accumulation equation, a lower value for the exchange rate leads to a further increase in net worth provided that the net foreign income from abroad for the banks is negative, which is true for the current parameter values. In that case, the banks pay the US households more than what they receive from the US government. Then, a currency appreciation means that the banks need to spend fewer resources to pay the same amount of dollars to foreigners, so the banks' net worth increases. The increase in net worth triggers again the financial accelerator mechanism in the Mexican economy, which leads to a further increase in capital investment. Again, output, labor demand, and labor income increase. Inflation initially increases, but the strong response of the monetary authority on inflation leads to an increase in nominal rates, which

Figure 9: Mexican Economy IRFs to 1% QE Shock



Notes: The above graphs depict the impulse response functions of various Mexican variables after a positive 1% shock in the government bond holdings of the US central bank.

increases the real interest rate and helps in bringing inflation down. In a currency appreciation scenario, the price of the goods produced in Mexico increases relative to the price of goods bought by Mexico, leading to higher real income, which leads households to consume more. Higher consumption boosts GDP further.

Regarding asset prices, the stock market index increases again since the banks buy more capital claims and increase Tobin's Q in Mexico. The initial jump in the price of capital also creates a jump in the realized return on capital. On the other hand, the price of Mexican government bonds falls since it is determined by the expected future returns on capital and bank deposits through the investment banks' optimality conditions. Those expected returns are initially lower since asset prices jump due to higher investments of the banks.

On the households' side, we observe an increase in liquid and a decrease in illiquid savings over time. Although inflation initially lowers the liquid return, households still accumulate more liquid assets. This could result from higher labor incomes and the desire of constrained Mexican households to substitute consumption intertemporally by increasing their liquid asset holdings. Over time, households accumulate more liquid assets as the central bank increases the nominal rate above the inflation rate, and the real liquid return increases. On the other hand, illiquid savings initially fall due to the lower illiquid returns implied by lower investment bank rates, but over time increase as the illiquid returns rise.

Finally, from Figure 9, we can see that after the QE shock, Mexican imports increase significantly, which is a clear consequence of the appreciation of the Mexican currency. The Mexican current account-to-GDP ratio declines. Nevertheless, in a two-country world, one country's trade deficit is the trade surplus of the second country. Therefore, the US current account moves opposite to the Mexican one.

5.2 Consumption in the Transmission Mechanism

The decision to implement a monetary expansion through QE will ultimately affect the long-term real interest rates, the short-term real interest rates, the real wages, and the lump-sum taxes. These changes will naturally lead households to change their savings, consumption, and labor supply decisions. The question arising at this point is how QE measures affect the previous decisions. To understand these effects better, I decompose the aggregate consumption function and examine the effects of various variables on it. It is well-known from the classical consumer's problem that every agent's consumption will be a function of prices, income, and taxes in equilibrium. Here, asset returns have the role of prices. Hence, since aggregate consumption is just the sum of individual consumption functions, it will be a function of the same variables, so for the US economy, where the shock hits, we will have

$$C_t^* = \mathcal{C}_t^* \left\{ \left(1 - \tau^{L^*}\right) w_s^* L_s^*,\ T_s^*,\ r_s^{D^*},\ r_s^{A^*} \right\}_{s \geq 0}. \tag{5.1}$$

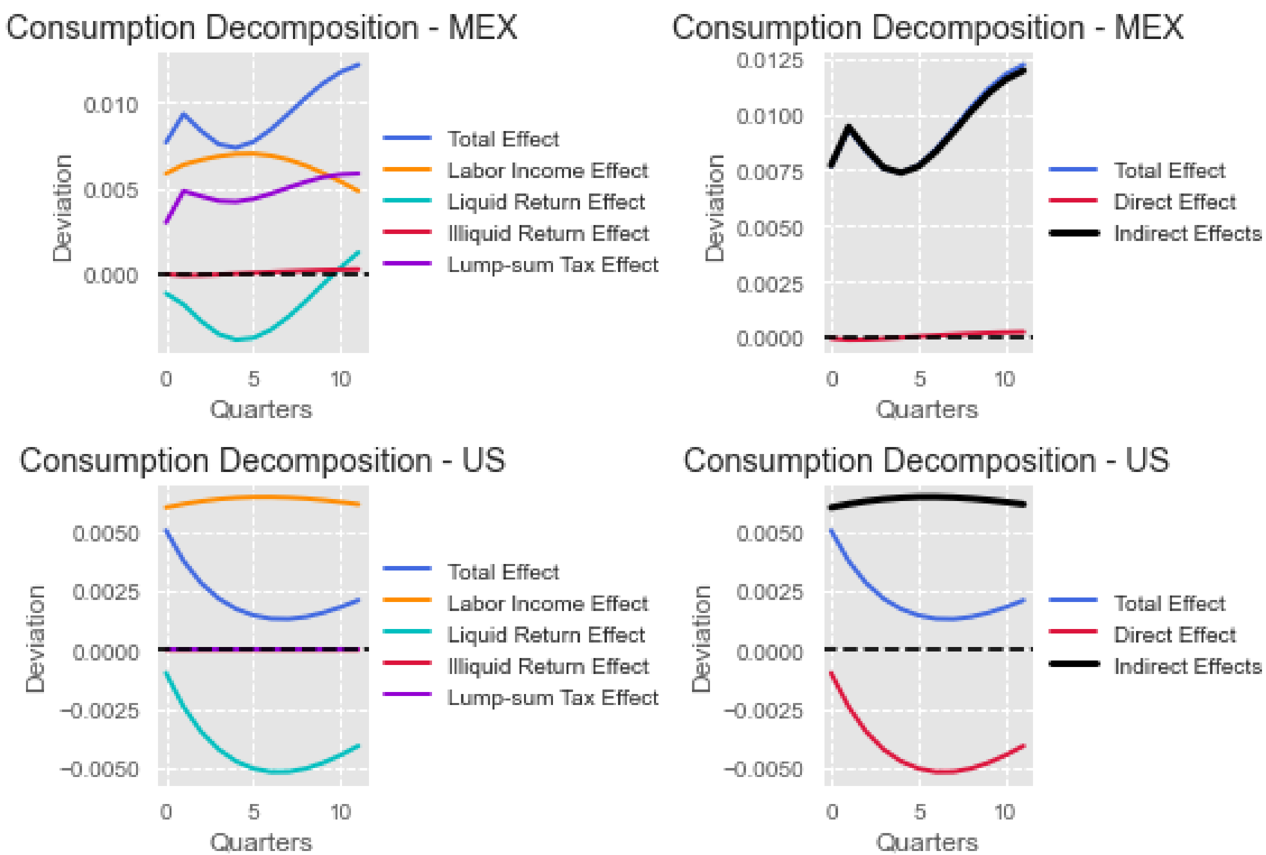
Let $Z_s^* \equiv \left(1 - \tau^{L^*}\right) w_s^* L_s^*$. Then, any change in aggregate consumption can be decomposed into changes in the variables of the right-hand side of (5.1) as follows

$$dC_t^* = \underbrace{\sum_s \frac{\partial \mathcal{C}_t^*}{\partial Z_s^*} dZ_s^*}_{\text{Labor Income Channel}} + \underbrace{\sum_s \frac{\partial \mathcal{C}_t^*}{\partial T_s^*} dT_s^*}_{\text{Lump-sum Tax Channel}} + \underbrace{\sum_s \frac{\partial \mathcal{C}_t^*}{\partial r_s^{D^*}} dr_s^{D^*}}_{\text{Liquid Savings Channel}} + \underbrace{\sum_s \frac{\partial \mathcal{C}_t}{\partial r_s^{A^*}} dr_s^{A^*}}_{\text{Illiquid Savings Channel}} \tag{5.2}$$

In the scenario of a QE shock in the US economy, the liquid savings channel is the channel that is most directly affected by the shock since QE affects the price of long-term assets, which are held indirectly in the liquid savings account. The other three channels capture effects on short-term rates that affect consumption and the effects of the change in labor income and government transfers.

The lower panels of Figure 10 depict the path of aggregate consumption for the US economy and the breakdown to direct and indirect effects using the decomposition in (5.2) and assuming that the variables in the right-hand side of (5.1) follow the same paths obtained in the previous subsection after a positive 1% QE shock in the US economy. Higher labor income leads to higher consumption on aggregate. Also, since lump-sum taxes are assumed not to respond to government debt, the lump-sum tax channel is irrelevant to the

Figure 10: Consumption Response Decomposition in the US and Mexico



Notes: The panels on the top show the decomposition of the aggregate consumption response in the US to a 1% positive QE shock, with the one at the left showing all channels as included in (5.2) and the right one aggregating the indirect channels. The panels on the right side depict the same channels for the US.

movements in aggregate consumption. Then, the illiquid savings channel, which works through the interest rate on foreign savings, affects positively aggregate consumption but the effect is very weak. The return on foreign savings increases at the time of the shock, then it falls, and then it slowly reverts to its steady state value. Hence, the positive effect on aggregate consumption reveals a dominant substitution effect. Overall, the indirect effects are considerable but do not entirely drive the aggregate consumption response for the US economy. The unresponsiveness of lump-sum taxes plays a significant role in this result.

On the other hand, QE leads to a decrease in the real rate earned by the households on their liquid savings, which initially leads to a decrease in households' consumption and a decrease in their liquid asset holdings, implying a dominant income effect. Then, as the real return on liquid savings increases and returns to its steady state value, households reduce their consumption, implying a dominating substitution effect. The direct effect is the primary driver of the aggregate consumption response.

As for the Mexican economy, it could be argued that the distinction between direct and indirect effects is not meaningful since US QE programs aim to change the interest rates in the US economy. Hence, any spillover effects to other countries are essentially indirect effects. However, since investors turn to emerging markets assets after the fall in the long-term rates in the US economy and the prices of long-term assets change, one could argue that there is a direct effect on the long-term returns paid in emerging markets. This leads households to change their consumption, savings, and labor supply decisions, creating indirect effects.

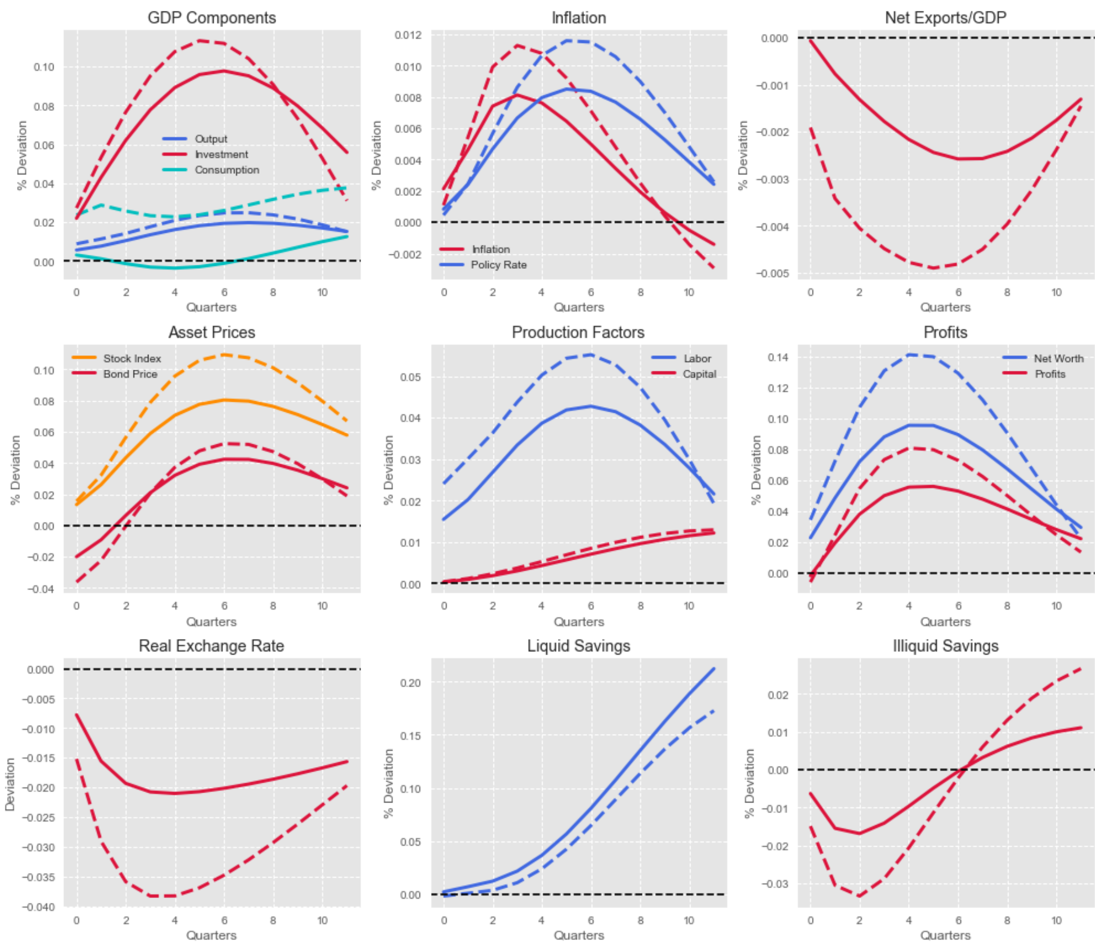
From the top left panel of Figure 10 we can see that the aggregate consumption response is driven by the movements of labor income, lump-sum taxes, and liquid returns. Labor income in Mexico increases, due to higher demand for labor. As a result, constrained households consume more, driving aggregate consumption higher. Moreover, government debt falls because of the higher tax revenues, leading to a reduction in lump-sum taxes, which boosts consumption even further. Next, the real interest rate remains positive over time due to the Mexican central bank's strong response to inflation, which tends to decrease consumption, implying a dominating substitution effect. All the indirect effects together determine almost entirely the path of aggregate consumption in Mexico, as shown in the upper right panel of Figure 10. The effect of QE on the illiquid savings channel works through the interest rate paid by the Mexican banks. This rate is determined by the movements of the other interest rates through the banks' optimallity conditions. Overall, the bank rate initially falls but reverts over time to its mean. Aggregate consumption falls initially by the decrease in the bank rate, revealing a dominating income effect. The direct effect has a negligible size overall.

5.3 Representative Agent in Mexico

In this part, I analyze the role of household heterogeneity in Mexico. Specifically, I shut off heterogeneity in Mexico and consider a representative household that decides about consumption and savings in a liquid and an illiquid asset, where, as before, the illiquid asset is subject to the same transaction cost. The model is calibrated to produce the same aggregate allocation as in the benchmark pure HANK model. The difference, in this case, is that the aggregate consumption response is determined by the individual Euler equation for the liquid asset and not by the sum of individual consumption functions of unconstrained and constrained households.

Figures 11 and 12 contain the IRFs for the Mexican and the US economy, respectively. Starting from the Mexican economy, the absence of heterogeneity has two immediate effects: first, since there are no constrained households anymore, the initial response of consumption is weaker and becomes negative over time, and second, unconstrained households in the RANK economy work less than households who are close to their liquidity constraints, so production is lower, and the demand for capital is lower than the benchmark

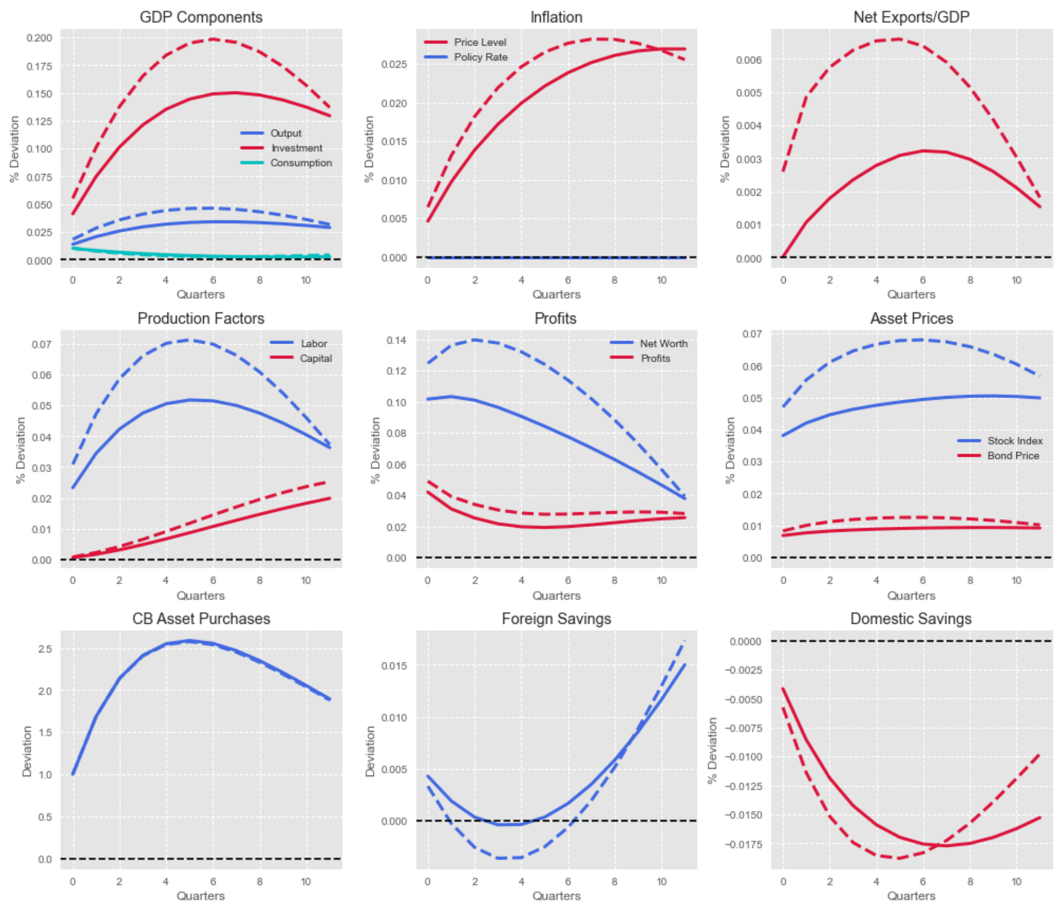
Figure 11: Mexican Economy IRFs to 1% QE Shock - Mexico RANK



Notes: The above graphs depict the IRFs of various Mexican variables after a positive 1% US QE shock under the assumption that there is a representative agent in Mexico. The solid lines depict the IRFs under the "Mexico RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

case. Asset prices are not as high either. The lower aggregate demand implies lower increase in prices, and this leads to a smaller real appreciation of the currency. The bank net worth increases by less. Hence, the effects of the financial accelerator are weaker. As a result, investment is lower. The smaller appreciation of the currency also creates a smaller real income effect for the households, which also plays a role in the initially smaller and then negative response of consumption. As a result, output is lower than the benchmark model. Inflation and the stock market are also lower. The smaller currency appreciation also leads to a less negative trade balance-to-GDP ratio over time.

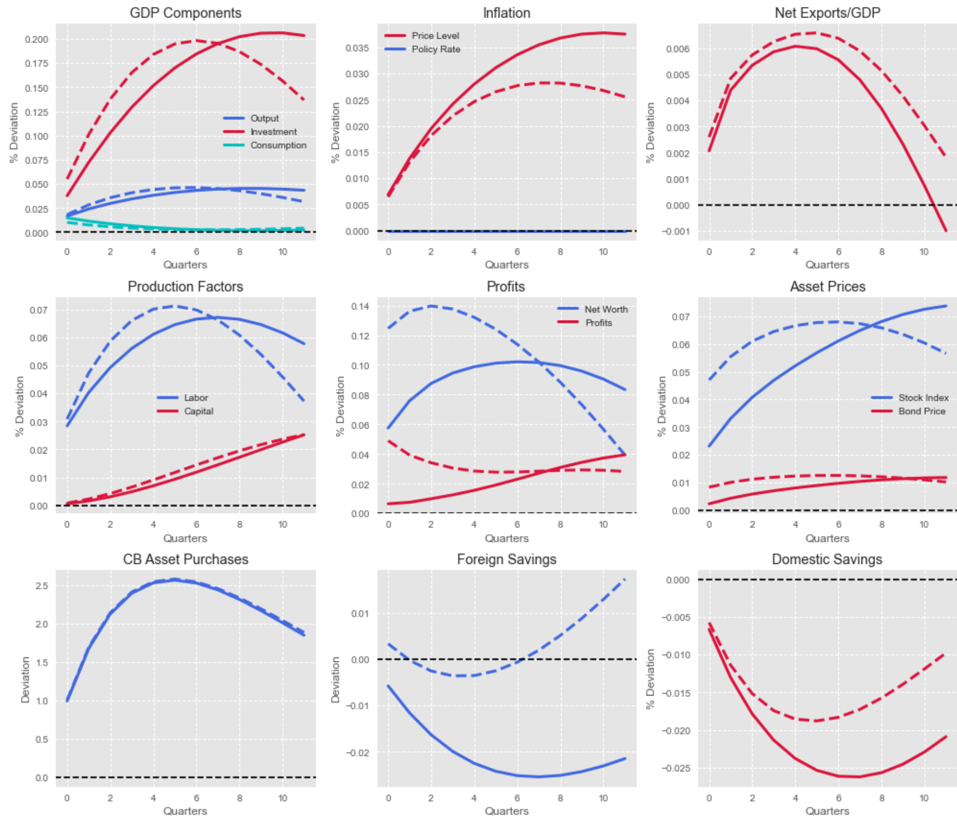
Figure 12: US Economy IRFs to 1% QE Shock - Mexico RANK



Notes: The above graphs depict the IRFs of various US variables after a positive 1% US QE shock under the assumption that there is a representative agent in Mexico. The solid lines depict the IRFs under the "Mexico RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

Turning to the US economy, foreign savings are higher whereas the liquid savings decrease by less relative to the benchmark case. The return on the liquid asset is slightly higher since the price level is lower. The weaker depreciation of the dollar implies a smaller negative real income effect for the households, which keeps consumption at around the same levels as before. Output is also lower relative to the benchmark model, due to the big drop in net exports resulting from the weaker appreciation of the peso, and also from the decrease in the demand for US goods from the Mexican economy now that consumption and investment is lower there as a result of the absence of constrained households. However, this decrease in output is not only due to the decrease in net exports, but also due to the decrease in investment, which is the result of lower net worth and lower asset prices. But the lower aggregate demand also leads to a lower demand for capital, which keeps investment and asset prices lower.

Figure 13: US Economy IRFs to 1% QE Shock - US RANK

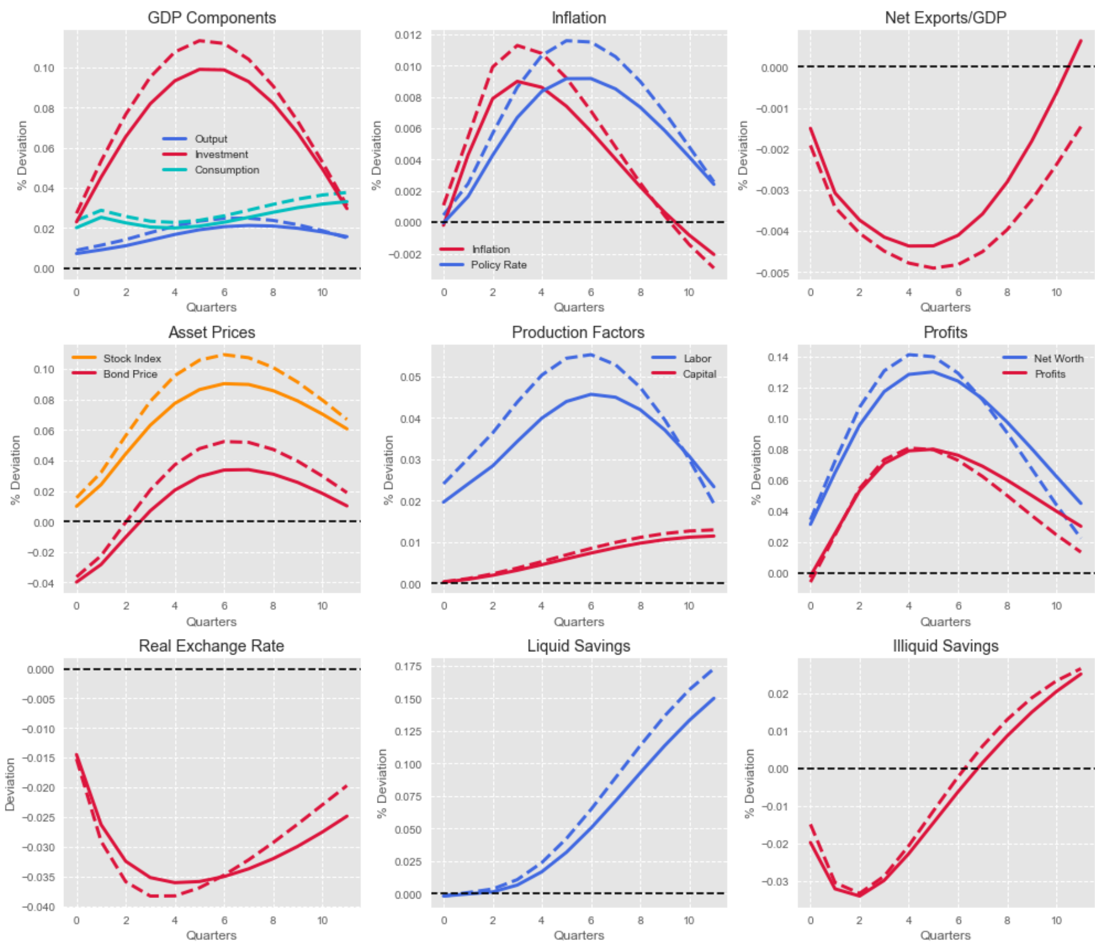


Notes: The above graphs depict the IRFs of various US variables after a positive 1% US QE shock under the assumption that there is a representative agent in the US. The solid lines depict the IRFs under the "US RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

5.4 Representative Agent in the US

In this part, I assume that there is no household heterogeneity in the US, but there is in Mexico. Again the model is calibrated to produce the same aggregate allocation as in the benchmark case. The IRFs in the US economy change significantly, even though the calibrated fraction of constrained households was 8% in the benchmark case. The top left panel of Figure 13 suggests that the consumption response is initially higher but then lower than the pure HANK model, implying lower aggregate demand in the medium run. Output is also lower over time due to the decrease in the net exports of the US economy, due to the weaker appreciation of the Mexican currency as suggested by Figure 14. The weaker appreciation of the peso, or the weaker depreciation of the dollar is one of the main reasons why the consumption response remains strong initially. The price level is higher over time relative to the HANK model. The lower output reduces tax revenues and boosts current and future fiscal deficits, leading to higher prices. Lower output leads also to lower demand for capital from the intermediate good producers initially, which leads to lower investment

Figure 14: Mexican Economy IRFs to 1% QE Shock - US RANK

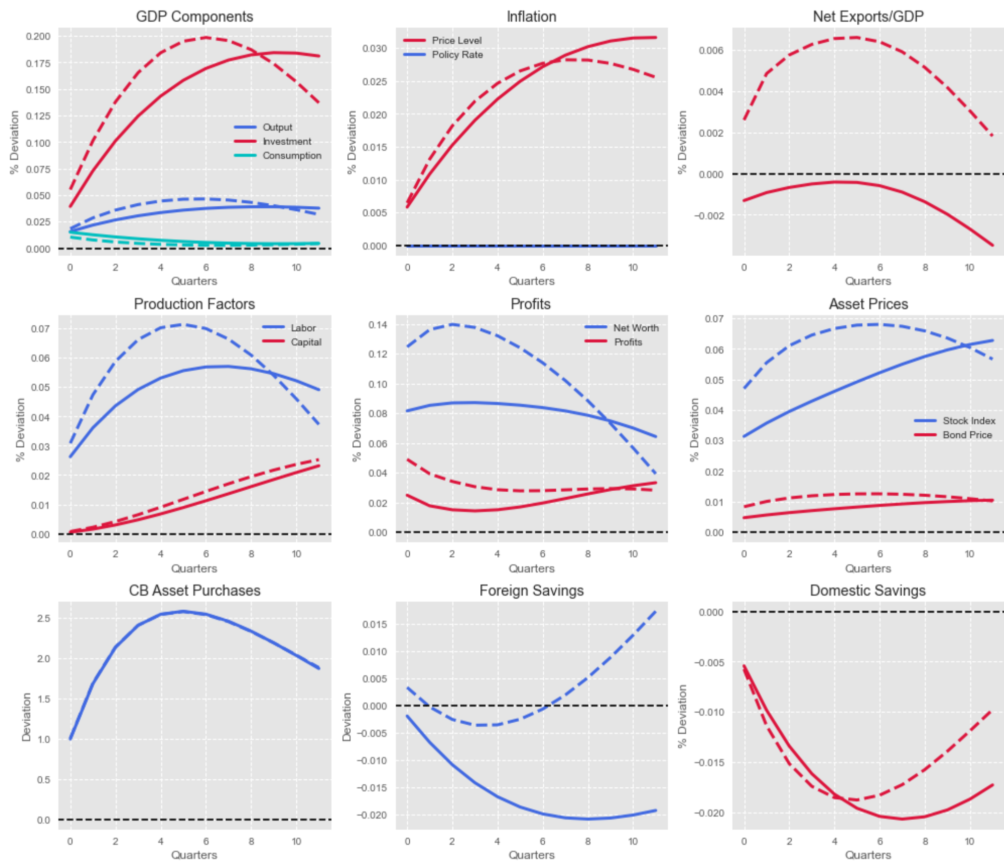


Notes: The above graphs depict the IRFs of various Mexican variables after a positive 1% US QE shock under the assumption that there is a representative agent in the US. The solid lines depict the IRFs under the "US RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

over time when compared to the HANK model. Bank net worth is also lower for the first seven quarters, so the banks invest less and the stock market index is lower over time.

In addition US households decrease initially their foreign savings relative to the benchmark case. The Mexican currency appreciates by less relative to the pure HANK model. Since now there are no constrained households that need to start accumulating assets using the liquid asset first due to lack of resources, the representative household chooses to increase consumption initially. The US banks see a smaller reduction in domestic savings, as well as lower investment and asset prices at the time of the shock, which slightly reduces the net worth of the banks, and total profits.

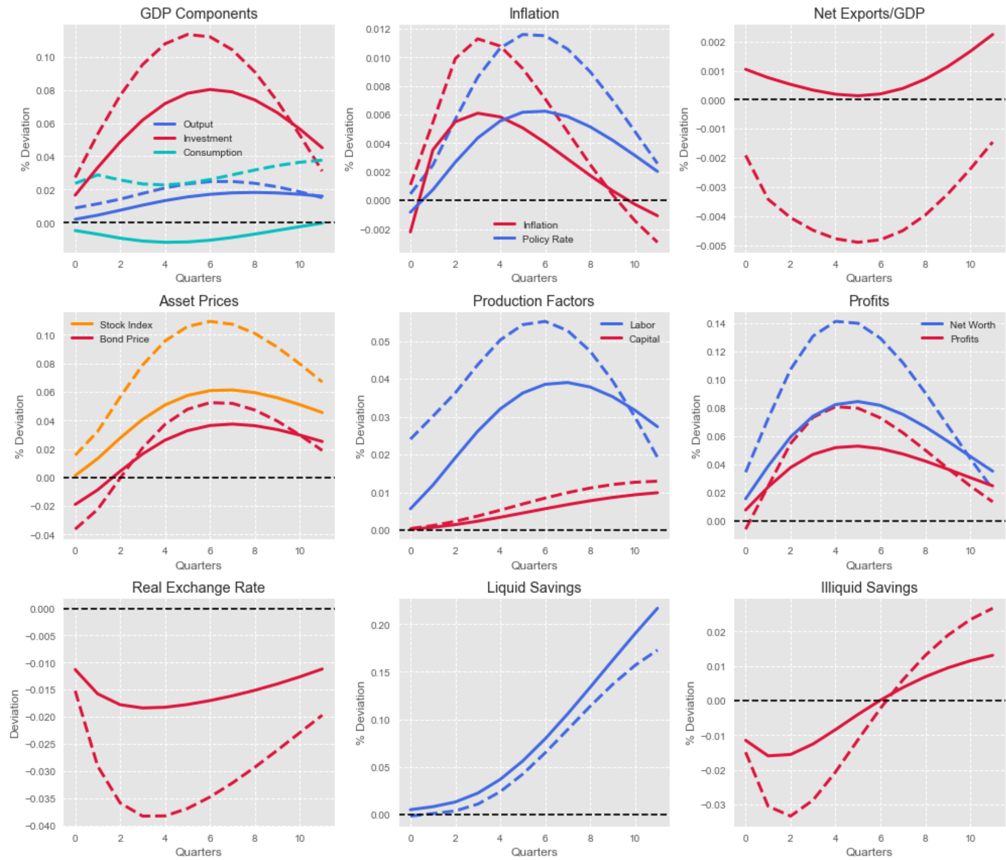
Figure 15: US Economy IRFs to 1% QE Shock - Pure RANK



Notes: The above graphs depict the IRFs of various US variables after a positive 1% US QE shock under the assumption that there is a representative agent in both countries. The solid lines depict the IRFs under the "Pure RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

As for the Mexican economy, the differences in the IRFs are shown in Figure 14. The Mexican investment banks now receive fewer resources initially from US households and become less leveraged. The real exchange rate appreciates less because of the lower prices in Mexico due to lower aggregate demand, and the lower demand for Mexican deposits. This lowers the net worth of the banks. As a result, the financial accelerator mechanism together with the smaller positive effects from currency mismatch lead to a lower increase in investment. The lower positive investment response propagates to the rest of the economy through lower demand for labor, lower production, and lower asset prices. The real labor income increases by less, and since there is a significant portion of constrained households in the Mexican economy, aggregate consumption and GDP increase by less relative to the pure HANK case. The bank net worth is also lower but profits do not fall because lower demand for labor reduces the real wage and keeps the profits of intermediate goods producers high. Due to the lower increase in aggregate income, households now have less resources and liquid savings

Figure 16: Mexican Economy IRFs to 1% QE Shock - Pure RANK



Notes: The above graphs depict the IRFs of various Mexican variables after a positive 1% US QE shock under the assumption that there is a representative agent in both countries. The solid lines depict the IRFs under the "Pure RANK" scenario, and the dashed lines depict the IRFs when both countries have heterogeneous households.

initially increase by less relative to the benchmark model. Illiquid savings fall more than the pure HANK, probably because of the higher expected returns created by the lower asset prices.

5.5 Representative Agents in both Countries

The last comparison between nested models is between the pure HANK model and the pure RANK model, in which both countries have representative agents. Again the model is calibrated to produce the same aggregate allocation as in the pure HANK model. This time aggregate demand is lower in both countries since there are no constrained households in both countries, and since the aggregate demand level of one country affects the output of the other, the negative externalities from lower aggregate demand are bigger in this case. The appreciation of the Mexican currency is now the weakest among all cases examined because of the low aggregate demand which leads to lower inflation in Mexico. In the US economy, the impulse responses of aggregate variables follow similar paths to the previous cases. The trade balance-to-GDP ratio now deteriorates relative to the pure HANK model because exports decrease significantly. Asset prices, factor demand and bank net worth are also lower due to the significant decrease in aggregate demand. Again foreign savings are lower because aggregate consumption is higher, but this effect is not strong enough in order to counterbalance the lower prices in Mexico, and as a result the Mexican currency appreciates by less.

As for the Mexican economy, again aggregate demand is lower, and since the currency appreciates slightly the banks invest less in capital. As a result, all macro aggregates are significantly lower than the benchmark HANK model. Asset prices are also lower, and the nominal interest rate set by the central bank is lower. The consumption response becomes negative because of the absence of hand-to-mouth households and due to the negative real income effect of weak currency appreciation. Interestingly the pure representative agent model can produce, at least qualitatively, similar movements to the ones found in the empirical section for most of the aggregate variables examined, except for the trade balance-to-GDP ratio, for the given calibation. However, at least quantitatively, the differences in the response of some variables, such as US employment or real investment in the Mexican economy, are significant. Moreover, RANK models cannot speak to inequality issues by construction. I turn now to this topic.

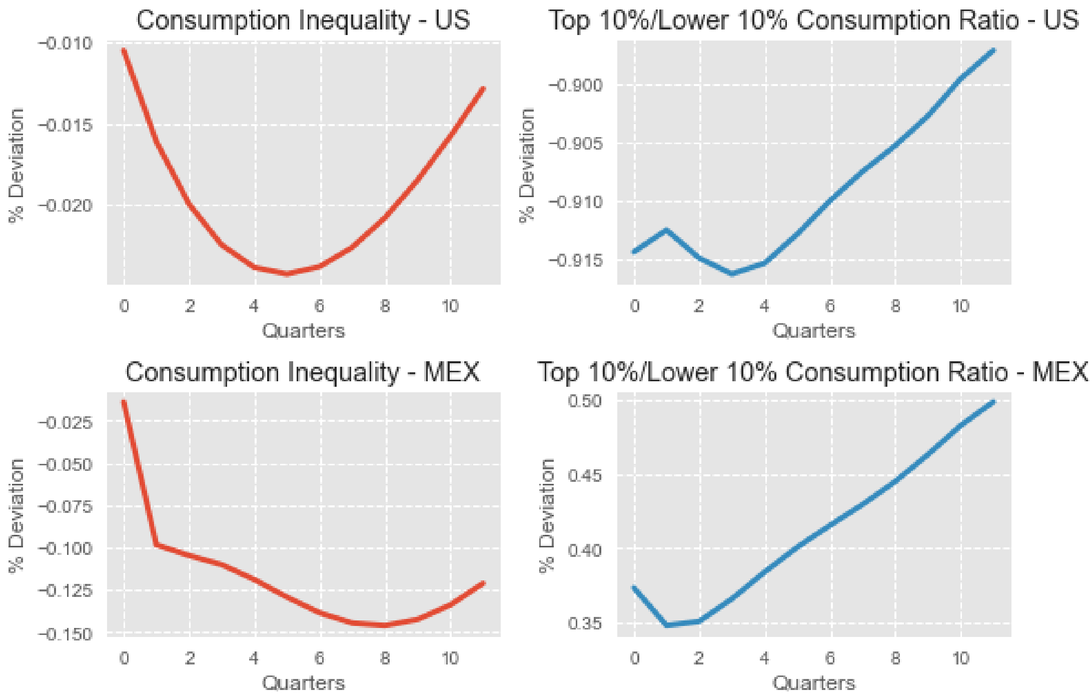
5.6 The Distributional Effects of Quantitative Easing

After examining the aggregate effects of the positive QE shock, we now turn to the distributional effects. The upper panels of Figure 17 contain the charts showing the evolution of consumption inequality variables for the US economy after the positive QE shock. Overall consumption inequality, as measured by the variance of the log, falls immediately at the time of the shock, further falls for six more quarters, and remains lower than its steady-state level for the rest of the periods. In addition, the ratio of the top 10% to the lower 10% of the consumption distribution is presented. This ratio also falls in the short-term, and its movement remains negative after the shock. The fall in consumption inequality implied by the two previous measures is driven mainly by higher labor income due to increased aggregate production and employment. With higher wages, constrained households can increase their consumption by more relative to unconstrained households.

In the case of Mexico, overall consumption inequality is also reduced with the QE shock. However, now the consumption of the top 10% increases, and the 10/90 consumption ratio increases, implying higher consumption inequality between the top and the lower end of the consumption distribution. Consumption inequality falls because households in the middle of the distribution, who depend on their income from real wages and previous assets, increase their consumption relatively more than the households at the top.

On the other hand, regarding the two assets available to US households, the results are mixed, as suggested by the upper panels of Figure 18. Specifically, liquid asset inequality increases for around two quarters.

Figure 17: Consumption Inequality Responses in the US and Mexico after a 1% QE Shock

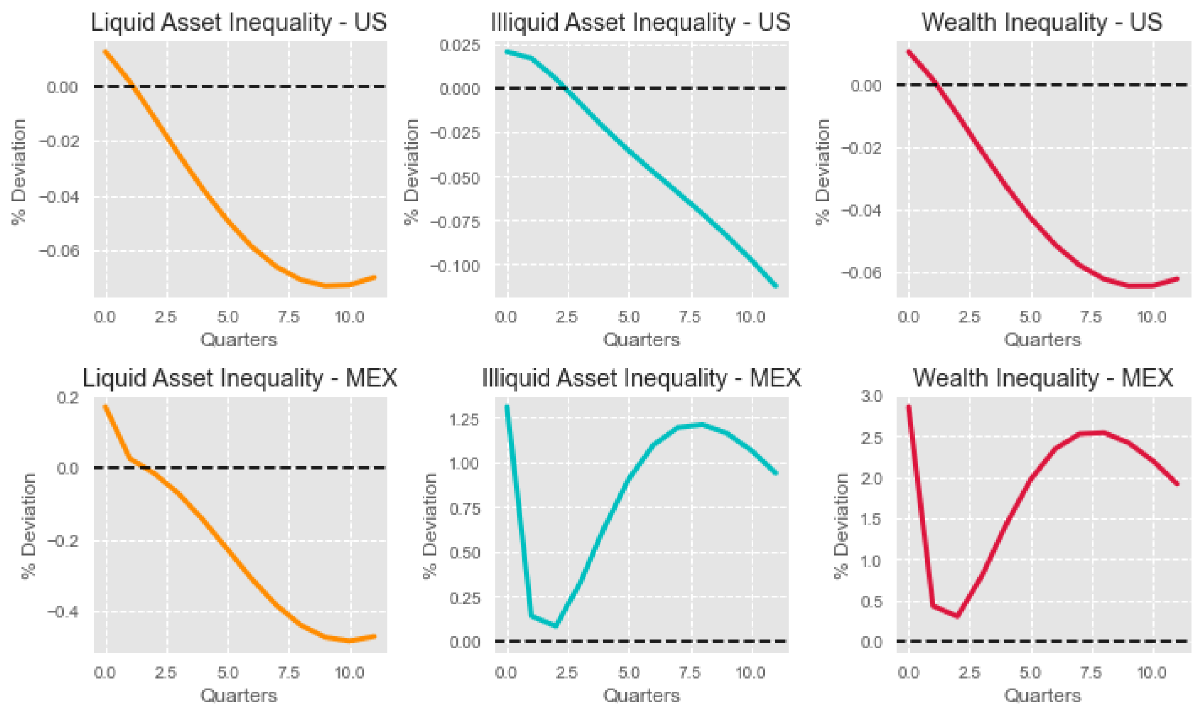


Notes: The graphs on the left side show the response of consumption inequality for the US economy (top) and Mexico (bottom), as measured by the variance of the log, and the graphs on the right show the response of the ratio of the top 10% to the lower 10% of the consumption distribution for the US economy (top), and Mexico (bottom).

It then falls relative to its steady state value, while illiquid asset inequality increases and remains elevated relative to its steady state value over time. As for the illiquid asset, the initial higher return, together with the negative real rate on the liquid asset, offers incentives to richer households to increase their illiquid asset holdings, given that they can afford the transaction cost of acquiring it. Constrained households cannot follow due to the lack of resources, and naturally, inequality in illiquid asset holdings increases. In terms of the liquid asset, constrained households, who need to substitute consumption intertemporally the most, begin to accumulate liquid assets. In contrast, the wealthier households decumulate due to the lower returns, resulting in lower inequality over time. Total wealth inequality follows the path of liquid asset inequality due to the prominent share that liquid wealth has in total wealth.

Turning to Mexico, liquid asset inequality rises at the time of the QE shock and, over time, decreases before starting increasing. Illiquid asset inequality initially increases and remains ellevated over time. Liquid asset inequality decreases due to higher labor incomes which allow constrained households to accumulate liquid assets and get out of their constraints. Even though the real interest rate increases due to the strong reaction of the central bank to inflation, and wealthier households start accumulating liquid assets, the poorer

Figure 18: Wealth Inequality Responses in the US and Mexico after a 1% QE Shock



Notes: The graphs from the left to the right side show the response of liquid wealth inequality, illiquid wealth inequality and total wealth inequality for the US economy (top) and Mexico (bottom), as measured by the variance of the log.

households accumulate more aggresively and liquid asset inequality falls. In terms of the illiquid asset, the initially higher profits due to higher bank net worth lead to a higher return on the illiquid asset, incentivizing households to increase their holdings in this asset. Households at the top of the distribution can afford the portfolio adjustment cost and increase their illiquid asset holdings relatively more. Over time, as profits return to their steady state value, richer households have incentives to lower their positions, which brings the inequality measure back to its steady state value. Overall, wealth inequality closely follows the path of illiquid asset inequality due to the prominent share that illiquid wealth has in total wealth.

Figure 19 contains the paths of the top 0.1%, the top 1-10%, and the lower 50% wealth shares, as well as the top 10% to lower 50% wealth share ratio following the QE shock for both countries. In the US economy the top 0.1% share increases over time and the top 1-10% share follows a similar path, implying that QE leads to higher wealth concentration in the hands of richer households, at least in the short run. The lower 50% wealth share increases after the shock, but not as much as the wealth shares of the top of the wealth distribution. The poorer households become less constrained over time as they earn higher labor incomes, and this allows them to start accumulating assets and increase their wealth share. This increase is significant enough to bring down the 10/50 wealth share ratio, bringing the poorer households closer to the richer ones.

Figure 19: Wealth Share Responses in the US and Mexico after a 1% QE Shock

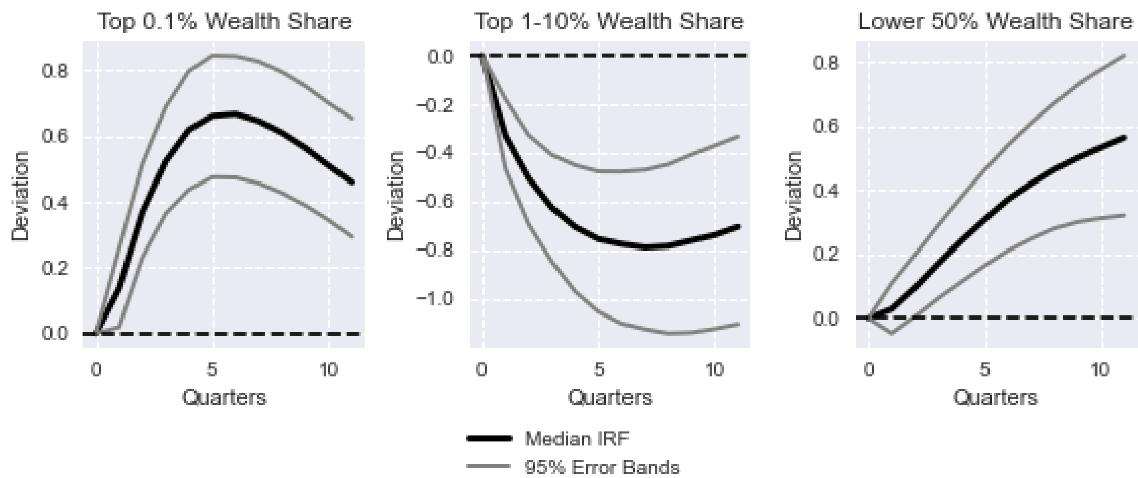
As for the Mexican economy, the top 0.1% wealth share slightly falls in the first two quarters but over time it increases fastly implying that the households at the very top of the distribution accumulate more assets. The 1-10% wealth share increases significantly over time and then returns to its steady state value, and the lower 50% welath share increases but at a slower rate, as in the case of the US economy. Nonetheless, again the increase in the lower 50% wealth share is significant enough to bring the 10/50 wealth share ratio down in the Mexican economy as well.

5.7 US Wealth Shares: Empirics

In this part I test the predictions of the two-country model for the paths of the top 0.1%, the top 1-10%, and the lower 50% wealth shares in the US economy following a QE shock. Specifically, I follow the methodology of Mumtaz and Theophilopoulou (2017) and I introduce the wealth share measures in the BVAR model, assuming that they are ordered before the QE measure. The data for the wealth shares are collected from the Distributional Financial Accounts of the Federal Reserve. In the spirit of the previous paper, the vector of endogenous variables contains real GDP, the PCE deflator, one relevant wealth share at each iteration of the exercise, the QE measure and the stock market index.[16] I abstract in this case from cointegration issues and I assume a simple Normal-Wishart prior.

[16]Adding the real investment variable in the BVAR model does not alter the results significantly, although the model in this case contains a substantial number of endogenous variables.

Figure 20: Empirical Wealth Share Responses in the US economy after a 1% QE Shock



According to Figure 20, after a 1% increase in the securities held outright by the Federal Reserve the wealth share of the top 0.1% increases over time. The maximum effect takes place six quarters after the shock when the top 0.1% wealth share increases by 0.67 percentage points. On the other hand, the wealth share of the top 1-10% falls over time. The maximum effect takes place after 7 quarters with a magnitude of -0.788 percentage points. Finally, the wealth share held by the lower 50% of the wealth distribution also increases with the QE shock and the positive effects become stronger over time.

Thus, in line with the model, the top 0.1% wealth share and the bottom 50% wealth share increase implying that QE helps both the very top of the wealth distribution but also households at lower parts of the wealth distribution. The households who see their wealth share falling are the ones in the top 1-10%. The model produces an increase in this wealth share instead.

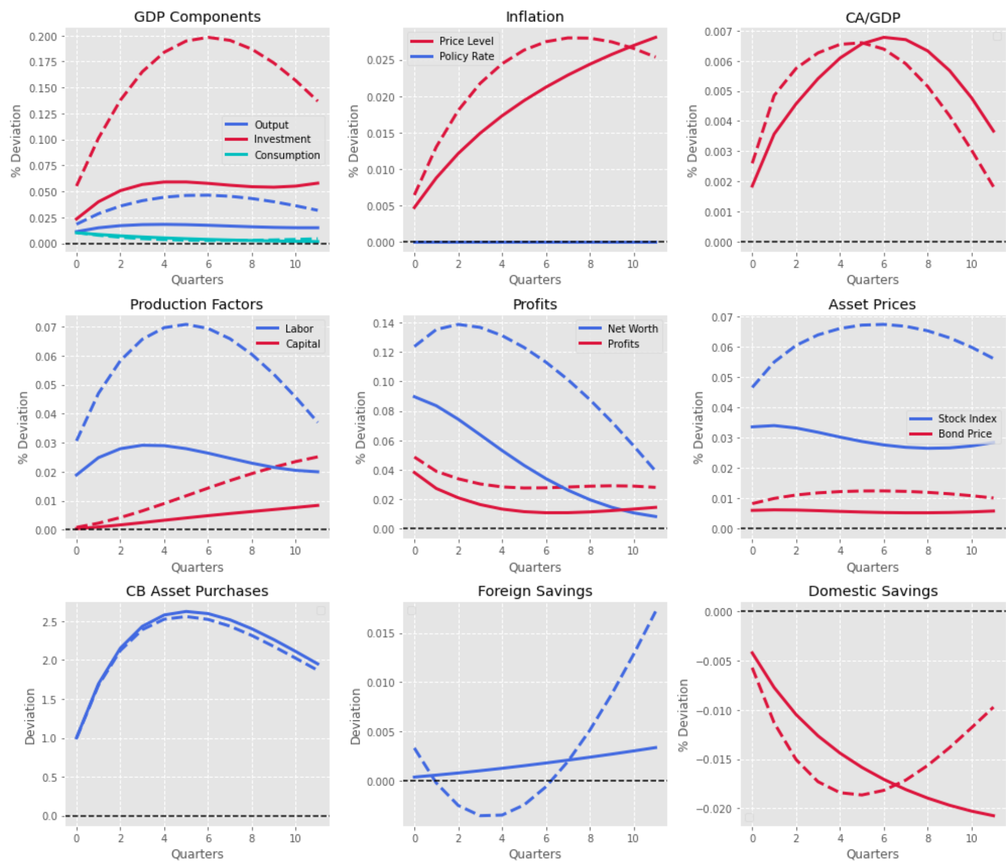
6 Capital Controls

In this section, I introduce capital controls as a macroprudential measure to reduce the foreign borrowing of Mexican banks. I examine the effects on aggregate variables and the welfare effects on different households in both countries.

6.1 Aggregate Effects of Capital Controls

Capital controls are introduced in a relatively simple way. The Mexican government imposes a tax $\tau_t^{H^*}$ on the interest payments the Mexican banks make to foreign depositors, so that the banks pay an interest

Figure 21: US Economy IRFs to 1% QE Shock in the US Economy with Capital Controls



Notes: The above graphs depict the IRFs of various US variables after a positive 1% US QE shock. The dashed lines depict the IRFs without capital controls whereas the solid lines depict the IRFs under the capital controls policy.

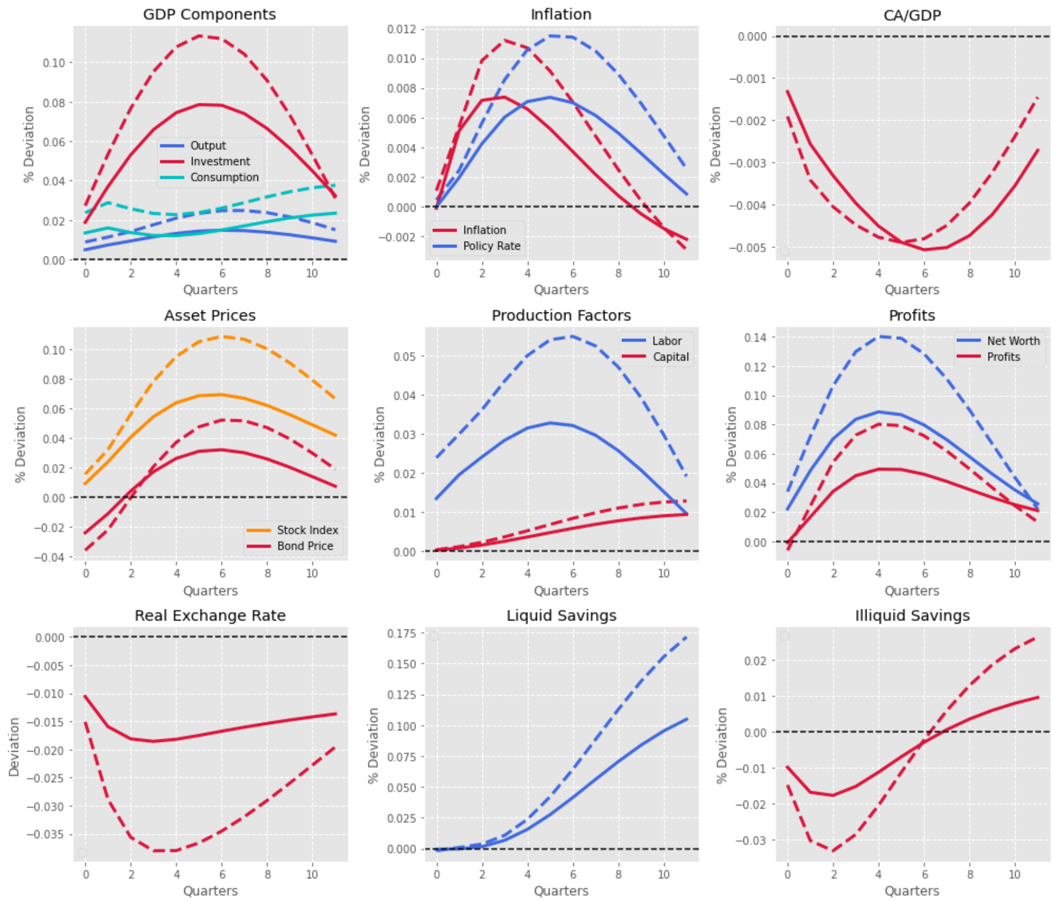
$\left(1+\tau_t^{H^*}\right)\left(1+r_t^{H^*}\right)H^*_{t-1}E_t$ to previous deposits. It is assumed that

$$\tau_t^{H^*} = \tau^{H^*} - \phi_{H^*}\left(\frac{CA_{t-1}}{Y_{Ht-1}} - \frac{CA}{Y_H}\right), \tag{6.1}$$

so that the government raises the tax on foreign borrowing when the current account as a fraction of GDP in the previous period deteriorates, since this implies more imports which are financed by more foreign borrowing. The imposition of the tax changes the optimality condition of the investment bank with respect to foreign savings since now the investment bank adjusts the expected rate paid to US households by the movements in the capital control tax rate:

$$1 + r_{t+1}^{H^*} = \frac{1 + r_{t+1}^F}{1 + \tau_{t+1}^{H^*}} \frac{E_t}{E_{t+1}} \tag{6.2}$$

Figure 22: Mexican Economy IRFs to 1% QE Shock in the US Economy with Capital Controls



Notes: The above graphs depict the IRFs of various Mexican variables after a positive 1% US QE shock. The dashed lines depict the IRFs without capital controls whereas the solid lines depict the IRFs under the capital controls policy.

In the baseline case it is assumed that τ^{H^*} is chosen so that US households still have incentives to save in foreign assets, but the excess return on the foreign asset relative to the domestic asset is 33% lower. Also it is assumed that $\phi_{H^*} = 0.2$. Starting from the US economy, households accumulate less foreign and slightly more domestic savings initially under the capital controls scenario, as shown in Figure 21. Net exports decrease but remain positive as the peso appreciates less now that less capital flows to Mexico. In addition, the price level starts at around the same point. However, it increases by less over time because of lower aggregate demand. Lower aggregate demand is also the result of lower foreign demand since the imposition of the capital controls tax rate leads to a lower increase in the net worth of the banks in Mexico, which leads to lower increase in investment, asset prices, output and consumption, implying lower demand for foreign goods. Then the lower aggregate demand in the US economy lowers the demand for production factors, which leads to lower capital accumulation, and lower asset prices.

Table 2: Consumption Equivalents Across the Wealth Distribution

Wealth Decile	**Consumption Equivalents**	
	Mexico	US
10^{th}	-0.166%	2.210%
9^{th}	0.031%	-8.837%
8^{th}	0.148%	0.626%
7^{th}	-0.256%	-0.062%
6^{th}	0.065%	-4.451%
5^{th}	0.070%	-0.289%
4^{th}	0.064%	0.241%
3^{rd}	0.060%	0.892%
2^{nd}	0.035%	0.124%
1^{st}	-0.012%	0.717%

On the other hand, the flow of foreign capital is initially reduced by the capital controls policy in the Mexican economy. The currency appreciates less due to the lower expected returns on Mexican foreign deposits as implied by Figure 22. Net imports decrease as a result of weaker currency appreciation. In addition, the investment banks have fewer resources available due to the reduction of US foreign savings and the imposition of the tax, which has negative consequences in the rest of the economy as argued above.

Overall, even if the imposition of a capital control tax may seem a reasonable policy that could reduce the leverage assumed by investment banks, the adverse effects of this policy on macro aggregates and asset prices in the small open economy can be significant. The reduction in capital flows is critical.

6.2 Welfare Effects of Capital Controls

We now turn to welfare consequences of capital controls. The tax rate now is a constant linear tax rate: $\tau_t^{H^*} = \tau^{H^*}$, since by assumption $\phi_{H^*} = 0$ now. I compute the consumption equivalents for each decile of the wealth distribution in both countries and report them in Table 2.

Starting from the country of Mexico where the capital control tax is imposed, it is evident from Table 2 that the tax leads to welfare losses for households at the very top, at the bottom, and at the middle of the wealth distribution. The reason for negative welfare effects at the top and the bottom could be that the capital control tax leads to lower economic activity, lower investments, lower net worth for the banks, and lower real wages, which affect the richer households through lower asset prices, and the poorer households through lower labor income. On the other hand, in the US economy the households at the top of the wealth distribution gain from the capital controls tax rate, and the same is true for the households at the bottom of the wealth distribution. Lastly, the results for the households at the middle of the wealth distribution in both countries are not uniform, since some categories of households gain, and some categories lose from this policy. Most categories of households in the middle of the wealth distribution in Mexico gain, while the opposite is true in the US economy.

7 Concluding Remarks

This paper explored the spillover effects of US quantitative easing programs on emerging market economies. Using Bayesian VAR models, I documented that shocks in central bank asset purchases in the US economy have positive statistically significant effects on macro aggregates and asset prices both in the US economy and in the EMEs. In addition, in the EMEs, currencies appreciate, and current accounts deteriorate. Then I developed a two-country HANK model with QE policies that matches the aggregate responses to the empirical ones. The bank balance sheets in both countries are at the heart of the international transmission mechanism.

Another finding was that heterogeneity matters in the two-country world, in some cases both quantitatively and qualitatively, and in some cases only quantitatively. Allowing at least one of the two countries to have a representative agent instead of heterogeneous agents led to significant differences in the magnitude of the IRFs produced by the model. In the case where we assumed a RANK specification for Mexico, we also had the IRFs changing directions in some cases. In terms of inequality, this paper showed that over the medium run, QE tends to decrease all types of inequality, mainly because the constrained households get higher labor income and surpass their constraints. This allows them to start accumulating assets and consume more. However, in the short run, QE tends to increase wealth inequality since wealthier households can accumulate more illiquid assets since they can pay the associated transaction cost.

Finally, a policy like capital controls that aims to reduce the leverage assumed by the banks in the small open economy can have adverse effects, as it can greatly reduce capital inflows and significantly reduce the positive effects of QE on small open economies.

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A Foreign Economy

In this appendix I present the foreign economy in the two-country model and the corresponding calibrated parameters along with the equilibrium definition.

A.1 Foreign Households

The demand side of the US economy consists of infinitely-lived households indexed by $i^* \in [0,1]$. Foreign households are also assumed to be *ex-ante* identical but *ex-post* heterogeneous and solve

$$\max_{\left\{c^*_{i^*t}, l^*_{i^*t}, a^*_{i^*t}, d^*_{i^*t}\right\}_{t=0}^{\infty}} U_i^* = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^{*t} \left(\frac{c^{*1-\sigma^*}_{i^*t} - 1}{1-\sigma^*} - \mu_L^* \frac{l^{*1+\nu^*}_{i^*t}}{1+\nu^*} \right) \tag{A.1}$$

subject to

$$c^*_{i^*t} + d^*_{i^*t} + a^*_{i^*t} + \Xi\left(a^*_{i^*t}, a^*_{i^*t-1}\right) + \mathcal{T}^*_t = \left(1 - \tau^{L^*}\right) w^*_t l^*_{i^*t} e^*_{i^*t} + \left(1 + r_t^{D^*}\right) d^*_{i^*t-1} + \left(1 + r_t^{A^*}\right) a^*_{i^*t-1} \tag{A.2}$$

$$\Xi\left(a^*_{i^*t}, a^*_{i^*t-1}\right) = \frac{\chi_1^*}{\chi_2^*} \left| \frac{a^*_{i^*t} - \left(1 + r_t^{A^*}\right) a^*_{i^*t-1}}{\left(1 + r_t^{A^*}\right) a^*_{i^*t-1} + \chi_0^*} \right|^{\chi_2^*} \left[\left(1 + r_t^{A^*}\right) a^*_{i^*t-1} + \chi_0^* \right] \tag{A.3}$$

$$a^*_{i^*t} \geq 0, \;\; d^*_{i^*t} \geq \underline{d}^*. \tag{A.4}$$

The problem of the foreign households is symmetric to problem of domestic households, so the interpretation of expressions (A.2)-(A.4) is the same as in the case of the domestic economy. Also, c_t^* is a consumption basket given as

$$c_t^* = \left[(\mu^*)^{\frac{1}{\eta}} \left(c^*_{Ht}\right)^{\frac{\eta-1}{\eta}} + (1-\mu^*)^{\frac{1}{\eta}} \left(c^*_{Ft}\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \tag{A.5}$$

The demand functions satisfy

$$c^*_{Ft} = (1-\mu^*) \left(\frac{P^*_{Ft}}{P^*_t} \right)^{-\eta} c^*_t \tag{A.6}$$

$$c^*_{Ht} = \mu^* \left(\frac{P^*_{Ht}}{P^*_t} \right)^{-\eta} c^*_t, \tag{A.7}$$

where in the previous expressions P_{Ft} is the price level of foreign goods in domestic currency units, P_{Ht} is the price level of domestic goods, and P_t is the general price level. This index, in turn, is defined by

$$P_t^* \equiv \left[\mu^* \left(P_{Ht}^*\right)^{1-\eta} + (1-\mu^*)\left(P_{Ft}^*\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{A.8}$$

A.2 Labor Unions

This subsection follows directly the discussion of the labor unions in the domestic economy. The problem of the labor recruiter is to minimize the cost of producing a given amount of aggregate labor:

$$\min_{l_{i^*t}^*} \mathcal{C}_t^{*LR} = \int_0^1 W_{i^*t}^* l_{i^*t}^* e_{i^*t}^* di^* \tag{A.9}$$

subject to the technology constraint

$$L_t^* = \left[\int_0^1 \left(l_{i^*t}^*\right)^{\frac{\varepsilon_w^*-1}{\varepsilon_w^*}} e_{i^*t}^*\right]^{\frac{\varepsilon_w^*}{\varepsilon_w^*-1}}, \tag{A.10}$$

where ε_w^* is the elasticity of substitution between differentiated labor services. The demand of the labor recruiter for each differentiated labor service is

$$l_{i^*t}^* = \left(\frac{W_{i^*t}^*}{W_t^*}\right)^{-\varepsilon_w^*} L_t^*, \tag{A.11}$$

where in the last equation $W_t^* = \left[\int_0^1 e_{i^*t}^* W_{i^*t}^{*1-\varepsilon_w^*}\right]^{\frac{1}{1-\varepsilon_w^*}}$ is the equilibrium nominal wage. The labor union picks the same nominal wage $W_{i^*t}^* = \hat{W}_t^*$ for all households to maximize profits, subject to a wage adjustment cost à la Rotemberg (1982). The problem of the union can be expressed as

$$V_t^{*w}\left(\hat{W}_{t-1}^*\right) \equiv \max_{\hat{W}_t^*} \left\{ \int \frac{e_{i^*t}^*\left(1-\tau^{L^*}\right)\hat{W}_t^*}{P_t^*} l\left(\hat{W}_t^*; W_t^*, L_t^*\right) di - \frac{v^*\left(l\left(\hat{W}_t^*; W_t^*, L_t^*\right)\right)}{u^{*\prime}\left(C_t^*\right)} \right.$$
$$\left. - \int \frac{\xi_w^*}{2}\left(\frac{\hat{W}_t^*}{\hat{W}_{t-1}^*} - 1\right)^2 L_t^* e_{i^*t}^* di^* + \frac{V_{t+1}^{*w}\left(\hat{W}_t^*\right)}{1+r_{t+1}^*} \right\}. \tag{A.12}$$

In equilibrium $\hat{W}_t^* = W_t^*$ and $l_{i^*t}^* = L_t^*$. The optimality condition for the union's problem is a Phillips curve relation for wages:

$$\left(1-\tau^{L^*}\right)\left(1-\varepsilon_w^*\right) w_t^* + \varepsilon_w^* \frac{v^{*\prime}\left(l^*\left(W_t^*, L_t^*\right)\right)}{u^{*\prime}\left(C_t^*\right)} + \frac{1}{1+r_{t+1}^*}\xi_w^*\left(\Pi_{t+1}^{w^*}-1\right)\Pi_{t+1}^{w^*}\frac{L_{t+1}^*}{L_t^*} = \xi_w^*\left(\Pi_t^{w^*}-1\right)\Pi_t^{w^*}. \quad \text{(A.13)}$$

where the wage inflation is given by

$$\Pi_t^{w^**} = \Pi_t^* \frac{w_t^*}{w_{t-1}^*}. \quad \text{(A.14)}$$

A.3 Investment Fund

In the economy there is a hypothetical investment fund which collects the liquid savings of households D_t^* and invests these resources in deposits issued by foreign investment banks. The investment fund is also the owner of all firms in the foreign economy and collects all the profits. In equilibrium it pays a real return to households $r_t^{D^*}$ subject to a cost of financial intermediation ξ_{D^*}. The balance sheet of the investment fund is

$$D_t^* = F_t^* \quad \text{(A.15)}$$

where F_t^* is the deposits of the foreign investment fund in the foreign investment banks. The budget constraint is

$$F_t^* + \left(1 + r_t^{D^*} + \xi_{D^*}\right) D_{t-1}^* = \left(1-\tau^{D^*}\right)\mathcal{D}_t^* + D_t^* + \left(1 + r_t^{F^*}\right) F_{t-1}^*, \quad \text{(A.16)}$$

where $\mathcal{D}_t^*$ is the aggregate profits of all firms in the economy taxed at the rate τ^{D^*}. The investment fund is assumed to operate under a no-retained earnings rule. Then,

$$r_t^{D^*} = \frac{\left(1-\tau^{D^*}\right)\mathcal{D}_t^*}{F_{t-1}} + r_t^{F^*} - \xi_{D^*}. \quad \text{(A.17)}$$

A.4 Investment Banks

The first financial intermediary in the foreign economy is investment banks. In any period t, investment banks collect the deposits of the investment fund $\mathcal{F}_{b^*t}^*$ and hold the nominal reserves issued by the central bank $\mathcal{M}_{b^*t}^*$. They also invest in long-term government bonds $q_t^*\mathcal{B}_{b^*t}^*$, capital claims issued by intermediate good producers $P_t^* Q_t^* K_{b^*t}^*$ and pay a nominal return $\left(1+i_t^{F^*}\right)$ in the next period to the investment fund. The balance sheet of the investment banks in real terms is the following

$$Q_t^* K_{b^*t}^* + q_t^* B_{b^*t}^* + M_{b^*t}^* = F_{b^*t}^* + N_{b^*t}^*. \quad \text{(A.18)}$$

The budget constraint of the investment bank in real terms has the following form

$$Q_t^* K_{b^*t}^* + q_t^* B_{b^*t}^* + M_{b^*t}^* + \left(1 + r_t^{F^*}\right) F_{b^*t-1}^* = \left(1 + r_t^{K^*}\right) Q_{t-1}^* K_{b^*t-1}^* + \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{bt-1}^* + \left(1 + r_t^*\right) M_{b^*t-1}^* + F_{b^*t}^* \tag{A.19}$$

The combination of the previous two equations gives the evolution of the investment bank net worth

$$\begin{aligned} N_{bt}^* = & \left[\left(1 + r_t^{K^*}\right) - \left(1 + r_t^{F^*}\right)\right] Q_{t-1}^* K_{bt-1}^* + \left[\left(1 + r_t^{B^*}\right) - \left(1 + r_t^{F^*}\right)\right] q_{t-1}^* B_{bt-1}^* \\ & + \left[\left(1 + r_t^*\right) - \left(1 + r_t^{F^*}\right)\right] M_{b^*t-1}^* + \left(1 + r_t^{F^*}\right) N_{bt-1}^* \end{aligned} \tag{A.20}$$

In each period a fraction of foreign banks $\theta_{b^*}^*$ continues to operate, while the remaining fraction $1 - \theta_{b^*}^*$ exits the market. The foreign banking sector is characterized also by a moral hazard problem similar to the investment banks in the domestic economy. In each period a bank can divert a fraction $\lambda_{K^*}^*$ of the equity holdings $Q_{b^*t} K_{b^*t}^*$, and a fraction $\lambda_{B^*}^*$ of the government bonds $q_t^* B_{b^*t}^*$. The value function of a bank is

$$V_{b^*t}\left(N_{b^*t}^*\right) = \max_{K_{b^*t}^*, B_{b^*t}^*, M_{b^*t}^*, F_{b^*t}^*} \left\{ \frac{1}{1 + r_{t+1}^*} \left[\left(1 - \theta_{b^*}^*\right) N_{b^*t+1}^* + \theta_{b^*}^* V_{b^*t+1}\left(N_{b^*t+1}^*\right)\right] \right\} \tag{A.21}$$

subject to equations (A.18) and (A.20), and the incentive constraint

$$V_{b^*t}\left(N_{b^*t}^*\right) \geq \lambda_{K^*}^* Q_t^* K_{b^*t}^* + \lambda_{B^*}^* q_t^* B_{b^*t}^*. \tag{A.22}$$

Proposition 2: *The investment bank's value function is linear in net worth and satisfies*

$$V_{b^*t}\left(N_{b^*t}^*\right) = \Sigma_{b^*t}^* N_{b^*t}^* \tag{A.23}$$

$$\Sigma_{b^*t}^* = \frac{\lambda_{K^*}^*}{\lambda_{K^*}^* - \frac{1}{1+r_{t+1}^*}\left(1 - \theta_{b^*}^* + \theta_{b^*}^* \Sigma_{b^*t+1}^*\right)\left(r_{t+1}^{K^*} - r_{t+1}^{F^*}\right)} \frac{1 + r_{t+1}^{F^*}}{1 + r_{t+1}^*}\left(1 - \theta_{b^*}^* + \theta_{b^*}^* \Sigma_{b^*t+1}^*\right). \tag{A.24}$$

Proof: The proof follows the same steps that were presented for the domestic investment bank. ■

The optimality conditions corresponding to the bank's problem are the following:

$$1 + r^{F^*}_{t+1} = 1 + r^*_{t+1} \tag{A.25}$$

$$1 + r^{B^*}_{t+1} = \frac{\lambda^*_{B^*}}{\lambda^*_{K^*}} \left(1 + r^{K^*}_{t+1}\right) + \left(1 - \frac{\lambda^*_{B^*}}{\lambda^*_{K^*}}\right) \left(1 + r^{F^*}_{t+1}\right). \tag{A.26}$$

Equation (A.25) says that the interest rate paid to the foreign investment fund will be determined by the expected real interest rate paid on central bank reserves. Using the Fisher equation, this condition can be written as an equality between the nominal return on fund's deposits at time t and the nominal return the bank gets on nominal reserves.

Equation (A.26) says that the real return on government bonds in equilibrium will be a weighted average of the real return paid on equity and the real return paid on the investment fund's deposits. The amount of capital equity held by the banks is determined by the aggregate incentive constraint

$$K^*_{b^*t} = \frac{1}{\lambda^*_{K^*} Q^*_t} \left(\Sigma^*_{b^*t} N^*_{b^*t} - \lambda^*_{B^*} q^*_t B^*_{b^*t}\right) \tag{A.27}$$

Aggregate net worth evolves according to

$$\begin{aligned} N^*_{b^*t} = \; & \theta^*_{b*t} \left\{ \left[\left(1 + r^{K^*}_t\right) - \left(1 + r^{F^*}_t\right) \right] Q^*_{t-1} K^*_{b^*t-1} + \left[\left(1 + r^{B^*}_t\right) - \left(1 + r^{F^*}_t\right) \right] q^*_{t-1} B^*_{b^*t-1} + \left(1 + r^{F^*}_t\right) N^*_{b^*t-1} \right\} \\ & + \omega^*_{b^*} \left(Q^*_{t-1} K^*_{b^*t-1} + q^*_{t-1} B^*_{b^*t-1} + M^*_{b^*t-1}\right) \end{aligned} \tag{A.28}$$

The profits of the investment banks are given by

$$\mathcal{D}^*_{b^*t} = \frac{1 - \theta^*_{b^*t}}{\theta^*_{b^*t}} N^*_{b^*t} - \frac{\omega^*_{b^*}}{\theta^*_{b^*}} \left(Q^*_{t-1} K^*_{b^*t-1} + q^*_{t-1} B^*_{b^*t-1} + M^*_{b^*t-1}\right). \tag{A.29}$$

The above expression is just the total net worth of existing banks minus the funds given to new banks. Part of the profits of the financial sector is taxed at a rate τ^{D^*}. The remaining part is given to the investment fund.

A.5 International Bank

The second financial intermediary in the foreign economy is an international bank that takes the illiquid savings of foreign households A^*_t and invests them in deposits H^*_t held by the bank operating in the home country.[17] The foreign investment bank earns an interest rate $1 + r_t^{H^*}$ and passes it to the foreign households. The balance sheet of the foreign investment bank is

$$A_t^* = H_t^*. \tag{A.30}$$

The no-arbitrage condition for interest rates is

$$1 + r_t^{A^*} = 1 + r_t^{H^*}. \tag{A.31}$$

A.6 Final Goods Producers

Firms in the foreign final good sector produce the final good Y_{Ft}^* using as inputs a continuum of intermediate goods $Y_{Ft}^{j^*}$ with $j^* \in [0, 1]$. They solve

$$\max_{Y_{Ft}^{j^*}} \mathcal{D}_t^{F^*} = P_{Ft}^* Y_{Ft}^* - \int_0^1 P_{Ft}^{j^*} Y_{Ft}^{j^*} dj^* \tag{A.32}$$

subject to

$$Y_{Ft}^* = \left[\int_0^1 \left(Y_{Ft}^{j^*} \right)^{\frac{\varepsilon_p^* - 1}{\varepsilon_p^*}} dj^* \right]^{\frac{\varepsilon_p^*}{\varepsilon_p^* - 1}}, \tag{A.33}$$

where $P_{Ft}^{j^*}$ is the price of intermediate good j^*. The solution to the above problem is standard and gives the demand for intermediate good j^*

$$Y_{Ft}^{j^*} = \left(\frac{P_{Ft}^{j^*}}{P_{Ft}^*} \right)^{-\varepsilon_p^*} Y_{Ft}^*. \tag{A.34}$$

A.7 Intermediate Goods Producers

There is a continuum of firms in the intermediate goods sector indexed by $j^* \in [0, 1]$. Each firm j^* has access to the same CRS production technology which combines labor $L_t^{*j^*}$, capital $K_{t-1}^{*j^*}$, and total factor productivity Z_t^* to produce output $Y_{Ft}^{j^*}$:

[17] The reason why the foreign households deposit their savings in a bank that invests in the emerging market instead of holding directly deposits in the banking sector of the emerging market is that In reality US households have very little to no exposure in emerging market deposits held by themselves, and they are exposed indirectly through the banking system.

$$Y_{Ft}^{j^*} = Z_t^* \left(K_{t-1}^{*j^*}\right)^{\alpha^*} \left(L_t^{*j^*}\right)^{1-\alpha^*} \tag{A.35}$$

Intermediate goods producers hire capital and labor in perfectly competitive markets in a way that minimizes the cost of production

$$\min_{K_{t-1}^{*j^*}, L_t^{*j^*}} \mathcal{C}_t^{*j^*} = w_t^* L_t^{*j^*} + \left(1 + r_t^{K^*}\right) Q_{t-1}^* K_{t-1}^{*j^*} - \left(Q_t^* - \delta^*\right) K_{t-1}^{*j^*} \tag{A.36}$$

The cost minimization is subject to the production function (A.35). The optimality conditions are

$$r_t^{K^*} = \frac{1}{Q_{t-1}^*} \left(\alpha^* \frac{Y_{Ft}^{j^*}}{K_{t-1}^{*j^*}} \mathrm{MC}_t^* + Q_t^* - \delta^*\right) - 1 \tag{A.37}$$

$$w_t^* = (1-\alpha^*) \frac{Y_{Ft}^{*j^*}}{L_t^{*j^*}} \mathrm{MC}_t^* \tag{A.38}$$

$$\mathrm{MC}_t^* = \left(\frac{r_t^{K^*}}{\alpha^*}\right)^{\alpha^*} \left(\frac{w_t^*}{1-\alpha^*}\right)^{1-\alpha^*}. \tag{A.39}$$

In the previous equations MC_t is the real marginal cost of production. Total cost is then

$$\mathcal{C}_t^{*j^*} = \left(1 + r_t^{K^*}\right) Q_{t-1}^* K_{t-1}^{*j^*} - \left(Q_t^* - \delta\right) K_{t-1}^{*j^*} + w_t^* L_t^{*j^*} = \mathrm{MC}_t^* Y_{Ft}^{j^*}. \tag{A.40}$$

The optimal pricing problem for intermediate good producer j^* is expressed as

$$V_t^{j^*}\left(P_{Ft-1}^{j^*}\right) = \max_{P_{Ft}^{j^*}} \left\{ \left(\frac{P_{Ft}^{j^*}}{P_t^*} - \mathrm{MC}_t^*\right) \left(\frac{P_{Ft}^{j^*}}{P_{Ft}^*}\right)^{-\varepsilon_p^*} Y_{Ft}^* - \frac{\xi_p^*}{2} \left(\frac{P_{Ft}^{j^*}}{P_{Ft-1}^{j^*}} - 1\right)^2 \frac{P_{Ft}^*}{P_t^*} Y_{Ft}^* + \frac{V_{t+1}^{j^*}\left(P_{Ft}^{j^*}\right)}{1 + r_{t+1}^*} \right\} \tag{A.41}$$

In equilibrium $P_{Ft}^{j^*} = P_{Ft}^*$, so the optimality condition for the optimal pricing problem gives rise to the New Keynesian Phillips Curve

$$(1-\varepsilon_p^*) \frac{S_t P_{Ht}^*}{P_t^*} + \varepsilon_p^* \mathrm{MC}_t^* + \frac{1}{1 + r_{t+1}^*} \xi_p^* \left(\Pi_{Ft+1}^* - 1\right) \Pi_{Ft+1}^* \frac{S_{t+1} P_{Ht+1}^*}{P_{t+1}^*} \frac{Y_{Ft+1}^*}{Y_{Ft}^*} = \xi_p^* \left(\Pi_{Ft}^* - 1\right) \Pi_{Ft}^* \frac{S_t P_{Ht}^*}{P_t^*}. \tag{A.42}$$

The dividend paid by each intermediate good producer is

$$\mathcal{D}_t^{IG^*} = Y_{Ft}^* \left[\frac{S_t P_{Ht}^*}{P_t^*} - \mathrm{MC}_t^* - \frac{\xi_p^*}{2} \left(\frac{P_{Ft}^*}{P_{Ft-1}^*} - 1\right)^2 \frac{S_t P_{Ht}^*}{P_t^*}\right] \tag{A.43}$$

Part of the dividends is taxed at rate τ^{D^*}. The remaining part is distributed to the investment fund.

A.8 Capital Producers

The problem of the capital producers in the foreign economy is very similar to the one faced by capital producers in the domestic economy

$$\max_{I_{nt}^*} \sum_{s=t}^{\infty} \left(\prod_{k=1}^{j|_{j\geq 1}} \frac{1}{1+r_{t+k}^*} \right) \left[\left(Q_s^* - 1\right) I_{ns}^* - \frac{S_t P_{Ht}^*}{P_t^*} \frac{\xi_I^*}{2} \left(\frac{I_{ns}^* + I^*}{I_{ns-1}^* + I^*} - 1 \right)^2 \left(I_{ns}^* + I^*\right) \right] \tag{A.44}$$

where new and total investment satisfy the law of motions

$$I_{nt}^* = I_t^* - \delta^* K_{t-1}^* \tag{A.45}$$

$$I_t^* = K_t^* - \left(1 - \delta^*\right) K_{t-1}^*. \tag{A.46}$$

The optimality condition is

$$\begin{aligned} Q_t^* + \frac{1}{1+r_{t+1}^*} \frac{S_{t+1} P_{Ht+1}^*}{P_{t+1}^*} \xi_I^* \left(\frac{I_{nt+1}^* + I^*}{I_{nt}^* + I^*} - 1 \right) \left(\frac{I_{nt+1}^* + I^*}{I_{nt}^* + I^*} \right)^2 = 1 + \frac{S_t P_{Ht}^*}{P_t^*} \xi_I^* \left(\frac{I_{nt}^* + I^*}{I_{nt-1}^* + I^*} - 1 \right) \frac{I_{nt}^* + I^*}{I_{nt-1}^* + I^*} \\ + \frac{S_t P_{Ht}^*}{P_t^*} \frac{\xi_I^*}{2} \left(\frac{I_{nt}^* + I^*}{I_{nt-1}^* + I^*} - 1 \right)^2 . \end{aligned} \tag{A.47}$$

Also, I_t^* is a basket of domestic and foreign investment goods given as

$$I_t^* = \left[\left(\mu^*\right)^{\frac{1}{\eta}} \left(I_{Ht}^*\right)^{\frac{\eta-1}{\eta}} + \left(1 - \mu^*\right)^{\frac{1}{\eta}} \left(I_{Ft}^*\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} . \tag{A.48}$$

The demand functions for domestic and foreign investment goods satisfy the optimality conditions

$$I_{Ft}^* = \left(1 - \mu^*\right) \left(\frac{P_{Ft^*}}{P_t^*} \right)^{-\eta} I_t^* \tag{A.49}$$

$$I_{Ht}^* = \mu^* \left(\frac{P_{Ht}^*}{P_t^*} \right)^{-\eta} I_t^*, \tag{A.50}$$

Part of the dividends of the capital producing firm is taxed at rate τ^{K^*}. The remaining part is distributed to the investment fund.

A.9 Monetary Authority

The central bank is conducting monetary policy by changing the nominal interest rate on reserves $i_t^{M^*}$ and by purchasing government debt $q_t^* \mathcal{B}_t^{CB^*}$. The central bank balance sheet in real terms takes the following form

$$q_t^* B_t^{CB^*} + (1 + r_t^*) M_{t-1}^* + T_t^{CB^*} = \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{t-1}^{CB^*} + M_t^*, \tag{A.51}$$

The behavior of the central bank is described by Taylor-type rules. The nominal rate on reserves is given by

$$1 + i_t^{M^*} = \max\left\{ (1 + r^*)^{1-\rho^*} \left(1 + i_{t-1}^{M^*}\right)^{\rho^*} \left(\frac{\Pi_t^*}{\Pi^*}\right)^{(1-\rho^*)\phi_{\Pi^*}} \left(\frac{Y_{Ft}^*}{Y_F^*}\right)^{(1-\rho^*)\phi_{Y_F^*}}, 1 \right\}. \tag{A.52}$$

The central bank's asset purchases are given by

$$B_t^{CB^*} = \left(B^{CB^*}\right)^{1-\rho_B^*} \left(B_{t-1}^{CB^*}\right)^{\rho_B^*} \left(\frac{\Pi_t^*}{\Pi^*}\right)^{-(1-\rho_B^*)\psi_{\Pi_F^*}} \left(\frac{Y_{Ft}}{Y_F}\right)^{-(1-\rho_B^*)\psi_{Y_F^*}} + u_t^*. \tag{A.53}$$

The last rule is about the amount of real reserves. By assumption, the central bank offers a an amount of real reserves equal to the amount of new total asset purchases, so

$$M_t^* = q_t^* B_t^{CB^*}. \tag{A.54}$$

Equations (A.53)-(A.54) specify how new assets purchases and new reserves will move in any period t. Then, the transfer of the central bank to the fiscal authority in every period t can be determined by

$$T_t^{CB^*} = \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{t-1}^{CB^*} - (1 + r_t^*) M_{t-1}^*. \tag{A.55}$$

A.10 Fiscal Authority

The fiscal authority obtains revenues from household lump-sum taxes and labor income taxes, and also from taxes on the dividends paid by all firms. It also issues new long-term debt and receives a transfer from the monetary authority. These revenues are used to finance an exogenous path of real government expenditures G_t^*, and pay the interest on previous debt. The government budget constraint is therefore

$$q_t^* B_t^* + \mathcal{T}_t^* + \tau^{L^*} w_t^* L_t^* + \tau^{D^*} \mathcal{D}_t^* + T_t^{CB^*} = \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{t-1}^* + \frac{P_{Ft}^*}{P_t^*} G_t^* \tag{A.56}$$

where the real interest rate on government bonds is given by

$$1 + r_t^{B^*} = \frac{1 + \gamma^* q_t^*}{q_{t-1}^*} \frac{1}{\Pi_t^*}. \tag{A.57}$$

The fiscal rule behind the lump-sum tax is given by

$$\mathcal{T}_t^* = T^* + \phi_{B^*} \left(\frac{q_{t-1}^* B_{t-1}^*}{Y_{Ft-1}^*} - \frac{q^* B^*}{Y_F^*} \right). \tag{A.58}$$

A.11 Foreign Market Clearing

The market clearing conditions for the foreign economy are all summarized by the following equations:

$$L_t^* = \int L_{j^*t}^* dj^* = \int l_{i^*t}^* di^* \tag{A.59}$$

$$B_t^* = B_{b^*t}^* + B_t^{CB^*} + B_t^{*MF} \tag{A.60}$$

$$K_t^* = K_{b^*t}^* \tag{A.61}$$

$$Y_{Ft}^* = C_{Ft}^* + I_{Ft}^* + G_t^* + \frac{\varsigma}{\varsigma^*} (C_{Ft} + I_{Ft}) + \Xi_t^{I^*} \left(I_{nt}^*, I_{nt-1}^* \right) + \Xi_t^{P^*} \left(\Pi_{Ft}^*, \Pi_{Ft-1}^*, Y_{Ft}^* \right). \tag{A.62}$$

Finally, if we combine the budget constraints of all agents with the market clearing conditions, we can derive the balance of payments equation

$$\begin{aligned} \frac{P_{Ft}^*}{P_t^*} (C_{Ft} + I_{Ft}) - \frac{P_{Ht}^*}{P_t^*} (C_{Ht}^* + I_{Ht}^*) = H_t^* - \left(1 + r_t^{H^*}\right) H_{t-1}^* - q_t^* B_t^{*MF} + \left(1 + r_t^{B^*}\right) q_{t-1}^* B_{t-1}^{*MF} \\ + \int \Xi \left(a_{i^*t}^*, a_{i^*t-1}^* \right) d\Gamma_t^* + \xi_{D^*} D_{t-1}^*. \end{aligned} \tag{A.63}$$

A.12 Equilibrium Definition

Definition: The monetary competitive equilibrium is given by a sequence of asset purchases shocks $\{u_t^*\}_{t=0}^{\infty}$, policy sequences for the fiscal and monetary authorities in both countries: $\{B_t, \mathcal{T}_t, i_t^M, M_t, B_t^{CB}, K_t^{CB}, T_t^{CB}\}_{t=0}^{\infty}$ and $\left\{B_t^*, T_t^*, i_t^{M^*}, M_t^*, B_t^{CB^*}, T_t^{CB^*}\right\}_{t=0}^{\infty}$, value functions for households in both countries $\{V_{it}\}_{t=0}^{\infty}$ and $\{V_{i^*t}^*\}_{t=0}^{\infty}$ with policies $\{c_{it}, l_{it}, a_{it}, d_{it}\}_{t=0}^{\infty}$ and $\{c_{i^*t}^*, l_{i^*t}^*, a_{i^*t}^*, d_{i^*t}^*\}_{t=0}^{\infty}$, value functions for labor unions in both countries $\{V_t^w\}_{t=0}^{\infty}$ and $\{V_t^{*w}\}_{t=0}^{\infty}$ with labor choices $\{L_t\}_{t=0}^{\infty}$ and $\{L_t^*\}_{t=0}^{\infty}$, value functions for intermediate goods producers $\left\{V_t^j\right\}_{t=0}^{\infty}$ and $\left\{V_t^{j^*}\right\}_{t=0}^{\infty}$ with optimal choices $\left\{P_{Ht}^j, K_{t-1}^j, L_t^j\right\}_{t=0}^{\infty}$ and $\left\{P_{Ft}^{j^*}, K_t^{j^*}, L_t^{j^*}\right\}_{t=0}^{\infty}$, value functions for capital producers $\{V_t^K\}_{t=0}^{\infty}$ and $\left\{V_t^{K^*}\right\}_{t=0}^{\infty}$, with optimal choices $\{I_t, K_t\}_{t=0}^{\infty}$ and $\{I_t^*, K_{t+1}^*\}_{t=0}^{\infty}$, prices

$\left\{w_t,\, r_t^K,\, P_{Ht}^j,\, P_t,\, q_t,\, Q_t\right\}_{t=0}^{\infty}$ and $\left\{w_t^*,\, r_t^{K^*},\, P_{Ft}^{j^*},\, P_t^*,\, q_t^*,\, Q_t^*\right\}_{t=0}^{\infty}$, domestic bank value functions $\{V_{nt}^{MF}\}_{t=0}^{\infty}$, and $\{V_{bt}\}_{t=0}^{\infty}$, with bank choices $\{K_{nt}^{MF},\, B_{nt}^{MF},\, A_{nt}^{MF},\, B_{nt}^{*MF},\, H_{nt}^*\}_{t=0}^{\infty}$, and $\{M_{bt},\, D_{bt}\}_{t=0}^{\infty}$, foreign bank value functions $\{V_{b^*t}\}_{t=0}^{\infty}$ with bank choices $\{K_{b^*t}^*,\, B_{b^*t}^*,\, M_{b^*t}^*,\, F_{b^*t}^*\}_{t=0}^{\infty}$, domestic bank net worth $\{N_{bt}\}_{t=0}^{\infty}$ and $\{N_t^{MF}\}_{t=0}^{\infty}$, and foreign bank net worth $\{N_{b^*t}^*\}_{t=0}^{\infty}$, interest rates $\{r_t,\, r_t^A,\, r_t^D,\, r_t^B,\, r_t^F\}_{t=0}^{\infty}$ and $\left\{r_t^*,\, r_t^{D^*},\, r_t^{A^*},\, r_t^{H^*},\, r_t^{B^*},\, r_t^{F^*}\right\}_{t=0}^{\infty}$, and joint distributions of assets and shocks $\Gamma_t\,(a,d,e)$ and $\Gamma_t^*\,(a^*,d^*,e^*)$ such that in any period t:

1. Given the prices, the interest rates, and taxes the value function V_{it} satisfies the Bellman equation for household i with policies c_{it}, a_{it}, d_{it}. Similarly for the foreign households.
2. The value function V_t^w solves the problem of the union and nominal wages are optimally set in both countries.
3. Final good firms maximize profits taking as given the prices P_{Ht}^j, P_t. Similarly in the foreign country.
4. Intermediate goods producers maximize profits taking as given the prices w_t and r_t^K. Similarly in the foreign country.
5. Commercial banks maximize their net worth with the optimal value being V_{bt}.
6. The domestic investment banks choose optimally their asset holdings in order to maximize net worth V_{nt}^{MF}. Similarly for foreign banks.
7. The investment fund satisfies its zero profit condition (3.32). Similarly in the foreign country.
8. The foreign investment bank satisfies the no arbitrage condition (A.31).
9. The capital producers maximize profits with the optimal value being V_t^K. Similarly for the foreign country.
10. The monetary authority follows the rules (3.67)-(3.70) in the domestic country, and (A.52)-(A.55) in the foreign country.
11. The fiscal authority satisfies its budget constraint (3.71) and the fiscal rule (3.73) in the domestic country, and (A.56) and (A.57) in the foreign country.
12. The aggregate law of motion Γ is generated by the choices a_{it}, d_{it} and the matrix $\Omega(.)$. Similarly in the foreign country.
13. The market clearing conditions (3.74)-(3.80), and (A.59)-(A.62) are satisfied.

A.13 Calibration - Foreign Economy

The foreign economy is assumed to be the US economy. The model is calibrated over the period 2008-2021 using quarterly data, in line with the period of interest in the empirical part of the paper.

Households: The households are again split into two categories: those with a high discount factor and those with a low discount factor. Discount factor heterogeneity is used to hit the following calibration targets: i) the high discount factor is set equal to $\beta^{H^*} = 0.997$ so that $D^* = 15.749Y_F^*$, which is the average value of total financial assets to GDP for the period 2008-2021 according to the Flow of Funds data, and ii) the low discount factor is set equal to $\beta^{L^*}0.9802$ so as to match the size of the hand-to-mouth households, which is equal to 8% in the SCF of 2019.[18] The parameter measuring the relative weight of labor disutility is set equal to $\mu_L^* = 1.371$ so as to satisfy the steady state version of the WNKPC given by (A.13). The pivot adjustment cost parameter is free and is set equal to $\chi_0^* = 0.01$. The scale adjustment cost parameter is set equal to $\chi_1^* = 24.413$ so as to match the ratio of bank domestic debt to foreign debt $\frac{EH^*}{F+D} = 0.3$, as implied in Akinci and Queralto (2018). The curvature adjustment cost parameter is set equal to $\chi_2^* = 2$. The trade openess parameter is set equal to $\mu^* = 0.323/3$ following Akinci and Queralto (2018). The labor productivity process e_t^* is assumed to follow an $AR(1)$ process with persistence $\rho_e^* = 0.966$ and standard deviation of the shocks equal to $\sigma_e^* = 0.92$ as in McKay et al. (2016). The labor productivity process is discretized as a Markov chain with nine nodes. Finally, the upper bound on the grid for the illiquid savings choice of the households is set equal to $\bar{d}^* = 41.203$ so as to match the average wealth share of the top 10% as given by the WID for the period 2008-2021.[19]

Labor Union: The elasticity of substitution between different types of labor is set equal to $\varepsilon_w^* = \varepsilon_p^* = 9$. The steady state amount of labor is normalized to $L^* = 1$.

Investment Fund: The unit cost of intermediation is set equal to $\xi_{D^*} = 0.0085$ so as to achieve a steady state real return on liquid savings equal to $r^{D^*} = 0.5\%$ per annum. [20]

Investment Bank: The divertible fraction of foreign capital claims is set equal to $\lambda_{K^*}^* = 0.345$, as in Gertler and Karadi (2011). Then, the divertible fraction of foreign government bonds is set equal to $\lambda_{B^*}^* = 0.067$ so as to satisfy the steady state version of equation (A.26). The steady sate real interest rate on government bonds used is equal to $r^{B^*} = 0.867\%$ per annum using the average real return for the period 2008-2021 on 10-year

[18] The SCF can be found here https://www.federalreserve.gov/econres/scfindex.htm

[19] See https://wid.world/data/

[20] This return is chosen on purpose to be lower than the return on foreign savings $r^{H^*} = 0.6\% per annum$ so as to incentivize households to hold foreign deposits at the steady state. Otherwise households would hold only domestic assets.

TIPS as provided by the FRED website. The real deposit rate earned by the investment fund is set equal to $r^F = 0\%$ per quarter. The bank survival rate is set equal to $\theta^*_{b^*} = 0.965$. Then, the parameter controlling the magnitude of the transfer received by new banks entering is calibrated to $\omega = 0.0011$.

Intermediate Goods Producers: Steady state output is normalized to $Y^*_F = 1$, and quarterly steady state capital is set equal to $K^* = 14.08Y^*_F$ as implied by the Penn World Tables 10.0.[21] The labor share is $1 - \alpha^* = 0.595$, the average for the period of interest in the same dataset. The capital share is $\alpha^* = 0.405$. Since $L^* = 1$, then $Z^* = (K^*)^{-\alpha^*} = 0.343$. The price indexation parameter ζ^* is set equal to 0. The elasticity of substitution between intermediate goods is set equal to $\varepsilon^*_p = 9$ implying a steady-state mark-up of 12.5%.

Capital Producers: The depreciation rate is set equal to $\delta^* = 0.0144$. The steady state investment rate then becomes $I = 0.2028$.

Monetary Authority: In the baseline scenario the economy is at the ZLB so $\phi_{\Pi^*} = \phi_{Y^*_F} = 0$ which then implies that $i^M_t = r^* = 0$. The government assets held by the central bank at steady state are $q^* B^{CB^*}/4Y^*_F = 12.75\%$, in annual terms. The central bank transfer is determined at the steady state so that $T^{CB^*} = 0.0011$.

Fiscal Authority: Given that $r^{B^*} = 0.867\%$ per annum, the duration parameter of long-term government bonds is set equal to $\gamma^* = 0.9771$ so as to match an average duration of 10 years / 40 quarters. The labor tax rate is set equal to $\tau^{L^*} = 0.3$, while the dividends tax rate is set equal to $\tau^{D^*} = 0.35$. The ratio of government debt over GDP is set equal to $q^* B^*/4Y^*_F = 71.19\%$ which is the average value for the federal government debt held by the public during the period 2008-2021. The government spending-to-GDP ratio G^*/Y^*_F is 14.98% during the same period. The adjustment speed of lump-sum taxes to public debt changes is set equal to $\phi^{B^*} = 0$ implying no reaction of taxes to government debt given that the economy is at the ZLB. The constant part of the lump-sum tax is determined at the steady state and is equal to $T^* = -0.0994$.

[21] See Feenstra et al. (2015)

Table 3: Baseline Calibration of Parameter Values - Foreign Economy

Parameter	Description	Value	Target/Source
Households			
β^{H^*}	Foreign Household High Discount Factor	0.997	$D = 15.749 Y_F^*$
β^{L^*}	Foreign Household Low Discount Factor	0.9802	HtM Households Size = 8%
σ^*	Relative Risk Aversion Coefficient	2	Standard Value
ν^*	Inverse Frisch Elasticity	2	Standard Value
μ_L^*	Relative Weight of Labor Disutility	1.371	Internally Calibrated
χ_0^*	Portfolio Adjustment Cost Pivot	0.01	Baseline Scenario
χ_1^*	Portfolio Adjustment Cost Scale	24.413	$EH^* = 0.3\,(F + D)$
χ_2^*	Portfolio Adjustment Cost Curvature	2	Baseline Scenario
μ^*	Trade Openess	0.323/3	Akinci and Queralto (2018)
ρ_e^*	Autocorrelation of Earnings	0.966	McKay et al. (2016)
σ_e^*	St. Dev. of Log-Earnings	0.92	McKay et al. (2016)
$\bar{d}^*$	Upper Bound on d^*-grid	41.203	Top 10% Wealth Share = 71.3%
Labor Union			
ε_w^*	Elasticity of Substitution in Labor	9	Baseline Scenario
Investment Fund			
ξ_{D^*}	Financial Intermediation Cost	0.0085	$r^{D^*} = 0.5\%$ per annum
Investment Bank			
$\lambda_{K^*}^*$	Divertible Fraction - Foreign Capital	0.345	Gertler and Karadi (2011)
$\lambda_{B^*}^*$	Divertible Fraction - Foreign Government Debt	0.067	Internally Calibrated
$\theta_{b^*}^*$	Bank Survival Rate	0.965	Average Bank Life 20 Years
ω^*	Entering Banks Transfer Magnitude	0.0011	Baseline Scenario
Intermediate Goods Producers			
α^*	Capital Share of Income	0.405	Avg. Value 2008-2021
ε_p^*	Elasticity of Substitution Interm. Goods	9	Baseline Scenario
Z^*	TFP	0.343	$Y^* = 1$
ζ^*	Price Indexation Degree	0	Baseline Scenario
Capital Producers			
δ^*	Capital Depreciation Rate	0.0144	Internally Calibrated
Monetary Authority			
$\phi_{\Pi_F^*}$	Inflation Coefficient - Interest Rate Rule	0	ZLB
$\phi_{Y_F^*}$	Output Coefficient - Interest Rate Rule	0	ZLB
ρ^*	Taylor Rule Inertia	0.8	Standard Value
$q^* B^{CB^*}/4Y_F^*$	CB-Held Debt over GDP	12.75%	Avg. Value 2008-2021
Fiscal Authority			
γ^*	Duration Parameter	0.9771	Avg. Duration of 40 Quarters
τ^{L^*}	Labor Income Tax Rate	30%	Standard Value
τ^{D^*}	Corporate Income Tax Rate	35%	National Accounts
G^*	Government Spending-to-Output Ratio	14.98%	Average Value 2008-2021
$q^* B^*/4Y_F^*$	Debt-to-GDP ratio	71.19%	Avg. Value 2008-2021

A.14 Computational Method

The model is solved using the sequence-space Jacobian methodology introduced by Auclert et al. (2021b). The logic behind this method is to break the model into different blocks containing the equations describing the behavior of each agent in the economy. Each block has the role of a function taking some aggregate sequences as inputs and producing some other aggregate sequnces as outputs.

In every period t, I select $[r_t, w_t, Y_{Ht}, \Pi_{Ht}, N_t, N_{bt}, K_t, K_t^{MF}, r_t^A, r_t^F, B_t^{CB}, E_t]$ to be the unknown variables for the domestic economy. The 12 equations chosen as targets when solving for the 12 unknown variables are the Fisher equation (3.24), the WNKPC (3.19), the goods market clearing condition (3.79), the NKPC (3.57), the evolution of aggregate investment bank net worth (3.45), the evolution of the domestic commercial bank net worth (3.28), the capital market clearing condition (3.77), the incentive constraint faced by the domestic investment bank (3.44), the equation determining the illiquid return (3.32), the budget constraint of the domestic investment bank (3.43), the central bank's government bond purchases (3.68), and the condition (3.42).

Regarding the foreign economy, I select $[r_t^*, w_t^*, Y_{Ft}^*, \Pi_{Ft}^*, N_t^*, K_t^*, K_{bt}^*, B_t^{*MF}, B_t^{CB^*}, r_t^{D^*}]$. The 10 equations chosen as targets when solving for the 10 unknown variables are a Fisher equation for the foreign economy similar to (3.24), the WNKPC (A.13), the goods market clearing condition (A.62), the NKPC (A.42), the foreign aggregate net worth evolution equation (A.28), the foreign capital market clearing condition (A.61), the incentive constraint faced by the foreign bank (A.27), the balance of payments equation for the domestic economy (3.80), the Taylor rule for foreign central bank asset purchases (A.53), and the equation determining the foreign liquid return (A.17).

B Algebraic Derivations

In this part of the appendix I present the algebraic manipulations behind some of the equations that appear in the model in the main text.

B.1 Proof of Proposition 1

Proposition 1: *The commercial bank's value function is linear in net worth and satisfies*

$$V_{bt}\left(N_{bt}\right) = \Sigma_t N_{bt} \text{ with } \Sigma_t = 1. \tag{B.1}$$

Proof: The commercial bank's problem can be expressed as follows

$$V_{bt}\left(N_{bt}\right) = \max_{M_{bt}, D_{bt}} \left\{ \frac{1}{1+r_{t+1}} \left[\left(1-\theta_b\right) N_{bt+1} + \theta_b V_{bt+1}\left(N_{bt+1}\right) \right] \right\} \tag{B.2}$$

subject to

$$D_{bt} = M_{bt} - N_{bt} \tag{B.3}$$

$$N_{bt} = \left(1+r_t\right) M_{bt-1} - \left(1 + r_t^D + \xi_D\right) D_{bt-1}. \tag{B.4}$$

Guess that the value function of the bank is linear in net worth

$$V_{bt}\left(N_{bt}\right) = \Sigma_t N_{bt}. \tag{B.5}$$

Using the previous guess and the constraints (B.3) and (B.4) we can rewrite equation (B.2) as follows

$$V_{bt}\left(N_{bt}\right) = \max_{M_{bt}, D_{bt}} \left\{ \frac{1}{1+r_{t+1}} \left(1-\theta_b+\theta_b \Sigma_{t+1}\right) \left[\left(r_{t+1} - r_{t+1}^D - \xi_D\right) M_{bt} + \left(1 + r_t^D + \xi_D\right) N_{bt} \right] \right\} \tag{B.6}$$

The optimality condition with respect to M_{bt} is

$$\frac{1}{1+r_{t+1}} \left(1-\theta_b+\theta_b \Sigma_{t+1}\right) \left(r_{t+1} - r_{t+1}^D - \xi_D\right) = 0 \Rightarrow r_{t+1} = r_{t+1}^D + \xi_D. \tag{B.7}$$

Finally we need to determine the coefficient Σ_t in the bank's value function. I start from equation (B.1) and use the guess (B.5) on both sides:

$$
\begin{aligned}
\Sigma_t N_{bt} &= \frac{1}{1+r_{t+1}} \left(1-\theta_b+\theta_b \Sigma_{t+1}\right) \left[\left(r_{t+1}-r^D_{t+1}-\xi_D\right) M_{bt} + \left(1+r^D_{t+1}+\xi_D\right) N_{bt}\right] \overset{(B.4)}{\Longrightarrow} \\
\Sigma_t N_{bt} &= \frac{1}{1+r_{t+1}} \left(1-\theta_b+\theta_b \Sigma_{t+1}\right) \left(1+r^D_{t+1}+\xi_D\right) N_{bt} \overset{(B.7)}{\Longrightarrow} \\
\Sigma_t &= 1-\theta_b+\theta_b \Sigma_{t+1} \Longrightarrow \Sigma_t = 1.
\end{aligned} \tag{B.8}
$$

B.2 Proof of Proposition 2

Proposition 2: *The investment bank's value function is linear in net worth and satisfies*

$$V^{MF}_{nt}\left(N^{MF}_{nt}\right) = \Sigma^{MF}_t N^{MF}_{nt} \tag{B.9}$$

$$\Sigma^{MF}_t = \frac{\lambda_B}{\lambda_B - \frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right)\left(r^B_{t+1}-r^F_{t+1}\right)} \frac{1+r^F_{t+1}}{1+r_{t+1}} \left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right). \tag{B.10}$$

Proof: The problem of the investment bank can be expressed as follows

$$V^{MF}_{nt}\left(N^{MF}_{nt}\right) = \max_{K^{MF}_{nt}, B^{MF}_{nt}, B^{*MF}_{nt}, H^*_{nt}} \left\{ \frac{1}{1+r_{t+1}} \left[\left(1-\theta^{MF}\right) N^{MF}_{nt+1} + \theta^{MF} V^{MF}_{nt+1}\left(N^{MF}_{nt+1}\right)\right]\right\} \tag{B.11}$$

subject to

$$Q_t K^{MF}_{nt} + q_t B^{MF}_{nt} + q^*_t B^{*MF}_{nt} E_t = F^{MF}_{nt} + H^*_{nt} E_t + N^{MF}_{nt}. \tag{B.12}$$

$$
\begin{aligned}
N^{MF}_{nt} = &\left[\left(1+r^K_t\right) - \left(1+r^F_t\right)\right] Q_{t-1} K^{MF}_{nt-1} + \left[\left(1+r^B_t\right) - \left(1+r^F_t\right)\right] q_{t-1} B^{MF}_{nt-1} + \left(1+r^F_t\right) N^{MF}_{nt-1} \\
&+ \left[\left(1+r^{B^*}_t\right)\frac{E_t}{E_{t-1}} - \left(1+r^F_t\right)\right] q^*_{t-1} B^{*MF}_{nt-1} E_{t-1} + \left[\left(1+r^F_t\right) - \left(1+r^{H^*}_t\right)\frac{E_t}{E_{t-1}}\right] H^*_{nt-1} E_{t-1}.
\end{aligned} \tag{B.13}
$$

$$V^{MF}_{nt}\left(N^{MF}_{nt}\right) \geq \lambda_K Q_t K^{MF}_{nt} + \lambda_B q_t B^{MF}_{nt} + \lambda_{B^*} q^*_t B^{*MF}_{nt} E_t \left(1 + \frac{\xi_{B^*}}{2} \frac{q^*_t B^{*MF}_{nt} E_t}{Q_t K^{MF}_t}\right) \tag{B.14}$$

I guess that the value function of the bank is linear in net worth

$$V_{nt}^{MF}\left(N_{nt}^{MF}\right)=\Sigma_t^{MF}N_{nt}^{MF}. \tag{B.15}$$

Using the previous guess we can rewrite equation (B.11) as follows

$$\Sigma_t^{MF}N_t^{MF}=\max\left\{\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)N_{t+1}^{MF}\right\} \tag{B.16}$$

Let $\mathcal{L}^{MF}$ be the Lagrange function for the previous constrained optimization problem. Let also Θ_t be the Lagrange multiplier. Then we can express the optimization problem as

$$\begin{aligned}
\mathcal{L}^{MF}&=\Sigma_t^{MF}N_t^{MF}+\Theta_t\left[V_{nt}^{MF}\left(N_{nt}^{MF}\right)-\lambda_K Q_t K_{nt}^{MF}-\lambda_B q_t B_{nt}^{MF}-\lambda_{B^*}q_t^*B_{nt}^{*MF}E_t\right]\overset{(B.15)}{\Longrightarrow}\\
\mathcal{L}^{MF}&=\left(1+\Theta_t\right)\Sigma_t^{MF}N_t^{MF}-\Theta_t\left[\lambda_K Q_t K_{nt}^{MF}+\lambda_B q_t B_{nt}^{MF}+\lambda_{B^*}q_t^*B_{nt}^{*MF}E_t\right]\overset{(B.16)}{\Longrightarrow}\\
\mathcal{L}^{MF}&=\left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)N_{nt+1}^{MF}-\Theta_t\left[\lambda_K Q_t K_{nt}^{MF}+\lambda_B q_t B_{nt}^{MF}+\lambda_{B^*}q_t^*B_{nt}^{*MF}E_t\left(1+\frac{\xi_{B^*}}{2}\frac{q_t^*B_{nt}^{*MF}E_t}{Q_tK_t^{MF}}\right)\right],
\end{aligned} \tag{B.17}$$

where N_{nt+1}^{MF} is just equation (B.13) written one period ahead and F_{nt}^{MF} is given by equation (B.12). The optimality conditions with respect to $\left\{K_{nt}^{MF}, B_{nt}^{MF}, B_{nt}^{*MF}, H_{nt}^{MF}\right\}$ are

$$\left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)\left(r_{t+1}^K-r_{t+1}^F\right)=\Theta_t\left[\lambda_K-\lambda_{B^*}\frac{\xi_{B^*}}{2}\left(\frac{q_t^*B_{nt}^{*MF}E_t}{Q_tK_t^{MF}}\right)^2\right] \tag{B.18}$$

$$\left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)\left(r_{t+1}^B-r_{t+1}^F\right)=\Theta_t\lambda_B \tag{B.19}$$

$$\left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)\left[\left(1+r_{t+1}^{B^*}\right)\frac{E_{t+1}}{E_t}-\left(1+r_{t+1}^F\right)\right]=\Theta_t\lambda_{B^*}\left(1+\xi_{B^*}\frac{q_t^*B_{nt}^{*MF}E_t}{Q_tK_t^{MF}}\right) \tag{B.20}$$

$$\left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma_{t+1}^{MF}\right)\left[\left(1+r_{t+1}^F\right)-\left(1+r_{t+1}^{H^*}\right)\frac{E_{t+1}}{E_t}\right]=0 \tag{B.21}$$

Equation (B.21) simplifies to

$$1+r_{t+1}^{H^*}=\left(1+r_{t+1}^F\right)\frac{E_t}{E_{t+1}} \tag{B.22}$$

Finally we need to determine the time-varying coefficient Σ_t in the bank's value function. I start from equation (B.16). Let $\Delta_{t+1} \equiv \frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right)$. Then

$$\Sigma^{MF}_t N^{MF}_{nt} = \Delta_{t+1} N^{MF}_{t+1} \overset{(B.13)}{\Longrightarrow}$$

$$\Sigma^{MF}_t N^{MF}_{nt} = \Delta_{t+1}\left\{\left[\left(1+r^K_{t+1}\right)-\left(1+r^F_{t+1}\right)\right] Q_t K^{MF}_{nt} + \left[\left(1+r^B_{t+1}\right)-\left(1+r^F_{t+1}\right)\right] q_t B^{MF}_{nt} + \left(1+r^F_{t+1}\right) N^{MF}_{nt}\right.$$

$$\left. + \left[\left(1+r^{B^*}_{t+1}\right)\frac{E_{t+1}}{E_t} - \left(1+r^F_{t+1}\right)\right] q^*_t B^{*MF}_{nt} E_t + \left[\left(1+r^F_{t+1}\right)-\left(1+r^{H^*}_{t+1}\right)\frac{E_{t+1}}{E_t}\right] H^*_{nt} E_t\right\} \overset{(B.18),(B.19),(B.20),(B.21)}{\Longrightarrow}$$

$$\Sigma^{MF}_t N^{MF}_{nt} = \Delta_{t+1}\left[\frac{1}{\Delta_{t+1}}\frac{\Theta_t}{1+\Theta_t}\lambda_K Q_t K^{MF}_{nt} + \frac{1}{\Delta_{t+1}}\frac{\Theta_t}{1+\Theta_t}\lambda_B q_t B^{MF}_{nt} + \frac{1}{\Delta_{t+1}}\frac{\Theta_t}{1+\Theta_t}\lambda_{B^*} q^*_t B^{*MF}_{nt} E_t\right.$$

$$\left. + \frac{1}{\Delta_{t+1}}\frac{\Theta_t}{1+\Theta_t}\lambda_{B^*}\frac{\xi_{B^*}}{2}\frac{\left(q^*_t B^{*MF}_{nt} E_t\right)^2}{Q_t K^{MF}_{nt}} + \left(1+r^F_{t+1}\right) N^{MF}_{nt}\right] \overset{(B.14),(B.15)}{\Longrightarrow}$$

$$\Sigma^{MF}_t N^{MF}_{nt} = \frac{\Theta_t}{1+\Theta_t}\Sigma_t N^{MF}_{nt} + \frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right)\left(1+r^F_{t+1}\right) N^{MF}_{nt} \Longrightarrow$$

$$\Sigma^{MF}_t N^{MF}_{nt} = \left(1+\Theta_t\right)\frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right)\left(1+r^F_{t+1}\right) N^{MF}_{nt} \overset{(B.19)}{\Longrightarrow}$$

$$\Sigma^{MF}_t = \frac{\lambda_B}{\lambda_B - \frac{1}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right)\left(r^B_{t+1}-r^F_{t+1}\right)}\frac{1+r^F_{t+1}}{1+r_{t+1}}\left(1-\theta^{MF}+\theta^{MF}\Sigma^{MF}_{t+1}\right). \tag{B.23}$$