Monetary Policy and Redistribution in Open Economies*

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Abstract

This paper examines how monetary policy affects the asymmetric effects of globalization. We build an open-economy heterogeneous-agent New Keynesian model (HANK) in which households differ in their income, wealth, and real and financial integration with international markets. We use the model to reassess classic questions in international macroeconomics, but from a distributional perspective: What are the effects of monetary policy in open economies? What are the international spillovers of policies and shocks? And how do alternative exchange-rate regimes compare? Our results reveal the presence of a trade-off between aggregate stabilization and inequality in consumption responses to external shocks. The asymmetric effects of globalization can be smaller for economies with higher international integration.

Keywords: Monetary policy, open economy, heterogeneous-agent models, consumption, globalization

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1. Introduction

The redistributional effects of globalization have featured prominently in policy debates in recent decades. An influential view, based on the idea of "globalization and its discontents" (Stiglitz, 2002, 2017), argues that international integration has asymmetric effects on households, and that if traditional policies do not consider this dimension, they can amplify the resulting inequalities. Although the traditional argument for discontents with globalization was formulated with regard to emerging economies' crises of the late 1990s, similar views have become prominent in developed economies over the last decade. Related to this policy discussion, a large body of academic research on the intersection of international trade and labor has studied the distributional consequences of international integration and trade policies (see, for example, Goldberg and Pavcnik, 2007; Autor, Dorn and Hanson, 2016). However, less is known in international macroeconomics about the extent to which traditional macroeconomic stabilization policies affect the asymmetric effects of globalization.

In this paper, we study the distributional effects of monetary policy in open economy, in the context of households' uneven international integration and exposure to external shocks. To this end, we build a framework that combines traditional elements of open-economy monetary transmission, heterogeneity in households' integration with international financial and real markets, and realistic income and wealth distributions. We then use this framework to reassess three classic questions in international economics that motivated the seminal work of Mundell (1963) and Fleming (1962),[1] but focus on their distributional aspects: What are the effects of monetary policy in open economies? What are the international spillovers of policies and shocks? And how do alternative exchange-rate regimes compare? We emphasize two key takeaways from our analysis. The first is related to how "macro matters for inequality," whereby heterogeneity in households' financial and real integration is a central dimension that drives inequality in consumption responses to macro shocks. The

[1]For instance, the first sentences in Mundell (1963) read: "The world is still a closed economy, but its regions and countries are becoming increasingly open. (...) The international economic climate has changed in the direction of financial integration and this has important implications for economic policy. My paper concerns the theoretical and practical implications of the increased mobility of capital."

second is related to how "inequality matters for macro," whereby households' heterogeneity reveals the presence of a trade-off between aggregate stabilization and inequality in the conduct of monetary policy.

The model we develop embeds household heterogeneity in a canonical New Keynesian open-economy framework. In particular, we consider a small open economy populated by households that consume three types of goods: Tradable goods produced by home firms, tradable goods produced by foreign firms, and nontradable goods (see, for example, Obstfeld and Rogoff, 2000; Gali and Monacelli, 2005). To study the distributional effects of monetary policy in this open-economy framework, we introduce households' heterogeneity along two dimensions. First, households differ in their income and wealth, modeled with uninsurable labor-income shocks as in the literature on monetary policy with households' heterogeneity in closed-economy models. Second, households differ in their international real and financial integration, with some working in tradable sectors and others in nontradable sectors, and some having access to internationally traded securities and some restricted to domestically traded securities. With these ingredients, we aim to construct a laboratory economy that has in play the main mechanisms of the monetary transmission of open-economy models, combined with realistic distributions of wealth and marginal propensities to consume across households and uneven exposures to external shocks. We refer to this as an open-economy heterogeneous-agent New Keynesian model (HANK in Kaplan, Moll and Violante, 2018).

The first takeaway from our analysis is that uneven households' integration to international markets plays a central role that drives inequality in consumption responses to macro shocks. The consumption of households working in tradable sectors is more sensitive to changes in the external demand of exportable goods or import competition. Additionally, the consumption of households that have direct or indirect holdings of foreign securities is more sensitive to international spillovers of foreign monetary policy. Quantitatively, we find that these sources of heterogeneity, which are characteristic of open economies, are as important as those of income and wealth inequality, which are emphasized in the closed-economy HANK literature.

The second takeaway is that households' heterogeneity reveals the presence of a trade-off

between aggregate stabilization and inequality in the conduct of monetary policy.[2] Representative-agent models emphasize that fixed-exchange-rate regimes amplify aggregate responses to external shocks vis-a-vis floating regimes (e.g., Taylor rules). Our open-economy HANK shows that a fixed exchange rate leads to less inequality in consumption responses to external shocks. For instance, an external monetary expansion generates a large response of households that are integrated with international capital markets through direct channels, leading to inequality in consumption responses vis-a-vis nonintegrated households. Under a fixed-exchange-rate regime, monetary authorities respond more aggressively by cutting domestic interest rates to avoid currency appreciation, which has direct effects on the consumption of nonintegrated households, thereby reducing the unequal consumption responses to the external shock.

Finally, our paper studies the role of globalization in terms of the aggregate and distributional effects of monetary policy and external shocks. For this, we compare the aggregate and distributional effects on an economy with the degree of international integration observed in Canada with that of an otherwise identical economy with the degree of international integration of the U.S., which is a relatively more closed economy. Economies with lower degrees of real and financial integration naturally experience milder aggregate effects of changes in foreign demand and monetary policy, respectively. However, in economies that have lower degrees of financial integration, external shocks tend to have more uneven responses across households, because external shocks do not induce large dampening forces from prices in the rest of the economy or the monetary authority. From this, we conclude that an important element to consider in the debate regarding the asymmetric effects of globalization is how generalized international integration is.

Related literature Our paper contributes to three strands of the literature. The first is the large body of literature on monetary policy in open economies. The three main questions that guide our work build on the literature that studies the effects on monetary policy in open economy, that compares exchange-rate regimes (see, for example, the early work of Obstfeld

[2]Related to this result Bilbiie and Monacelli (2020) highlight a stabilization-redistribution trade-off in the context of closed-economy heterogeneous-agent models with fiscal policy.

and Rogoff, 2000; Clarida, Gali and Gertler, 2001; Chari, Kehoe and McGrattan, 2002; Devereux and Engel, 2003; Gali and Monacelli, 2005); and that analyzes the international spillovers of policies and shocks (see, for example, Rey, 2015; Schmitt-Grohé and Uribe, 2011).[3] We contribute to this literature by analyzing the distributional aspects of these classic questions in international macroeconomics.

Second, a recent and growing body of research studies the role of households' heterogeneity in open-economy models. De Ferra, Mitman and Romei (2020) and Cugat (2019) introduce household heterogeneity in an open-economy New Keynesian model and study its role in the transmission of foreign shocks. Auclert, Rognlie, Souchier and Straub (2020) study monetary transmission in an open-economy HANK; they provide general conditions under which households' heterogeneity matters for aggregate transmission and identify the presence of a strong real-income channel that can lead to contractionary devaluations. Zhou (2020) analyzes different channels of the redistribution of monetary policy in an open economy. Guntin, Ottonello and Perez (2020) show how introducing household heterogeneity can inform macro theories of aggregate consumption adjustment and sudden stops.[4] We complement this body of work by showing how monetary policy affects redistribution in a context in which households face heterogeneity in their international real and financial integration, and globalization leads to asymmetric effects among households.

Third, our paper is related to the macroeconomics literature that analyzes consumption inequality (see, for example, Attanasio, Battistin and Ichimura, 2004; Krueger and Perri, 2006; Aguiar and Bils, 2015; Quadrini and Ríos-Rull, 2015, and references therein) and the

[3]The study of monetary policy in open economies is a central topic in international economics and includes work on the role of the international price system in affecting monetary policy (see, for example, Engel, 2006; Corsetti, Dedola and Leduc, 2010; Mukhin, 2018; Gopinath, Boz, Casas, Díez, Gourinchas and Plagborg-Møller, 2020; Burstein and Gopinath, 2014, and references therein); the role of international financial intermediaries and currency risk (see, for example, Gabaix and Maggiori, 2015; Hassan, Mertens and Zhang, 2016; Itskhoki and Mukhin, 2017, 2019); domestic financial frictions (see, for example, Céspedes, Chang and Velasco, 2004; Ottonello, 2013; Fornaro, 2015; Arellano, Bai and Mihalache, 2020); and international coordination in the conduct of monetary policy (see, for example, Corsetti and Pesenti, 2005). Complementing this literature, there is a large body of empirical work on the global financial cycle and international spillovers (see, for example Forbes and Rigobon, 2002; Giovanni, Kalemli-Ozcan, Ulu and Baskaya, 2017; Gourinchas, 2018)

[4]A related empirical literature has documented the heterogeneous impacts of currency depreciation (see, for example, Gopinath and Neiman, 2014; Cravino and Levchenko, 2017; Drenik, Pereira and Perez, 2018; Blanco, Drenik and Zaratiegui, 2020).

redistributive effects of macroeconomic policies (see, for example, Doepke and Schneider, 2006; Ahn, Kaplan, Moll, Winberry and Wolf, 2018; Auclert, 2019; Kaplan and Violante, 2018, and references therein). Our paper complements this literature by studying the distributional aspects of monetary policy in open economies, which are characterized by inequality stemming from international integration.

Layout The rest of the paper is organized as follows. Section 2 presents the model and Section 3 its parameterization. Section 4 studies the three classic questions in international macroeconomics from a distributional perspective. Section 5 analyzes how the degree of real and financial integration affects the distributional effects of monetary policy and the responses to external shocks. Section 6 concludes.

2. Model

This section describes the open-economy HANK model. The environment is that of a canonical New Keynesian small open-economy model with home tradable goods, foreign tradable goods, and nontradable goods, enriched with household heterogeneity. The small open economy is populated by households, firms, and a government. Firms in the economy produce the home tradable goods and nontradable goods. The rest of the world exchanges tradable goods and financial securities with the small open economy. Households in the small open economy are heterogeneous in two dimensions. First, households face uninsurable labor-income shocks, as is standard in closed-economy HANK models. Second, households are heterogeneous in their access to international financial and real markets: Some work in tradable sectors and others in nontradable sectors; some are able to save and borrow in internationally traded securities and others only in domestically traded securities.

2.1. Households

Households have preferences over consumption described by the lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t), \tag{1}$$

where c_t and l_t denote consumption and hours worked in period t; $u : \mathbb{R}^2_+ \to \mathbb{R}$ is a continuous and differentiable function, increasing in the first argument and decreasing in the second argument; $\beta \in (0, 1)$ denotes the subjective discount factor; and $\mathbb{E}_t$ denotes the expectation conditional on the information set available at time t. The consumption good is a composite of tradable and nontradable goods, with a constant-elasticity-of-substitution (CES) aggregation technology $c_t = \mathcal{C}_{\mathrm{TN}}(c_{\mathrm{T}t}, c_{\mathrm{N}t}) = \left[\omega_{\mathrm{T}}^{\frac{1}{\eta}} (c_{\mathrm{T}t})^{1-\frac{1}{\eta}} + (1-\omega_{\mathrm{T}})^{\frac{1}{\eta}} (c_{\mathrm{N}t})^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$, where $c_{\mathrm{T}t}$ and $c_{\mathrm{N}t}$ denote tradable and nontradable consumption and $\eta > 0$ is the elasticity of substitution between tradable and nontradable goods. The tradable good is, in turn, a composite of home and foreign tradable goods with a CES aggregation technology $c_{\mathrm{T}t} = \mathcal{C}_{\mathrm{HF}}(c_{\mathrm{H}t}, c_{\mathrm{F}t}) = \left[\omega_{\mathrm{H}}^{\frac{1}{\eta}} (c_{\mathrm{H}t})^{1-\frac{1}{\eta}} + (1-\omega_{\mathrm{H}})^{\frac{1}{\eta}} (c_{\mathrm{F}t})^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$, where $c_{\mathrm{H}t}$ and $c_{\mathrm{F}t}$ denote home tradable and foreign tradable goods and we assume that the substitution between home tradable and foreign tradable goods shares the same elasticity with the substitution between tradable and nontradable goods.

We set up the household's problem recursively. The idiosyncratic state vector of a household includes its idiosyncratic income shock, z, its asset holdings, b, and its integration with international financial and real markets, $\mathbf{o} \equiv [o_R, o_F]$, with o_R denoting a dummy variable that takes the value of one if the household receives its income from the tradable sector and zero if it receives it from the nontradable sector and o_F denoting a dummy variable that takes the value of one if the household is integrated with international financial markets and and zero if the household only has access to domestic markets. Households' recursive

problem is given by

$$V_t(z,b,\mathbf{o}) = \max_{c_{\mathrm{H}},c_{\mathrm{F}},c_{\mathrm{N}},l,b'} u(c,l) + \beta\mathbb{E}_t\left[(1-\xi)\cdot V_{t+1}(z',b',\mathbf{o}') + \xi\cdot\tilde{V}_{t+1}(z',b',\mathbf{o}')\right] \quad (2)$$

$$\text{s.t. } c = \mathcal{C}_{\mathrm{TN}}\left(c_{\mathrm{T}},c_{\mathrm{N}}\right), c_{\mathrm{T}} = \mathcal{C}_{\mathrm{HF}}\left(c_{\mathrm{H}},c_{\mathrm{F}}\right), \quad (3)$$

$$q_t(o_F,b')b' = b + z(1-\tau_t)W_t(\mathbf{o})l + T_t + \bar{\gamma}(z,b,\mathbf{o})\gamma_t - P_{\mathrm{H}t}c_{\mathrm{H}} - P_{\mathrm{F}t}c_{\mathrm{F}} - P_{\mathrm{N}t}c_{\mathrm{N}} \quad (4)$$

$$b' \geq \underline{b}$$

$$\mathbf{o}' = \Gamma_t(z,b,\mathbf{o}),$$

where $P_{\mathrm{H}t}$, $P_{\mathrm{F}t}$, and $P_{\mathrm{N}t}$ are the prices of home tradable goods, foreign tradable goods, and nontradable goods denominated in local currency; $W_t(\mathbf{o})$ is the nominal wage per unit of effective labor in the sector in which the household is employed; τ_t is a labor-income tax; T_t is a lump-sum transfer from the government; $\bar{\gamma}(z,b,\mathbf{o})$ and γ_t are transfers from firms to households, which potentially depend on households' idiosyncratic states; $q_t(o_F,b')$ is the price of the zero-coupon bond that, as further detailed below, depends on whether the household is integrated with international capital markets and whether households are borrowing or saving; $\Gamma_t(z,b,\mathbf{o})$ denotes the law of motion of the household's financial and real integration, which can potentially depend on the aggregate and individual households' states; $\underline{b}$ is a fixed debt limit; ξ is the households' death rate; and $\tilde{V}_t(z,b,\mathbf{o})$ is the value of a household that receives the realization of a shock whereby it dies and retires from the economy in the following period, given by $\tilde{V}_t(z,b,\mathbf{o}) = \max_{c_{\mathrm{H}},c_{\mathrm{F}},c_{\mathrm{N}},l} u(c,l)$ s.t. $P_{\mathrm{H}t}c_{\mathrm{H}} + P_{\mathrm{F}t}c_{\mathrm{F}} + P_{\mathrm{N}t}c_{\mathrm{N}} = \bar{\gamma}(z,b,\mathbf{o})\gamma_t + b + z(1-\tau_t)W_t(\mathbf{o})l_t$. Each period, a new mass of households, ξ, is born with no assets, so the total mass of households is always fixed at one.

2.2. Firms

The economy has access to technologies to produce two types of goods: home tradable goods (H) and nontradable goods (N). Two types of firms occupy each sector, described next. All firms are owned by domestic households.

Final-good Producers A continuum of representative final-good producers occupies each sector and transform intermediate goods $\tilde{y}_{jst}$, where $j \in [0,1]$ and $s \in \{\text{H}, \text{N}\}$, into final goods with production technology

$$Y_{st} = \left(\int_0^1 \tilde{y}_{jst}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}.$$

Final-good producers in each sector choose intermediate inputs $(\tilde{y}_{jst})_{j\in[0,1]}$ to maximize their static profits, which leads in equilibrium to a demand function faced by intermediate-good producers in each sector, $\mathcal{Y}_{jst}(p_{jst}) = \left(\frac{p_{jst}}{P_{st}}\right)^{-\epsilon} Y_{st}$ and the price aggregator $P_{st} = \left(\int_0^1 p_{jst}^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$.

Intermediate-good Producers A continuum of intermediate-good producers indexed by $j \in [0,1]$ use capital and labor to produce intermediate goods with the technology $y_{jst} = n_{jst}$ for $s \in \{\text{H}, \text{N}\}$. The markets for intermediate goods and labor are competitive. The marginal cost of producing each unit of intermediate good is $mc_{st} = \frac{w_{st} N_{st}}{Y_{st}}$, where mc_{st} and $w_{st} \equiv \frac{W_{st}}{P_{st}}$ denote the marginal cost and wage in sector s, and N_{st} and Y_{st} refer to aggregate labor and output in sector s. Each intermediate-good producer sets its price facing an adjustment cost *à la* Rotemberg (1982), $\Theta_{st}\left(\frac{p_{st}}{p_{st-1}}\right) = \frac{\theta}{2}\left(\frac{p_{st}}{p_{st-1}} - 1\right)^2 Y_{st} P_{st}$. The problem of each intermediate-good producer is then given by

$$\max_{p_{st}} \tilde{\Pi}_s(p_{st}) - \Theta_{st}\left(\frac{p_{st}}{p_{st-1}}\right) + \sum_{l=1}^{\infty} \mathbb{E}_t \left[\left(\prod_{k=1}^{l} \frac{1}{1+r_{t+k}} \right) \left[\tilde{\Pi}_s(p_{s,t+l}) - \Theta_{st}\left(\frac{p_{s,t+l}}{p_{s,t+l-1}}\right) \right] \right],$$

where $r_t = i_t - \pi_{t+1}$ is the real interest rate and $\tilde{\Pi}_{st}(p_t) \equiv \left(\frac{p_{st}}{P_{st}} - mc_{st}\right)\left(\frac{p_{st}}{P_{st}}\right)^{-\epsilon} Y_{st}$. From the solution to this problem, we can derive the New Keynesian Phillips curve for each sector $s \in \{\text{H}, \text{N}\}$:

$$\pi_{st}(1+\pi_{st}) = \frac{\epsilon}{\theta}\left(mc_{st} - \frac{\epsilon-1}{\epsilon}\right) + \mathbb{E}_t\left[\frac{1}{1+r_{t+1}} \frac{Y_{s,t+1}}{Y_{st}} (1+\pi_{s,t+1}) \cdot \pi_{s,t+1}\right], \tag{5}$$

where $\pi_{st} \equiv \frac{P_{st}}{P_{s,t-1}} - 1$.

2.3. Government

The government determines monetary and fiscal policies in the small open economy. For monetary policy, we assume that the government follows a simple Taylor rule,

$$i_t = i_{ss} + \phi(\pi_t - \bar{\pi}) + v_t, \tag{6}$$

where v_t is an exogenous monetary policy shock that follows the autoregressive process $v_t = \rho_m v_{t-1} + \epsilon_{m,t}$; $\pi_t \equiv \frac{P_t}{P_{t-1}} - 1$ is the inflation of the ideal price index; and i_{ss} and $\bar{\pi}$ are linked to steady-state nominal rates and levels of inflation. This interest rate determines the price of the zero-coupon bond at which unintegrated households invest, which is given by

$$q_t(0, b') = \frac{1}{1 + i_t}. \tag{7}$$

In Section 4.3, we compare the dynamics under a fixed-exchange-rate regime instead of a Taylor rule. On the fiscal side, government raises the labor tax and issues domestic debt to finance their spending and transfer:

$$\frac{B_{t+1}}{1 + i_t} - B_t + \tau_t \left(N_{Ht} W_{Ht} + N_{Nt} W_{Nt}\right) = T_t + G_t. \tag{8}$$

We assume that the government maintains a constant level of spending, transfer, and debt, i.e., $G_t = G_{ss}$, $T_t = T_{ss}$, and $B_t = B_{ss}$, where T_{ss}, G_{ss}, and B_{ss} are parameters that govern the steady-state level of spending, transfer, and government debt.

2.4. The Rest of the World

The rest of the world trades financial securities and tradable goods with the small open economy. From the perspective of the small open economy, the rest of the world provides an international interest rate for trading securities in foreign currency, a foreign demand for the home tradable good, and a foreign supply of the foreign tradable good.

For financial securities, the small open economy faces a perfectly elastic demand, with

a nominal interest rate in foreign currency, i_t^*, following an exogenous autoregressive process $i_t^* = (1-\rho_{m^*})i_{ss}^* + \rho_{m^*} i_{t-1}^* + \epsilon_{m^*,t}$, where i_{ss}^* is the steady-state rate and $0 < \rho_{m^*} < 1$. The shock, $\epsilon_{m^*,t}$, can be interpreted as a foreign monetary-policy shock, which we consider in Section 4.2 in analyzing international spillovers. This interest rate determines the price of the zero-coupon bond at which financially integrated households invest, which is given by

$$q_t(1, b') = \frac{1}{1 + i_t^* + \mathbb{E}_t \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}}, \tag{9}$$

where $\mathcal{E}_t$ denotes the nominal exchange rate of domestic currency per unit of foreign currency.

On the tradable goods side, we assume a completely elastic supply of the foreign good at a fixed price in foreign currency, which we denote as P_{Ft}^*, and a downward-sloping foreign demand of the home tradable good, which is given by

$$C_{\mathrm{H}t}^* = \left(\frac{P_{Ht}^*}{P_{Ft}^*}\right)^{-\eta} Y_{\mathrm{F}t}^*, \tag{10}$$

where P_{Ht}^* is the price of the home tradable good expressed in foreign currency and $Y_{\mathrm{F}t}^*$ is a foreign demand shifter that follows an exogenous autoregressive process $\log Y_{\mathrm{F}t}^* = \rho_{y^*} \log Y_{\mathrm{F}t-1}^* + \epsilon_{y^*,t}$.

These conditions can be micro-founded from the problem of a representative foreign household that is risk neutral, has CES preferences over H and F tradable goods, and is infinitely large relative to the small open economy, but the share of home tradable good consumption in its consumption basket is infinitely small.[5]

2.5. Equilibrium

We define the competitive equilibrium as follows.

***Definition* 1.** *Given exogenous processes* $\{v_t, Y_{\mathrm{F}t}^*, i_t^*\}$ *and government policies* $\{i_t,\ \tau_t, T_t\}$,

[5]Under this structure, the foreign supply of the foreign good is infinitely large relative to the small open economy, which gives rise to a completely elastic supply of that good. On the other hand, the foreign demand of the home tradable good is finite from the perspective of the small open economy, by making the share of the home tradable good infinitesimally small. In fact, in this case the demand shifter is equal to $Y_{\mathrm{F}t}^* \equiv \lim_{\omega_{\mathrm{H}}^* \to 0, C_{\mathrm{F}t}^* \to \infty} \left(\frac{\omega_{\mathrm{H}}^*}{1-\omega_{\mathrm{H}}^*}\right)^{\frac{1}{\eta}} C_{\mathrm{F}t}^* > 0$ and finite.

an equilibrium is a stochastic sequence of households' value functions $\{V_t(z,b,\mathbf{o})\}$ *and policy functions* $\{c_{\mathrm{H},t}(z,b,\mathbf{o})$, $c_{\mathrm{F},t}(z,b,\mathbf{o})$, $c_{\mathrm{N},t}(z,b,\mathbf{o})$, $l_t(z,b,\mathbf{o})$, $b'_t(z,b,\mathbf{o})\}$*; firms' choices* $\{\tilde{y}_{st}$, y_{st}, n_{st}, $p_{st}\}$*; aggregate quantities* $\{Y_t$, $Y_{\mathrm{N},t}$, $Y_{\mathrm{H},t}$, C_t, $C_{\mathrm{H},t}$, $C_{\mathrm{F},t}$, $C_{\mathrm{N},t}$, $N_t, N_{\mathrm{H},t}$, $N_{\mathrm{N},t}\}$*; prices* $\{W_{\mathrm{H},t}$, $W_{\mathrm{N},t}$ $P_{\mathrm{H}t}$, $P_{\mathrm{F}t}$, $P_{\mathrm{N}t}, \mathcal{E}_t\}$*; bond prices* $\{q_t(o_F, b')\}$*; and a distribution of households* $\mu_t(z,b,\mathbf{o})$ *such that*

1. *Household optimization: Value function* $V_t(z,b,\mathbf{o})$ *solves households' problem* (2) *with the associated policy functions* $\{c_{\mathrm{H},t}(z,b,\mathbf{o})$, $c_{\mathrm{F},t}(z,b,\mathbf{o})$, $c_{\mathrm{N},t}(z,b,\mathbf{o})$, $l_t(z,b,\mathbf{o})$, *and* $b'_t(z,b,\mathbf{o})\}$ *taking as given the equilibrium prices, interest rates, policies, and transfers.*

2. *Firm optimization: Individual firms' choices solve their problems given the equilibrium prices, interest rates, policies, and transfers.*

3. *Bond prices satisfy* (7) *and* (9).

4. *Prices of foreign tradable goods satisfy the law of one price:* $P_{\mathrm{F}t} = P^*_{\mathrm{F}}\mathcal{E}_t$.

5. *The sequence of aggregate quantities and distributions satisfies aggregate consistency conditions.*

6. *All markets clear.*

3. Parameterization

We calibrate our model to Canada, which is a prototypical small open economy that has been extensively analyzed in the literature. Our calibration strategy targets key macro moments of the economy and micro moments related to household heterogeneity. One period is a quarter. We calibrate the model in three steps.

In the first step we fix a subset of parameters to standard values in the literature. These are reported in Table 1. The exit rate for households is set at $\frac{1}{82.5\times 4}$ to match the average life expectancy for Canada in 2020 at 82.5 years old. For households' preferences, we assume

a separable period utility:

$$u(c,l) = \frac{c^{1-\nu_c}}{1-\nu_c} - \psi \frac{l^{1+\nu_L}}{1+\nu_L},$$

and set the intertemporal elasticity of substitution $1/\nu_c$ and the Frisch elasticity of labor supply ν_L to one. We set the disutility of labor supply ψ to target a steady-state level of hours of 0.5, and the discount factor to target a steady-state domestic annual interest rate of 4%. For firms, we set the elasticity of substitution in the technology of final good producers to $\epsilon = 10$, which implies a markup of 11%. We set the parameter governing the adjust costs of prices to $\theta = 100$, which implies a slope of the Phillips curve of 0.1, as in Kaplan *et al.* (2018) For the government, we set the income tax rate to $\tau = 0.2$ and the government's transfers to 12% of the aggregate labor income in steady state to match the ratios between the tax payment and the total household income and the fraction of transfer within the total household income. Regarding the government debt, we calibrate it to equal to 76% of the aggregate labor income in steady state to target the median liquid wealth-to-income ratio at 0.35. Finally, we set the international interest rate, determined by the rest of the world, to $i^*_{ss} = 1\%$.

The second step of our calibration targets steady-state moments with the subset of parameters reported in Table 2. For the parameters that govern households' idiosyncratic income processes, we follow the recent literature on households' heterogeneity applied to the case of Canada. In particular, the idiosyncratic income shock process is constructed as a mixture of two independent Markov processes: $z = z_1 + z_2$, where z_1 and z_2 are, respectively, the persistent and temporary components of households' idiosyncratic income process. We follow Rouwenhorst (1995) to construct the discretized process of of z_1 and z_2. Under this construction, each of these two processes is uniquely determined by three moments: the process's first-order autocorrelation ρ_i, the unconditional distribution's standard deviation σ_i, and the skewness $skew_i$, for $i = 1, 2$. The mixture of these two processes allow us to match a key set of data moments of log-earnings dynamics, reported in Table D.1 the variance, skeweness, and kurtosis of the 1-year and 5-year changes in log annual earnings. For further

Table 1: Fixed Parameters

Parameter	Description	Value
Households		
ξ	Exit rate	$\frac{1}{82.5\times4}$
$1/\nu_c$	Intertemporal elasticity of substitution	1
$1/\nu_l$	Frisch elasticity of labor supply	1
ψ	Disutility of labor	3.45
β	Discount factor	0.96
Government		
τ	Income tax rate	0.20
T_{ss}	Total transfer	0.12
B_{ss}	Government debt	0.76
i^*_{ss}	Steady-state international interest rate	0.01
Firms		
ϵ	Elasticity of substitution for final goods aggregator	10
θ	Adjustment cost of goods price	100

Note: The values for T_{ss} and B_{ss} are expressed in the unit of households' quarterly average labor income in steady state.

details on the identification of these moments using the Rowenhorst method, see Galindev and Lkhagvasuren (2010); Gospodinov and Lkhagvasuren (2014); and Lkhagvasuren (2012). Given these income processes, the borrowing constraint $\underline{b}$ is set to one-fifth of the average quarterly labor income to match the median MPC of households. In the steady state of our model, the median MPC is 15%, which is within the range of the estimates for the MPC of nondurable goods reported in Parker, Souleles, Johnson and McClelland (2013). Additionally, we calibrate the share of home goods in the tradable consumption basket $\omega_{\mathrm{H}} = 0.6$ to match the ratio of exports to output and the share of tradable goods in the consumption basket $\omega_{\mathrm{T}} = 0.3$ to target equal wages per efficiency for households working in different sectors, which makes analysis of the distributional implications of macroeconomic shocks more transparent.

The most novel part of our calibration is the group of steady-state moments and parameters that are related to households' international integration. In our baseline calibration,

Table 2: Calibrated Parameters

Parameter	Description	Value
Panel 1. Parameters Governing the Steady State		
Idiosyncratic risk		
ρ_1	Persistent idiosyncratic income, autocorrelation	0.75
σ_1	—, unconditional standard deviation	0.78
$skew_1$	—, unconditional skewness	−4.07
ρ_2	Transitory idiosyncratic income, autocorrelation	0.25
σ_2	—, unconditional standard deviation	0.31
$skew_2$	—, unconditional skewness	−2.05
$\underline{b}$	Borrowing constraint	−0.21
International integration		
λ_F^1	Financial integration, probability of remaining integrated	99%
λ_F^0	—, probability of remaining nonintegrated	99.81%
λ_R^1	Real integration, probability of remaining integrated	99%
λ_R^0	—, probability of remaining integrated	99.46%
Preferences		
ω_T	Fraction of tradable goods in consumption basket	0.30
ω_H	Fraction of home goods in tradable goods consumption basket	0.60
Panel 2. Parameters Governing the Aggregate Responses		
Households and government		
η	Intratemporal elasticity of substitution	4.62
ϕ_π	Taylor rule, coefficient of inflation	1.10
ϕ_i	—, coefficient of lagged nominal interest rate	0.87
Aggregate shocks		
ρ_m	Domestic monetary shock, persistence	0.68
σ_m	—, std.	0.25%
ρ_{m^*}	Foreign monetary shock, persistence	0.81
σ_{m^*}	—, std.	0.25%
ρ_{y^*}	Foreign demand shock, persistence	0.44
σ_{y^*}	—, std.	15%

Notes: The value of $\underline{b}$ is expressed in the unit of households' quarterly average labor income in steady state.

we assume an exogenous evolution of households' real and financial integration and study the case of endogenous transitions in Appendix A.1. We model real and financial integration

as independent Markov processes with transition-probability matrices $\begin{bmatrix} \lambda_j^1 & 1-\lambda_j^1 \\ 1-\lambda_j^0 & \lambda_j^0 \end{bmatrix}$ for $j = R, F$, where λ_R^1, λ_R^0 denote the probabilities of remaining in the state of real integration and nonintegration, respectively; and λ_F^1, λ_F^0 denote the probabilities of remaining in the state of financial integration and nonintegration, respectively. Under this process, the unconditional share of integrated households is given by $\frac{1-\lambda_j^0}{2-\lambda_j^1-\lambda_j^0}$. The two states for real integration correspond to working in the tradable sector (integrated) and in the non-tradable sector (nonintegrated). We set $\lambda_R^1 = 99\%$ and calibrate $\lambda_R^0 = 99.46\%$ to target the share of households working in the tradable sector in Canada of 37%; see Appendix B for details on this measurement.[6] Similarly, we set $\lambda_F^1 = 99\%$ and calibrate $\lambda_F^0 = 99.81\%$ to target the share of households that are financially integrated at 18%. In the data, we identify financially integrated households as those with direct holdings of foreign bonds or checking and savings accounts denominated in U.S. dollars. Appendix B provides more details on this measurement and analyzes the robustness of our results of a measurement financial integration based on indirect holdings of external securities through financial intermediaries.

The last step of our calibration targets aggregate responses to macroeconomic shocks. We target these aggregate responses to highlight the distributional implications of shocks whose aggregate implications are aligned with the data. The first of these targeted aggregate responses are to a domestic monetary policy shock. We focus on the peak responses of aggregate consumption, the nominal policy rate, and the CPI to a 25 b.p. monetary policy shock, documented by Champagne and Sekkel (2018). The parameters that govern these responses are the inflation coefficient in the Taylor rule ϕ_π; the persistence of Taylor rule ϕ_i, and the persistence of the monetary policy shock ρ_M. The second set of targeted aggregate responses are to the foreign demand shock, as documented by Charnavoki and Dolado (2014). We set the persistence and standard deviation of the foreign demand shock, ρ_Y^H and σ_Y^H, and the intratemporal elasticity of substitution in the consumption aggregator, η, to match the peak responses of exchange rate, export, and aggregate consumption to foreign demand shocks.

[6]Note that there exist a set of combinations of $\{\lambda_R^0, \lambda_R^1\}$ that are consistent with the targeted share of households working in the tradable sector. Among these combinations, our baseline calibration focuses on $\lambda_R^1 = 0.99$ to capture the idea that sectoral transitions are unusual. In Appendix A.1 we analyze an environment with endogenous transitions.

Finally, we set the persistence of foreign monetary policy shocks to match the autocorrelation of U.S. policy rates between 1980Q1 and 2007Q1 and set its standard deviation to be 25 b.p. to obtain a clear comparison of the effects from the domestic monetary shock with those from the foreign monetary shock. All parameter values are reported in Table 2, and the targeted moments in Table D.2.

We solve the model using the method proposed by Reiter (2009), which consists of two steps. First, we solve the steady state with no aggregate shocks. The steady state characterizes the distribution of households and the heterogeneity of their consumption and saving when the aggregate quantities and prices are fixed at their steady-state levels. Then we solve the first-order perturbation around the steady state. The solved dynamics characterize the responses of different households' consumption and saving policies, the distribution of households, and the aggregate quantities and prices following the different types of aggregate shocks.

4. Classic Questions in International Macroeconomics from a Distributional Perspective

This section uses our open-economy HANK model to reassess three classic questions in international macroeconomics from a distributional perspective: Section 4.1 analyzes the effects of monetary policy, Section 4.2 analyzes the international spillovers of external shocks and policies, and Section 4.3 studies the implications of different exchange-rate regimes.

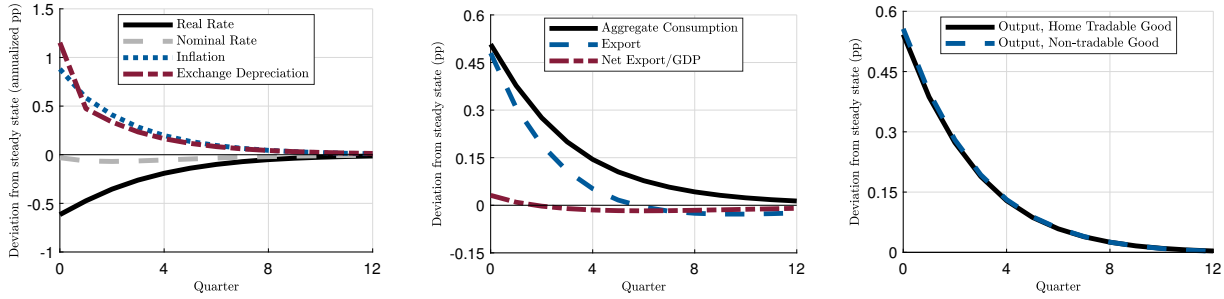
4.1. Effects of monetary policy

Aggregate effects We begin by studying the aggregate and distributional effects of changes in domestic monetary policy. Figure 1 shows the aggregate response to an expansionary monetary policy shock: a negative innovation to the Taylor rule $\epsilon_t^m = -0.0025$; more detailed responses are depicted in Appendix Figure D.1. The peak responses of aggregate consumption, inflation, and the exchange rate are targeted by our calibration and, by design, aligned

with the data. Due to price rigidities, the nominal decline in rates translates to a decline in real rates, which increases consumption. Currency depreciates, generating an increase in external demand and higher exports. Firms respond to increased external and domestic demand by increasing both their output and prices. The increase in firms' output leads to higher wages, leading to additional increases in domestic consumption.

Figure 1: Aggregate Effects of Monetary Policy Shocks

(a) Interest Rates and Inflation (b) Aggregate Demand (c) Aggregate Supply



Notes: This figure shows the responses of various aggregate variables to a 25 b.p. expansionary monetary policy shock (i.e., $\epsilon_{m,t} = -0.0025$). Panel (a) shows the responses of nominal and real interest rates, the inflation rate of the ideal price index, and the rate of nominal currency depreciation. Panel (b) shows the responses of aggregate consumption, exports, and the trade balance to GDP ratio. Panel (c) shows the output of the home tradable goods and non-tradable goods.

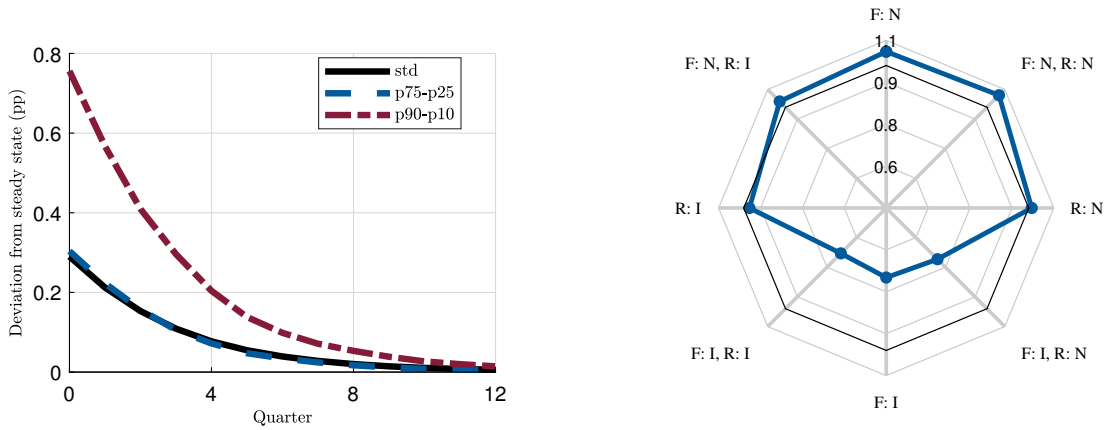
Appendix C compares these results with two benchmark models: a representative-agent open-economy model and a heterogeneous-agent closed-economy model. Regarding the first comparison, the aggregate effects of monetary shocks are aligned with those of the representative-agent open-economy New Keynesian model. This result is consistent with the findings of Auclert *et al.* (2020), who provide general conditions under which households' heterogeneity does not lead to an aggregate response significantly different from that of the representative-agent open-economy New Keynesian model. Regarding the second comparison, the response of aggregate consumption is smaller in the open economy than in the closed economy model, since the direct effects of interest changes on financially integrated households are dampened. We further analyze this comparison in Section 5, in which we study the role of international integration.

Distributional effects Our main focus is on the distributional consequences of monetary policy in the open-economy HANK. Figure 2 illustrates the effects of changes in monetary policy for different households in the economy. Panel (a) shows that changes in monetary policy have uneven effects on households, as measured by the standard deviation of consumption responses, the difference between the 75th and 25th percentiles of consumption responses, and the difference between the 90th and 10th percentiles, all scaled by the peak effect of aggregate consumption. All of these measures increase in response to the shock. For instance, the differential consumption effect of households in the 90th and 10th percentiles is 75% of the consumption peak effect.

Figure 2: Distributional Effects of Monetary Policy Shocks on Consumption

(a) Dispersion of Individual Responses

(b) Average Responses by Real and Financial Integration



Notes: This figure shows the distributional effects of a 25 b.p. expansionary monetary policy shock (i.e., $\epsilon_{m,t} = -0.0025$) on consumption. Panel (a) shows the responses of three statistics that measure the cross-sectional dispersion of consumption responses: the standard deviation and the differences between percentiles 75 and 25 and 90 and 10. All are scaled by the peak response of aggregate consumption. Panel (b) shows the responses of the total consumption of different subgroups of households in the period when the aggregate consumption response reaches its peak. Households are categorized by their type of *real* and *financial* integration. For notational simplicity, we use "R" and "F" for real and financial integration, and "I" and "N" to indicate *integrated* and *not integrated*. All responses are normalized by the peak response of aggregate consumption. To facilitate visual interpretation of the unevenness of consumption responses, we add a thin black solid line to depict the scenario in which different subgroups of households share homogeneous consumption responses.

Panel (b) shows the novel dimension of heterogeneity in our model stemming from households' uneven international integration. The figure depicts the peak consumption response

to a monetary policy shock for different types of households, normalized by the peak aggregate consumption response.[7] We vary the real integration of households along the horizontal axis, with the west (respectively, east) point showing the response of households working in the tradable (respectively, non-tradable) sector. Similarly, we vary the financial integration of households along the vertical axis, with the north (respectively, south) point showing the response of households not integrated (respectively, integrated) with international capital markets. The diagonals show different cases, conditioning on both dimensions of international integration. Results show that the main source of heterogeneity in the responses is financial integration. The differential consumption effect of financially integrated and non-integrated households is 30% of the average consumption peak effect. As we discuss later in further detail, this is because the direct effect of changes in the domestic interest rates is smaller for financially integrated households.

The heterogeneity of consumption responses in our model also stems from households' differences in wealth, which has been the main focus of closed-economy models with households' heterogeneity. Consistent with the findings of these models, households with lower levels of wealth exhibit larger marginal propensities to consume and are more responsive to changes in monetary policy. In fact, as shown in Appendix C, the heterogeneous responses by wealth are quantitatively similar in our model to those in the closed-economy HANK.

To assesses the quantitative importance of each source of heterogeneity, we conduct a variance decomposition analysis. For each source of heterogeneity (real and financial integration and wealth), we decompose the cross-sectional variance of the peak consumption responses in share that is explained within and across groups. Table 3 reports the share of the variance explained across groups for each source of heterogeneity. As shown in the first column, financial integration constitutes a source of heterogeneity that is almost as relevant as that of wealth.[8]

[7] Peak consumption responses at the individual level in this paper refer to the individual consumption responses in the period when the aggregate consumption response reaches its peak. Under the current calibration, the consumption responses of almost all of the households reach their peaks in the same period when the aggregate consumption response reaches its peak.

[8] To facilitate the comparison across the different sources of heterogeneity, we categorize wealth differences in two groups (above and below the median). As we narrow the wealth groups, the share of the variance explained across these groups increases.

Table 3: Contribution of Different Dimensions of Heterogeneity to Consumption Responses Dispersion (%)

	Domestic Monetary Shock	Foreign Demand Shock	Foreign Monetary Shock
Real integration	0.3	68.1	4.4
Financial integration	17.7	3.9	65.7
Net wealth	18.8	0.6	2.8

Notes: In this table, we decompose the cross-sectional variance of consumption responses in the period when aggregate consumption response reaches its peak. The decomposition is based on the identity $\mathbb{V}[Y] = \mathbb{E}[\mathbb{V}[Y|X]] + \mathbb{V}[\mathbb{E}[Y|X]]$, where $\mathbb{V}[Y]$ denotes the cross-sectional variance of consumption responses Y; $\mathbb{E}[\mathbb{V}[Y|X]]$ denotes the average of within-group consumption response variance across the groups categorized by household characteristic X (i.e., real integration, financial integration, net wealth); and $\mathbb{V}[\mathbb{E}[Y|X]]$ denotes the variance of the corresponding within-group averages. The reported contributions of different dimensions of heterogeneity are measured by $\frac{\mathbb{V}[\mathbb{E}[Y|X]]}{\mathbb{V}[Y]}$.

Decomposition of channels To further analyze the heterogeneity in consumption responses in our model for different types of households, Panel 1 of Table 4 decomposes the effects of monetary policy, with a decomposition in the spirit of Auclert (2019) and Kaplan *et al.* (2018). In particular, we decompose consumption responses into a *Real interest rate channel*, which measures the effect on consumption of changes of nominal rates in local currency and inflation; a *Labor income channel*, which measures the effect on consumption of households' labor income changes in response to shocks; and *Other channels*, which measures the effect of consumption on the rest of the general equilibrium responses to shocks, including profits, government taxes and transfers, and changes in the distribution.[9]

This decomposition yields two main results. First, consistent with findings from closed-economy studies, indirect effects play a major role in explaining aggregate responses. In particular, changes in labor income induced by changes in monetary policy and its effect on aggregate demand account for more than 50% of aggregate responses. Second, the interest rate channel plays an important role in accounting for heterogeneous responses of

[9]We focus on decomposing the peak consumption responses. To decompose the consumption responses, we first solve the equilibrium paths of the aggregate prices and quantities. For a specific variable, we fit its equilibrium path into the decision problem of households and keep all other relevant variables constant at their steady-state levels. The fraction between the solved consumption response and their full-equilibrium response is our measure of the contribution from the variation in this specific variable.

consumption to monetary policy. For instance, for households that are not integrated with international markets, the real interest rate channel is six times larger than for households that are integrated with international capital markets, for which changes in the real interest rate only occur because of differences between currency depreciation and inflation. In the case of monetary policy shocks, changes in labor income are not a major source of inequality in consumption responses, because monetary policy has a similar impact on the economic activity of both home tradable and nontradable sectors. For other shocks we will discuss in the next section, such as external demand shock, the labor income channel is a major source of heterogeneity in consumption responses.

Extensions Appendix A analyzes the results of the redistributional effects of monetary policy under different model extensions. Appendix A.1 endogenizes households' international integration. We show that the distributional effects of monetary policy are dampened with endogenous transitions to international integration, which highlights the importance of households' ability to switch across sectors or invest in international capital markets in mitigating the uneven effects of macroeconomic shocks; we further discuss this in Section 5. Appendix A.2 compares the aggregate and distributional responses to external shocks under the Producer-currency pricing in our baseline model with those in an economy with Dollar-currency pricing, in which firms face a cost of adjusting the price in foreign currency. This extension is important because the literature has documented that there is a high degree of Dollar-currency pricing in the data and that this reduces the ability of monetary policy to stimulate exports through the expenditure-switching channel relative to a case in which prices are set in the currency of producers.[10] We complement these findings by emphasizing the distributional consequences of Dollar-currency pricing and showing that in this case, monetary policy generates more uneven responses across households in the economy because it stimulates more income and consumption by workers in nontradable sectors than by those working in tradable sectors.

[10]For empirical evidence related to Dollar pricing and the international price system see Goldberg and Tille (2008); Gopinath, Itskhoki and Rigobon (2010); Gopinath (2015); Corsetti, Crowley, Han and Song (2019); Drenik and Perez (2020); Burstein and Gopinath (2014) and references therein.

Table 4: Decomposition of Consumption Responses by Transmission Channels (%)

	Aggregate	By Real Integration		By Fin. Integration		By Net Wealth	
		N	I	N	I	Low	High
Panel 1. Domestic Monetary Shock							
Response w.r.t. the aggregate	1	1.01	0.98	1.05	0.71	1.24	0.86
Decomposition by different channels							
Real interest	0.36	0.36	0.36	0.42	0.07	0.22	0.46
Nominal rate in dom. currency	0.004	0.004	0.003	0.06	-0.29	-0.02	0.01
Inflation	0.36	0.36	0.36	0.36	0.36	0.24	0.45
Labor income	0.54	0.55	0.52	0.54	0.54	0.84	0.35
Others	0.10	0.10	0.09	0.10	0.10	0.18	0.05
Panel 2. Foreign Demand Shock							
Response w.r.t. the aggregate	1	0.33	2.25	1.13	0.33	1.16	0.90
Decomposition by different channels							
Real interest	0.30	0.30	0.30	0.42	-0.37	0.17	0.38
Nominal rate in dom. currency	0.23	0.23	0.23	0.36	-0.44	0.17	0.28
Inflation	0.07	0.07	0.07	0.07	0.07	0.001	0.10
Labor income	0.61	-0.07	1.86	0.61	0.60	0.91	0.42
Others	0.10	0.10	0.10	0.10	0.10	0.08	0.11
Panel 3. Foreign Monetary Shock							
Response w.r.t. the aggregate	1	1.33	0.39	0.08	5.85	0.53	1.29
Decomposition by different channels							
Real interest	0.99	0.99	0.99	0.06	5.84	0.49	1.30
Nominal rate in dom. currency	0.95	0.95	0.94	0.02	5.80	0.47	1.24
Inflation	0.04	0.04	0.04	0.04	0.04	0.02	0.06
Labor income	0.13	0.46	-0.48	0.13	0.13	0.25	0.06
Others	-0.12	-0.12	-0.12	-0.12	-0.12	-0.21	-0.07

Notes: In this table, we focus on the consumption responses in the period when the aggregate consumption response reaches its peak. We decompose them into the contribution of the variation of different groups of aggregate variables. The first group includes the aggregate variables that affect the real return to households' saving or borrowing. Within this group, we further divide the variables into two subgroups: the ones that affect the nominal return rate in domestic currency (domestic and foreign nominal interest rate and nominal exchange rate) and the inflation of the ideal price index. The second group includes the aggregate variables that affect households' income from the labor market, i.e., the real wages in both nontradable goods and home tradable goods sectors. The third group includes all other variables relevant to households' consumption: the tax rate and dividends.

4.2. International spillovers

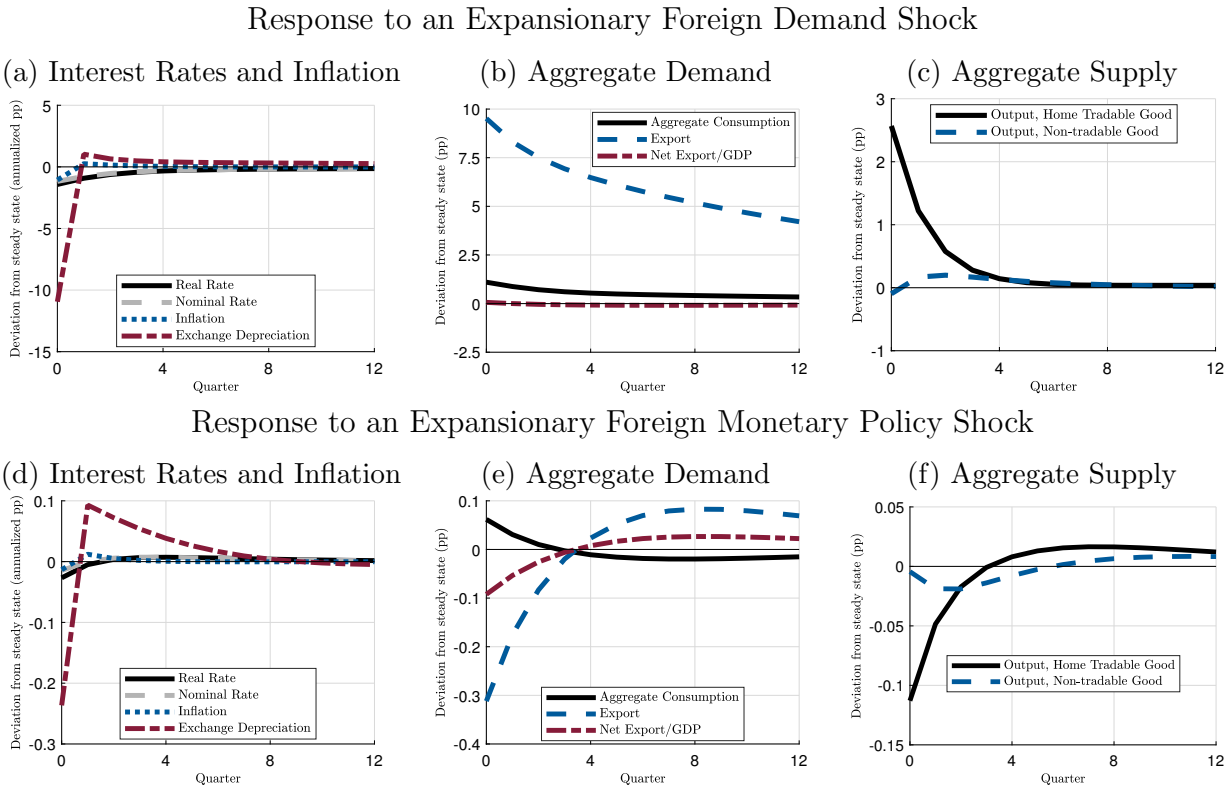
We study the aggregate and distributional effects of two sources of macroeconomic exposure that result from real and financial international integration: changes in external demand and foreign monetary policy.

External demand The top panels in Figure 3 show the aggregate responses of a positive shock to the external demand of home tradable goods, with more details provided in Appendix Figure D.2. Firms in the home tradable goods sector respond to higher external demand by increasing their output and prices. On the one hand, the increase in output leads to higher wages and consumption for workers employed in the tradable sector, which in turn leads to higher output and wages in the non-tradable sector. On the other hand, the relative price of home and foreign tradable goods adjusts through a currency appreciation and leads to an expenditure switching of domestic households toward foreign tradable goods.[11] Currency appreciation pushes down inflation, leading the monetary authority to cut its policy rate, which further amplifies the increase in domestic demand. In spite of currency appreciation, the initial external demand shock implies that the economy increases its exports and its trade balance.

The top panels in Figure 4 show the distributional effects of the external demand shock. Panel (a) shows that the external demand shock leads to uneven responses in consumption across households, as measured by the standard deviation of consumption responses, the difference between the 75th and 25th percentiles, and the difference between the 90th and 10th percentiles, which all increase in response to the shock. Quantitatively, these differences are larger than for a domestic monetary policy shock. For instance, the standard deviation of consumption responses, scaled by the the peak effect of aggregate consumption, is twice as large for an external demand shock than for a domestic monetary policy shock. Panel (b) shows that the consumption of households working in the tradable sector is six times more responsive to external demand shocks than that of households working in the non-

[11] The effects of an external demand shock on output and the real exchange rate in our model are qualitatively consistent with the effects of the terms of trade shocks documented in the literature (see, for example, Mendoza, 1995; Schmitt-Grohé and Uribe, 2018).

Figure 3: Aggregate Effects of External Shocks



Notes: Panels (a)-(c) show the responses of various aggregate variables to a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$). Panels (d)-(f) show the responses of various aggregate variables to a 25 b.p. expansionary foreign monetary policy shock (i.e., $\epsilon_{m^*,t} = -0.0025$). Panels (a) and (d) show the responses of nominal and real interest rates, the inflation rate of the ideal price index, and the rate of nominal currency depreciation. Panels (b) and (e) show the responses of aggregate consumption, exports, and the trade balance to GDP ratio. Panels (c) and (f) show the output of home tradable goods and non-tradable goods.

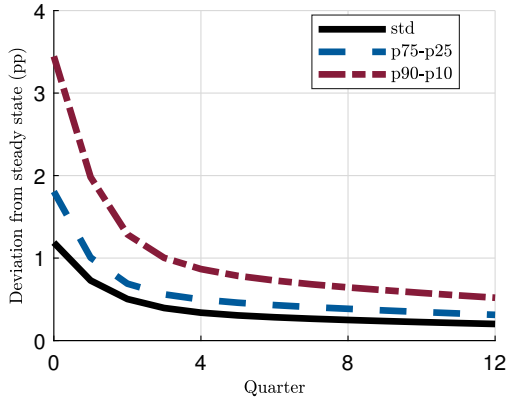
tradable sector. As shown in Table 4, this is mostly due to the effect of external demand shocks on labor income, which are mostly concentrated in households working in the tradable sector. The second column of Table 3 shows that the uneven real integration of households constitutes the most relevant dimension that drives heterogeneity in consumption responses to external demand shocks, accounting for 68% of the cross-sectional variance of consumption responses.

Foreign monetary policy The bottom panels in Figure 3 show the aggregate responses to a foreign monetary policy expansion, with more details provided in Appendix Figure D.3.

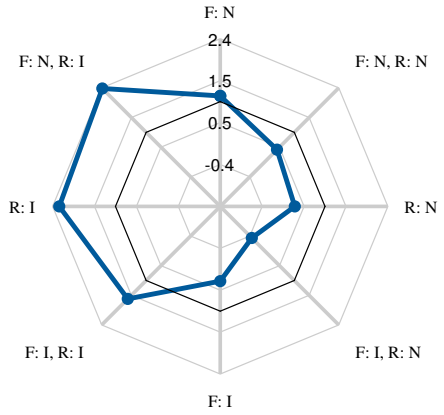
Figure 4: Distributional Effects of External Shocks

Heterogeneous Consumption Responses to an Expansionary Foreign Demand Shock

(a) Dispersion

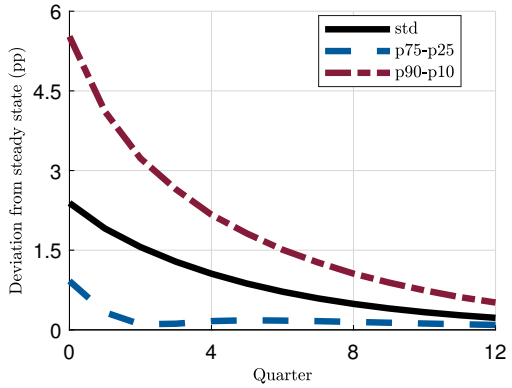


(b) by Real and Financial Integration

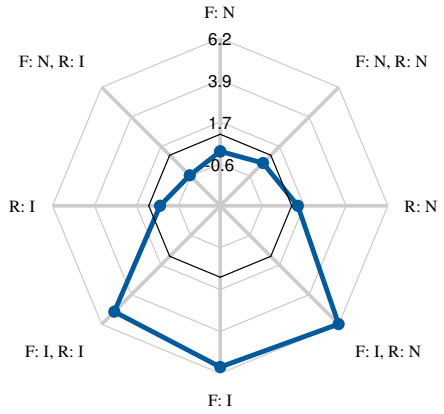


Heterogeneous Consumption Responses to an Expansionary Foreign Monetary Shock

(c) Dispersion



(d) by Real and Financial Integration



Notes: Panels (a)-(b) show the distributional effects of a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$) on consumption. Panels (c)-(d) show the distributional effects of a 25 b.p. expansionary foreign monetary policy shock (i.e., $\epsilon_{m^*,t} = -0.0025$) on consumption. Panel (a) and (c) show the responses of three statistics measuring the cross-sectional dispersion of consumption responses: the standard deviation and the differences between percentiles 75 and 25 and 90 and 10. All are scaled by the peak response of aggregate consumption. Panel (c) and (d) show the responses of the total consumption of different subgroups of households in the period when the aggregate consumption response reaches its peak. Households are categorized by their type of *real* and *financial* integration. For notationAL simplicity, we use "R" and "F" for real and financial integration, and "I" and "N" to indicate *integrated* and *not integrated*. All responses are normalized by the peak response of aggregate consumption. To facilitate the visual interpretation of the unevenness of consumption responses, we add a thin black solid line to depict the scenario in which different subgroups of households share the homogeneous consumption responses.

The decline in foreign interest rates increases the consumption of households integrated with international capital markets. Home tradable firms and nontradable firms respond to the increase in demand by increasing their output and prices. The increase in output leads to higher wages, which reinforces the increase in consumption. The increased prices of home tradable and nontradable goods leads to an expenditure switching of domestic households toward foreign tradable goods, which is associated with currency appreciation; this pushes down inflation and leads the monetary authority to cut its policy rate. Currency appreciation ends up leading to a decline in exports and to trade-balance deficits, which are financed with the capital inflows generated by lower external interest rates.

The bottom panels in Figure 4 show that the foreign monetary policy shock has uneven effects across different households. Quantitatively, the distributional effects of foreign monetary policy shocks are larger than those of domestic monetary policy shocks. For instance, the standard deviation of consumption responses, scaled by the the peak effect of aggregate consumption, is two times larger than than for external demand shocks and four times larger than domestic monetary policy shocks. Panel (b) shows that households integrated with international capital markets significantly increase their consumption in response to foreign monetary policy shocks, while those not integrated with international capital markets exhibit only a modest consumption increase in response to these shocks. Table 4 shows that the latter is because, given that only a small fraction of households in the economy are integrated with international financial markets, foreign monetary policy shocks lead to small indirect effects in the domestic economy. Table 4 also shows that the differential response of integrated and nonintegrated households is mostly explained by direct channels-namely, that changes in foreign interest rates induce small changes in domestic real interest rates. The last column of Table 3 shows that this is the most relevant dimension of heterogeneity, accounting for 66% of the cross-sectional variance of consumption responses to foreign monetary policy shocks.

How does macro matter for inequality? We conclude by emphasizing the key takeaway from this section. It is well documented that an important part of fluctuations in open

economies stems from foreign macroeconomic shocks. Our analysis shows that the uneven international integration of households gives rise to inequality in the individual responses to these shocks; this mainly operates through the direct effects of foreign shocks on households' labor income or borrowing and savings rates. In this sense, the uneven aspect of globalization makes "macro matters for inequality" (Ahn *et al.*, 2018).

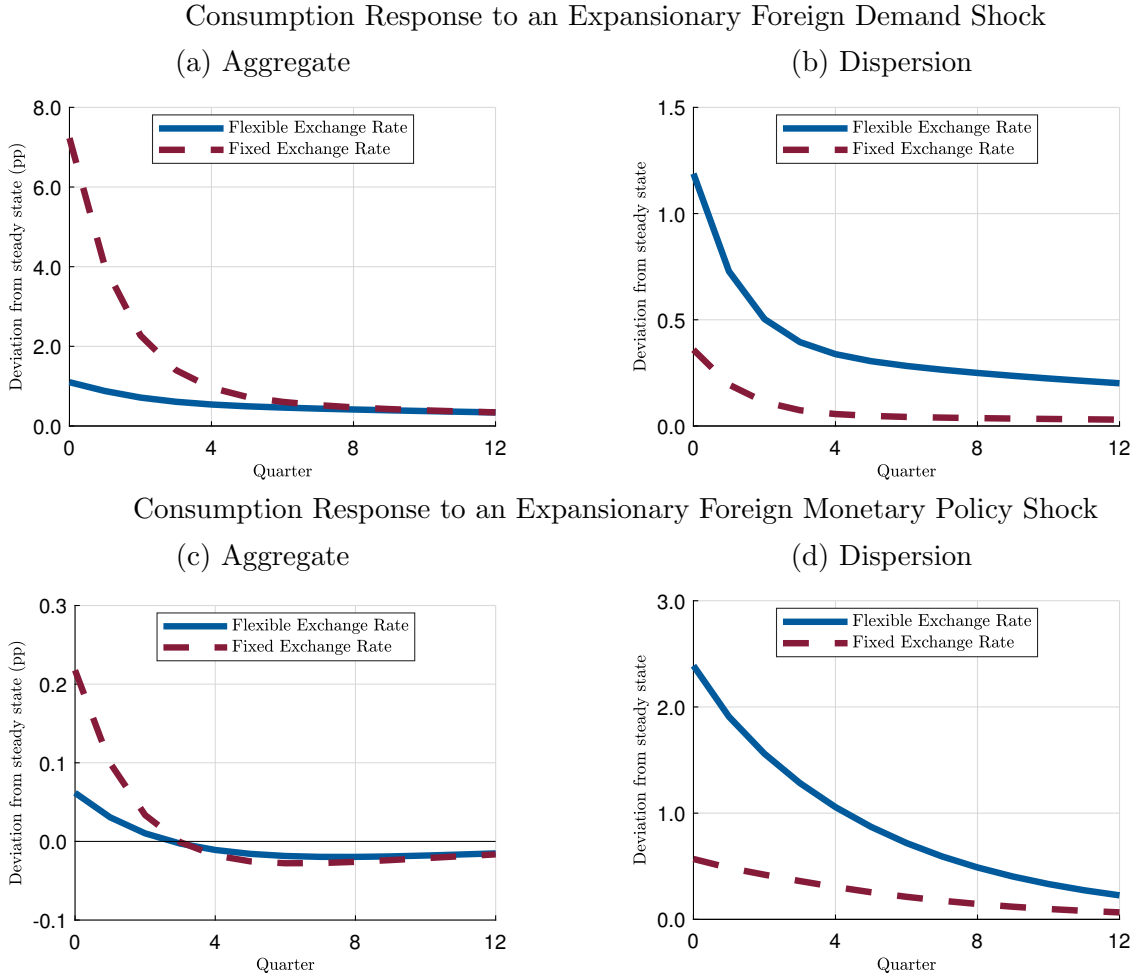
4.3. Exchange-rate regimes

The third classic question we address is how different exchange-rate regimes compare. To answer this question, we compare the aggregate and distributional responses to external shocks under the flexible exchange-rate regime from the Taylor rule in our baseline model (described in Section 4.2) with those in an economy in which the monetary authority chooses domestic interest rates to set $\mathcal{E}_t = 1$ for all periods.

Panels (a) and (c) of Figure 5 show that, as is standard in representative-agent open-economy New Keynesian models (e.g., Gali and Monacelli, 2005), aggregate consumption has a larger response to shocks under a fixed-exchange-rate regime that under a flexible regime. As further detailed in Appendix Figures D.4 and D.5, this is because when there is an expansion induced by either an external demand shock or a foreign monetary policy shock, under a fixed-exchange-rate regime the monetary authority decreases its interest rate more sharply to avoid currency appreciation, which creates additional expansions in domestic demand. As a result, for both increases in external demand or declines in foreign interest rates, the aggregate consumption response is larger under a fixed-exchange-rate regime than under a Taylor rule.[12]

[12]See Broda (2004) for empirical evidence on the larger output response to a terms-of-trade shock in countries with fixed-exchange-rate regimes vs. those with flexible-exchange-rate regimes.

Figure 5: Aggregate and Distributional Effects of External Shocks under Alternative Exchange-rate Regimes



Notes: Panels (a)-(b) show the effects of a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$) on consumption under different exchange-rate regimes. Panels (c)-(d) show the effects of a 25 b.p. expansionary foreign monetary policy shock (i.e., $\epsilon_{m^*,t} = -0.0025$) on consumption under different exchange-rate regimes. Panels (a) and (b) show the responses of aggregate consumption. Panels (b) and (d) show the standard deviation of consumption responses across households, scaled by the peak response of aggregate consumption. *Flexible exchange rate* corresponds to the baseline model (described in Section 2); *Fixed exchange rate* corresponds to the equilibrium under which the monetary policy sets the nominal rate to target $\mathcal{E}_t = 1$ in all periods.

Panels (b) and (d) of Figure 5 compare the distributional implications of the different exchange-rate regimes, as measured by the standard deviation of consumption responses. In both cases, fixed-exchange-rate regimes lead to a lower dispersion of consumption responses relative to the aggregate response. To understand this result, Table 5 compares the decompo-

sition of channels of consumption response for the flexible- and fixed-exchange-rate regimes for both types of external shocks, and Appendix Figure D.6 provides details on consumption responses for households with different international integration.

Table 5: Decomposition of the Distributional Effects under Alternative Monetary Policy Rules

	Flexible				Fixed			
	by Real Integration		by Fin. Integration		by Real Integration		by Fin. Integration	
	N	I	N	I	N	I	N	I
Panel 1. Foreign Demand Shock								
Consumption responses	0.33	2.25	1.13	0.33	0.90	1.18	1.07	0.63
Decomposition of consumption responses by different channels								
Real Interest Rate	0.30	0.30	0.42	-0.37	0.40	0.40	0.47	0.03
Nominal rate in dom. currency	0.23	0.23	0.36	-0.44	0.36	0.36	0.43	-0.01
Inflation	0.07	0.07	0.07	0.07	0.04	0.04	0.04	0.04
Labor income	-0.07	1.86	0.61	0.60	0.33	0.62	0.43	0.43
Others	0.10	0.10	0.10	0.10	0.17	0.17	0.17	0.17
Panel 2. Foreign Monetary Shock								
Consumption responses	1.33	0.39	0.08	5.85	1.09	0.83	0.78	2.14
Decomposition of consumption responses by different channels								
Real Interest Rate	0.99	0.99	0.06	5.84	0.60	0.60	0.38	1.74
Nominal rate in dom. currency	0.95	0.94	0.02	5.80	0.64	0.64	0.43	1.78
Inflation	0.04	0.04	0.04	0.04	-0.05	-0.04	-0.05	-0.05
Labor income	0.46	-0.48	0.13	0.13	0.38	0.11	0.28	0.28
Others	-0.12	-0.12	-0.12	-0.12	0.12	0.12	0.12	0.12

Notes: Panels 1 and 2 show the decomposition of different households' peak consumption response to one-standard-deviation of expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$) and those of a 25 b.p. expansionary foreign monetary policy shock (i.e., an innovation to the foreign interest rate $\epsilon_{m^*,t} = -0.0025$) under different exchange-rate regimes. *Flexible exchange rate* corresponds to the baseline model (described in Section 2); *Fixed exchange rate* corresponds to the equilibrium under which the monetary policy sets the nominal rate to target $\mathcal{E}_t = 1$ in all periods.

In the case of external demand shocks, the main source of inequality in consumption responses under the flexible-exchange-rate regime is the uneven impact of this shock on the labor income of households working in different sectors. Under a fixed-exchange-rate regime, the monetary authority reduces its domestic interest rate more sharply to prevent the

currency appreciation induced by the external shock (see Appendix Figure D.4). The decline in rates then dampens the inequality in consumption responses originated by the external demand shock for two reasons. First, the decline in interest rates increases consumption for households working in both sectors, causing the consumption expansion to be more generalized in the economy. Second, the decline in rates increases domestic demand and the labor income of households working in nontradable sectors, which dampens the uneven labor income dynamics generated by the external demand shock.

In the case of a foreign monetary policy shock, the main source of inequality in consumption responses under the flexible-exchange-rate regime is the uneven impact of direct changes in interest rates for households that are integrated with international financial markets vis-à-vis those not integrated with international markets. Under the fixed-exchange-rate regime, the monetary authority must again reduce its policy rate to prevent the currency appreciation induced by the shock (see Appendix Figure D.5). The domestic monetary policy response triggers direct expansionary channels in households not integrated with international financial markets, causing the interest-rate channel to be more even for both integrated and nonintegrated households.

How does inequality matter for macro? A second takeaway is that the choice of monetary policy in open economies and, in particular, the choice of exchange-rate regimes entails distributional consequences for households with different degrees of international integration. To the extent that the objective of monetary authorities includes inequality considerations, our results indicate the presence of a trade-off between aggregate stabilization and consumption inequality in the conduct of monetary policy.

5. The Role of International Integration

So far, we have focused on how monetary policy affects the asymmetric effects of external shocks for a given degree of international integration. In this section, we study how our conclusions are affected by the degree of international integration that characterizes the

economy. From a positive perspective, this exercise helps us understand how changes in the international integration that countries often experience is expected to affect the effects of shocks and the ability of monetary policy to influence these effects. From a normative perspective, this is an important input to the debate on the consequences of globalization that motivated this paper.

To study the role of international integration, we compare the responses to macro shocks of the baseline economy, calibrated to Canada, with an identical economy calibrated to match the degree of international integration of the US. In the data, the US exhibits a substantially lower degree of international integration on both the real and financial side.[13] Panel (a) of Table 6 shows the aggregate responses to macro shocks. On the one hand, domestic monetary policy is less effective in an environment of relatively high real and financial integration, such as Canada. From the perspective of financial integration, monetary policy loses an important part of its direct channel in stimulating the consumption of households that borrow and save in domestic securities (see Figure D.7). From the perspective of real integration, monetary policy loses its effects on nontradable sectors, which play an important role in monetary transmission (see Figure D.7). On the other hand, higher international integration amplifies the aggregate effect of external shocks. This is because changes in external demand have larger effects when the share of the tradable sector is high, and changes in foreign monetary policy are larger when the share of households integrated with international capital markets is large.

[13] In the U.S., 10% of households are working in the home goods sector, and financially integrated households account for 5% of the population.

Table 6: Effects of External Shocks under Different Levels of International Integration

	CA Level of Int. Integration	US Level of Int. Integration
Aggregate effects: aggregate consumption responses (%)		
Domestic monetary shock	0.51	0.55
Foreign demand shock	1.09	0.16
Foreign monetary shock	0.06	0.01
Distributional effects: dispersion of consumption responses		
Domestic monetary shock	0.29	0.26
Foreign demand shock	1.18	2.53
Foreign monetary shock	2.39	8.56

Note: This table shows the effects of a 25 b.p. expansionary monetary policy shock ($\epsilon_{m,t} = -0.0025$), a 15% expansionary external demand shock ($\epsilon_{y^*,t} = 0.15$), or a 25 b.p. expansionary foreign monetary policy shock ($\epsilon_{m^*,t} = -0.0025$) within two economies with different degrees of international integration. In the case of "*CA Level*," the economy is specified to be the same as in the baseline model, where the degrees of international integration are calibrated to the levels of Canada, i.e., the fraction of financially integrated households and real integrated households are 18% and 37%. In the case of "*US Level*," we calibrate the degrees of international integration to the levels of U.S. economy, i.e., the fraction of financially integrated households and real integrated households are 5% and 10%. In both cases, we calibrate the model to have the same wealth distribution as baseline model. For the aggregate effects, we focus on the peak aggregate consumption responses. For the distributional effects, the dispersion refers to the cross-sectional standard deviation of households' consumption responses in the period when the aggregate consumption response reaches its peak, normalized by the peak aggregate consumption response.

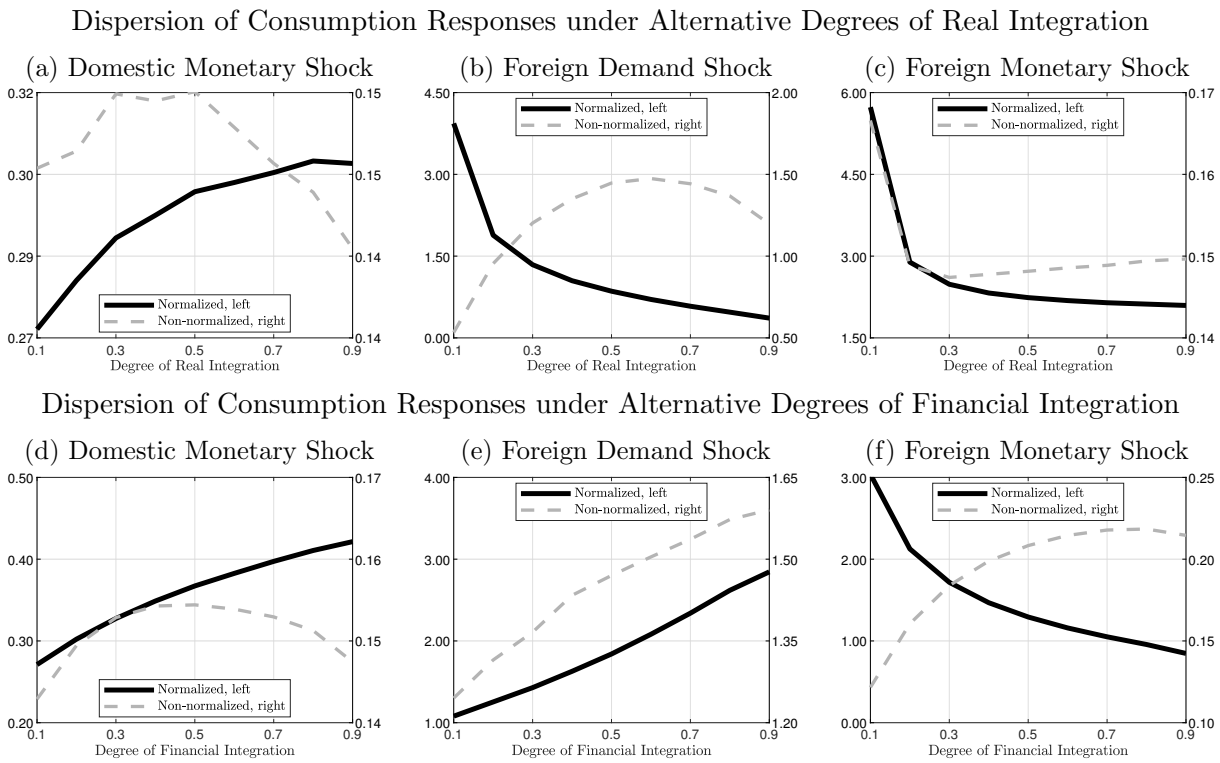
Panel (b) compares the distributional effects of macroeconomic shocks. The main takeaway is that the higher degree of international integration dampens the distributional impacts of external shocks and those of domestic monetary polcy shocks. To explain this result, Figure 6 shows how the distributional effects of macro shocks vary when we vary the degree of real and financial integration separately.[14] We show these results by tracing the standard de-

[14]For real integration, we consider economies with different shares of households working in the home tradable goods sector vs. the nontradable sector and those in which households' consumption baskets are composed of home tradable goods vs. nontradable goods. For financial integration, we consider economies with different shares of households that have access to financial securities internationally traded. In each scenario, we calibrate the level of government debt to keep the average level of households' wealth at the same level as in the baseline calibration. These alternative economies aim to capture changes that occur, for instance, due to trade and financial liberalizations, in which some goods the economy produces switch from only being traded by domestic households to also face demand from the rest of the world, and in which households that only have access to domestically traded securities start having access to financial securities

viation of consumption responses, with and without normalizing by the aggregate response to the shocks. Panels (a)-(c) show that without normalizing for the aggregate response, there is a nonmonotonic relationship between the dispersion of consumption responses and the degree of international integration. The dispersion is maximal in economies that have considerable shares of both integrated and nonintegrated households. Panels (d)-(f) show that once we normalize by the aggregate reponse, the dispersion becomes monotonically decreasing (increasing) in the degree of international integration in response to external (domestic) shocks. In economies with a high degree of integration, domestic monetary policy shocks have little impact on aggregates and the small share of households that are nonintegrated bear most of the burden of the shock. By a similar argument, in economies with low degrees of international integration, external shocks have little impact on aggregates and the small share of households that are integrated experience large swings relative to the aggregate response to international shocks. In this sense, economies with a low degree of international integration can suffer more unequal responses to globalization.

traded with the rest of the world.

Figure 6: Distributional Effects under Alternative Degrees of International Integration



Note: Panels (a) and (d) show the effects of a 25 b.p. expansionary monetary policy shock (i.e., $\epsilon_{m,t} = -0.0025$); Panels (b) and (e) show the effects of a 15% expansionary external demand shock ($\epsilon_{y^*,t} = 0.15$); and Panels (c) and (f) show the effects of a 25 b.p. expansionary foreign monetary policy shock ($\epsilon_{m^*,t} = -0.0025$). The *degree of real integration* refers to the fraction of households working in the home tradable goods sector, and the *degree of financial integration* refers to the fraction of households with access to international financial markets. When we vary the degree of international integration, we calibrate the model to have the same wealth distribution across households. In each panel, we compute the cross-sectional standard deviation of households' consumption responses when the aggregate consumption response reaches its peak, and normalize it by the peak aggregate consumption response.

6. Conclusion

Motivated by the asymmetric effects of globalization documented over the last three decades, we study how monetary policy shapes the effects of external shocks in open economies. External shocks have larger effects on households employed in tradable sectors or that have access to international capital markets. In confronting these shocks, monetary authorities might face a trade-off between maintaining aggregate stability and reducing income and consumption inequalities. Fixed-exchange-rate regimes, which typically amplify the aggregate effects of an external shock, can reduce the consumption inequalities that stem from external shocks. Our paper also shows that although lower international integration dampens the aggregate exposure to external shocks, it also increases the distributional impacts of these shocks. From this, we conclude that the discontents of globalization might arise, perhaps paradoxically, from international integration's not being sufficiently generalized. Overall, our results indicate that redistribution constitutes a relevant consideration for monetary policy in open economies. This suggests that an important area for future research is the interaction between monetary and fiscal policies with households' heterogeneity in open economies.

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A. Model Extensions

We extend the model in two dimensions as robustness tests for the baseline results. First, we incorporate the endogenous transition of households' international integration status into the model. Second, we change the pricing system from producer pricing to international pricing. In this section, we focus on and discuss the key differences in the setup and implications under each extension compared with the baseline model.

A.1. Endogenous transitions for international integration

Setup In this extension, we assume that the timeline for households' decision is as follows:

1. At the beginning of each period t, households inherit the predetermined states $(z^-, b, \mathbf{o}^-)$.

2. *Exogenous Evolution of Idiosyncratic Productivity.* Idiosyncratic labor productivity evolves following the exogenous Markov process as specified in the baseline model (see Section 2 for more details).

3. *Endogenous Evolution of International Integration Status.* Households get a randomly arriving opportunity to adjust their type of international integration. Their adjustment opportunity is denoted by $a_R \in \{0, 1\}$ and $a_F \in \{0, 1\}$, which indicate the arrival of the opportunity to adjust the status of real and financial integration. a_R and a_F are independent, and both follow Bernoulli distributions with the arrival rates depending on their previous integration status $\mathbf{o}^-$. We denote the probability of $a_R = 0$ as $\lambda_R(o_R^-)$ and that of $a_F = 0$ as $\lambda_F(o_F^-)$. Based on the realized opportunity to adjust their status of international integration, households make their adjustment decision and determine their status of international integration $\mathbf{o}$ to maximize their lifelong utility.

4. *Realization of Exogenous Exit Shock.* Households get an i.i.d. exogenous exit shock with arrival probability of ξ.

5. *Optimal Choice of Consumption, Labor, and Saving.* Surviving households choose their consumption, labor and saving. Exiting households have to exit, so they must spend all of their savings or pay back all of their debt, and choose their optimal consumption and labor supply.

Analysis Given the above timeline of decisions in each period t, we can reformulate the Bellman equation system to characterize the households' decision problem as:

1. *Exogenous Evolution of Idiosyncratic Productivity*

$$U_t(z^-, b, \mathbf{o}^-) = \mathbb{E}_{\mathbf{t}}\left[\hat{\mathbf{V}}_{\mathbf{t}}\left(\mathbf{z}, \mathbf{b}, \mathbf{o}^-\right)|\mathbf{z}^-\right],$$

where $U_t(z^-, b, \mathbf{o}^-)$ denotes the ex ante value for households with predetermined state $(z^-, b, \mathbf{o}^-)$ and $\hat{V}_t\left(z, b, \mathbf{o}^-\right)$ denotes the value for households before the realization of the opportunity to adjust their international integration status.

2. *Endogenous Evolution of International Integration Status*

$$\hat{V}_t(z, b, \mathbf{o}^-) = \mathbb{E}_{\mathbf{t}}\left[\max_{\mathbf{o}\in\mathcal{S}(\mathbf{a_R},\mathbf{a_F})}\left\{\varepsilon_{\mathbf{o}} + \bar{\mathbf{V}}_{\mathbf{t}}(\mathbf{z}, \mathbf{b}, \mathbf{o})\right\}\right],$$

where $\mathcal{S}(a_R, a_F)$ denotes the optional set for households to choose:

   (a) $\mathcal{S}(a_R, a_F) = \{(0,0), (0,1), (1,0), (1,1)\}$ if $a_R = 1$ and $a_F = 1$;

   (b) $\mathcal{S}(a_R, a_F) = \{(o_R^-, 0), (o_R^-, 1)\}$ if $a_R = 0$ and $a_F = 1$;

   (c) $\mathcal{S}(a_R, a_F) = \{(0, o_F^-), (1, o_F^-)\}$ if $a_R = 1$ and $a_F = 0$;

   (d) $\mathcal{S}(a_R, a_F) = \{(o_R^-, o_F^-)\}$ if $a_R = 0$ and $a_F = o$.

   Here, we also add an i.i.d. nonpecuniary preference shock $\varepsilon^{\mathbf{o}}$ distributed following the Gumbel distribution with the C.D.F. as $e^{-e^{-\sigma\mathbf{o}\cdot\varepsilon\mathbf{o}}}$. As we will discuss later, this preference shock can help us govern the degree of state dependency of households' adjustment decision.

3. *Realization of Exogenous Exit Shock*

$$\bar{V}_t(z, b, \mathbf{o}) = (\mathbf{1} - \xi) \cdot \mathbf{V_t}(\mathbf{z}, \mathbf{b}, \mathbf{o}) + \xi \cdot \tilde{\mathbf{V}}_{\mathbf{t}}(\mathbf{z}, \mathbf{b}, \mathbf{o})$$

4. *Optimal Choice of Consumption, Labor, and Saving*

$$
\begin{aligned}
V_t(z,b,\mathbf{o}) =& \max_{c,l,b'} u(c,l) + \beta \cdot \mathbb{E}_t\left[U_{t+1}\left(z,b',\mathbf{o}\right)\right] \\
\text{s.t.} \qquad q_t(\mathbf{o})\cdot \mathbf{b}' =& T_t + \bar{\gamma}(b,z,\mathbf{o})\cdot\gamma_{\mathbf{t}} + \mathbf{b} + \mathbf{z}\cdot(\mathbf{1}-\tau_{\mathbf{t}})\cdot\mathbf{w_t}(\mathbf{o})\cdot\mathbf{l} - \mathbf{c} \\
b' \geq& \underline{b} \\
\tilde{V}_t(z,b,\mathbf{o}) =& \max_{c,l,b'} u(c,l) \\
\text{s.t.} \qquad 0 =& T_t + \bar{\gamma}(b,z,\mathbf{o})\cdot\gamma_{\mathbf{t}} + \mathbf{b} + \mathbf{z}\cdot(\mathbf{1}-\tau_{\mathbf{t}})\cdot\mathbf{w_t}(\mathbf{o})\cdot\mathbf{l} - \mathbf{c}
\end{aligned}
$$

The above Bellman equation system shares most of the elements with the benchmark setup, except for the evolution of international integration status. Under this extension, the transition probability from $\mathbf{o}^-$ to $\mathbf{o}$ is

$$
\begin{aligned}
&\mathbb{1}[o_R = o_R^-, o_F = o_F^-]\cdot\lambda_R(o_R^-)\cdot\lambda_R(o_R^-) \\
+&\mathbb{1}[o_R = o_R^-]\cdot\lambda_R(o_R^-)\cdot(1-\lambda_R(o_R^-))\cdot\frac{\exp\left(\sigma_{\mathbf{o}}\cdot\bar{V}_t(z,b,\mathbf{o})\right)}{\sum_{\tilde{\mathbf{o}}\in\mathcal{S}(0,1)}\exp\left(\sigma_{\mathbf{o}}\cdot\bar{V}_t(z,b,\tilde{\mathbf{o}})\right)} \\
+&\mathbb{1}[o_F = o_F^-]\cdot(1-\lambda_R(o_R^-))\cdot\lambda_R(o_R^-)\cdot\frac{\exp\left(\sigma_{\mathbf{o}}\cdot\bar{V}_t(z,b,\mathbf{o})\right)}{\sum_{\tilde{\mathbf{o}}\in\mathcal{S}(1,0)}\exp\left(\sigma_{\mathbf{o}}\cdot\bar{V}_t(z,b,\tilde{\mathbf{o}})\right)} \\
+&(1-\lambda_R(o_R^-))\cdot(1-\lambda_R(o_R^-))\cdot\frac{\exp\left(\sigma^{\mathbf{o}}\cdot\bar{V}_t(z,b,\mathbf{o})\right)}{\sum_{\tilde{\mathbf{o}}\in\mathcal{S}(1,1)}\exp\left(\sigma^{\mathbf{o}}\cdot\bar{V}_t(z,b,\tilde{\mathbf{o}})\right)}.
\end{aligned}
$$

Under this construction of the transition probability, $\lambda^F(o_-^F)$ and $\lambda^R(o_-^R)$ control the persistence in households' international integration status, and $\sigma_{\mathbf{o}}$ controls the state dependency of the transition probability. When $\sigma_{\mathbf{o}} = 0$, the model degenerates back to the baseline setup. When $\sigma_{\mathbf{o}} > 0$, households tend to transit to the status $\mathbf{o}$ with higher value $\bar{V}_t(z,b,\tilde{\mathbf{o}})$.

Similar to the baseline model, we still calibrate the model to have a steady state with equal wages in different sectors and equalize the returns from different financial markets. Under this calibration, we calibrate the parameters governing the persistence of international integration status to satisfy $\lambda_i(o) + \frac{1}{2}\cdot(1-\lambda_i(o)) = \lambda_i^o \ \forall i \in \{R,F\}$ and $o \in \{0,1\}$, where λ_i^o are the transition probability parameters in the baseline model. Under this calibration, the transition probability across the international integration status in steady state is identical to that in the baseline model. We also calibrate $\sigma_{\mathbf{o}} = 1$ to control the degree of state dependency. Except for the above five new

parameters, we calibrate all other parameters to the same values as in the baseline model.

We summarize the effects of different aggregate shocks in Table A.1. With the endogenous transitions, we find that the magnitudes of all of the results are very similar to the baseline results, but the distributional effects of monetary policy are dampened, which highlights the importance of households' ability to switch across sectors or invest in international capital markets in mitigating the uneven effects of macroeconomic shocks.

A.2. The international price system

Setup The only change we make compared with the benchmark model is that the price adjustment cost for home tradable goods is based on the price change in the term of foreign currency, i.e.,

$$\Theta_{H,t}\left(\frac{p_{H,t}}{p_{H,t-1}}\right)=\frac{\theta}{2}\cdot\left(\frac{p_{H,t}/\mathcal{E}_t}{p_{H,t-1}/\mathcal{E}_{t-1}}-1\right)^2\cdot Y_{H,t}\cdot P_{H,t} \tag{11}$$

Analysis Under this setup, the inflation dynamics of the home goods price becomes

$$\tilde{\pi}_{H,t}-\widetilde{\Delta\mathcal{E}}_t=\frac{\epsilon}{\theta}\cdot(\widetilde{mc}_{H,t}-\tilde{p}_{H,t})+\frac{1}{1+i_{ss}}\cdot\mathbb{E}_t\left[\tilde{\pi}_{H,t+1}-\widetilde{\Delta\mathcal{E}}_{t+1}\right], \tag{12}$$

where $\tilde{x}$ denotes the deviation of x from its steady-state level. Compared with the baseline model, the above equation shares all of the elements except for the extra term of the exchange rate depreciation rate.

We parameterize this model with the same values for all parameters as in the baseline model. The effects of different aggregate shocks are collected in Table A.1. Under international pricing, monetary policy generates more uneven responses across households in the economy because it stimulates the income and consumption of workers in nontradable sectors more than of those working in tradable sectors.

Table A.1: Model Extensions

	Baseline	International Pricing	Endogenous Transition
	Domestic Monetary Shock		
Aggregate Effects (%)			
Inflation	0.88	1.04	0.88
Exchange Rate	0.29	0.35	0.29
Consumption	0.51	0.37	0.51
Distributional Effects on Consumption			
Std.	0.29	0.67	0.29
Gap by Real Integration	0.03	1.00	0.03
Gap by Financial Integration	0.35	0.26	0.34
Gap by Net Wealth	0.38	0.46	0.38
	Foreign Demand Shock		
Aggregate Effects (%)			
Inflation	-1.07	-3.93	-1.07
Exchange Rate	-2.74	-3.85	-2.75
Consumption	1.10	2.80	1.08
Distributional Effects on Consumption			
Std.	1.19	1.63	1.15
Gap by Real Integration	-1.93	-2.46	-1.84
Gap by Financial Integration	0.80	0.78	0.78
Gap by Net Wealth	0.26	0.22	0.25
	Foreign Monetary Shock		
Aggregate Effects (%)			
Inflation	-0.01	-0.09	-0.02
Exchange Rate	-0.06	-0.09	-0.06
Consumption	0.06	0.10	0.06
Distributional Effects on Consumption			
Std.	2.39	1.31	2.36
Gap by Real Integration	0.94	-0.62	0.94
Gap by Financial Integration	-5.78	-3.08	-5.64
Gap by Net Wealth	-0.76	-0.36	-0.78

Notes: All aggregate responses here are the peak responses of each variable. All distributional effects on consumption are normalized by the peak aggregate consumption response.

B. Measurement of international integration

B.1. Real international integration

We decompose the employment, GDP and labor compensation into different sector categories based on the data from Statistics Canada. We measure Canada's degree of real integration by the average share of the employees hired in tradable sectors between 1976 and 2019. Based on our categorization, tradable goods sector includes: Agriculture, Forestry, fishing, mining, quarrying, oil and gas; Information, culture and recreation; Finance and insurance; Manufacturing; Professional, Scientific, and technical services; and Wholesale trade. See Table B.1 for the detailed sectorial composition of employment, GDP and labor compensation in Canada.

B.2. Financial international integration

We measure the degree of financial integration in Canada based on the Canadian Financial Monitor (CFM). CFM is a survey conducted by Ipsos Reid Canada that collects detailed information on households' balance sheet, income and consumption. Since 2008, the survey has been conducted monthly and there are roughly 1000 households surveyed in each round. In the survey, households are asked to report the detailed information of their financial portfolio. We focus on 5 categories of financial asset: 1) Checking and savings accounts; 2) Guaranteed investment certificates (GICs); 3) Bonds and other guaranteed investments; 4) Individual stocks and income trusts; 5) Mutual funds, segregated funds, hedge funds, and PPN.

Within each category, households need to report the balance of each type financial product they hold, as well as the financial institutes in which they hold these financial products. Within these details, we focus on the reported balance of following two types of financial products to measure households' financial integration status:

1. Under the category of Checking and saving accounts, households need to report the whether they have an account denominated in U.S. dollar and its balance if they do.

2. Under the category of Bonds and other guaranteed investments, households need to report whether they hold foreign government or corporate bonds and its balance if they do.

Table B.1: Canadian Economy Decomposed by Sectors (%)

	Employment	GDP	Labor Compensation
Non-tradable	63	55	58
Utilities	1	3	1
Real estate and rental and leasing	2	-	-
Finance, insurance, and real estate	-	12	9
Accommodation and food services	6	3	3
Construction	6	8	10
Transportation and warehousing	5	6	6
Public administration	6	-	-
Retail trade	12	6	8
Other private services	25	16	20
Tradable	37	45	42
Agriculture, mining and energy	5	11	6
Information, culture and recreation	4	4	3
Finance and Insurance	4	-	-
Manufacuring	14	21	21
Professional and technical services	6	4	5
Wholesale trade	4	6	7

Notes: In this table, we calculate the average faction of the employment, GDP, and labor compensation in each sector category between 1976 and 2019. *Employment* is measured by the number of both male and female workers who are above 15 years old and working in either part-time or full-time positions. *GDP* and *Labor Compensation* refer to the GDP and total labor compensation in business sector. The decomposition of employment is based on `Statistics Canada Table 14-10-0023-01`, and the decomposition of GDP and labor compensation is based on `Statistics Canada Table 36-10-0208-01`. Since these two tables use categorize sectors differently, a few sector categories are not available in both data sets. "-" in the table indicates that the specific sector category is not applicable in the underlying data source. For simplicity, we use a shortened name *Agriculture, mining and energy* for the category including agriculture, forestry, fishing, mining, quarrying, oil and gas.

We categorized a household as the financially integrated if it has positive balance in either of the above two financial products. We first compute the fraction of financially integrated households in each monthly survey. To make the results representative for the Canadian population, we applied the statistical weights provided in CFM data. Then, we average the fraction of financially integrated household between January of 2009 and December of 2018. As summarized in Table B.2, 17.5% of households in Canada are financially integrated. Owning checking and saving accounts in U.S. dollars is the major reason for these households to be categorized as "financially integrated". This

is largely due to the fact that most of Canadian households do not hold any bonds. In CFM, only 12% of households hold bonds, but 93% of them have checking and saving accounts. To provide a comprehensive picture about the exposure of households' financial asset to international financial markets, we also calculate the average fraction of the balance hold in above two accounts within the whole financial portfolio hold by the households. We present the results in Table B.2. The fraction of "financially integrated" asset is much smaller than the fraction of "financially integrated households" due to the fact that most households do not allocate much of their asset in the liquid accounts.

Table B.2: The Degree of Financial Integration in Canada (%)

	Fraction of Households	Fraction of Balance
Total	17.5	6.0
Foreign gov. or corp. bonds	0.8	1.1
Checking and saving in USD	16.7	4.9

Notes: Under "Fraction of Households", we calculate the average fraction of households with positive balance in foreign government or corporate bonds or checking and saving accounts denominated in U.S. dollar between January of 2009 and December of 2018. Under "Fraction of Balance", we calculate the average fraction of total balance of the above accounts within the total balance of all of the five categories of financial accounts. We use the statistical weights provided in CFM for the calculation to make the estimates representative for the Canadian population.

C. Comparison with Benchmark Models

C.1. Comparison with open-economy RANK

Setup Compared with the benchmark, we remove households' heterogeneity in their idiosyncratic labor productivity and degree of international integration. We assume no segmentation in labor markets, i.e., both home goods producers and non-tradable goods producers hire workers from the same labor market. We also assume that households are all saving in foreign bonds and working in the same labor market.

Analysis Under the current setup, households' decisions can be summarized by their consumption Euler equation and labor supply function:

$$C_t^{-\nu_c} = \beta \cdot \mathbb{E}_t \left[\frac{(1+i_t^*) \cdot (1+\Delta\mathcal{E}_{t+1})}{1+\pi_{t+1}} \cdot C^{-\nu_c} \right] \tag{13}$$

$$C_t^{-\nu_c} \cdot \frac{W_t}{P_t} = \psi \cdot L^{\nu_l}, \tag{14}$$

where C_t and L_t denote households' consumption bundle and labor supply, and W_t and P_t denote the wage and price of the consumption bundle in nominal terms. Besides the households' decision problem, we also need to change the clearing condition in the labor market as

$$L_t = N_{N,t} + N_{H,t}. \tag{15}$$

We calibrate the model to share the same parameter values with the baseline model. Then we collect the effects of the monetary shock and its transmission in Table C.2. In terms of the aggregate effects, the aggregate consumption response is weaker than that in the baseline model because all of the households are financially integrated now. When we decompose the aggregate consumption response into different transmission channels, we find that most of the response is driven by variation in the real interest rate rather than the labor income, which is opposite to the baseline model and consistent with the findings of Kaplan *et al.* (2018).

C.2. Comparison with closed-economy HANK

Setup Compared with the benchmark model, we remove the tradable goods sector, the non-arbitrage condition in the currency market, and the household heterogeneity in financial and real integration. Now there is only one type of goods in this economy; final goods and nontradable goods are equivalent. All households are saving in domestic bonds and working in the nontradable goods sector.

Analysis The Bellman equation for households becomes

$$V_t(z,b) = \max_{c,l,b'} u(c,l) + \beta \cdot \mathbb{E}_t \left[(1-\xi) \cdot V_{t+1}(z',b') + \xi \cdot \hat{V}_{t+1}(z',b') \right] \tag{16}$$

$$\text{s.t.} \quad \frac{b'}{1+i_t} = b + z \cdot (1-\tau_t) \cdot W_t \cdot l + T_t + \bar{\gamma}(z,b) \cdot \gamma_t - P_t \cdot c \tag{17}$$

$$b' \leq \underline{b} \tag{18}$$

where c and l denote households' consumption of final goods and labor supply, and W_t and P_t denote the wage and final goods price in nominal terms.

We recalibrate the parameters collected in Table C.1 to match the same steady-state moments and aggregate responses to the monetary shock to obtain a reasonable comparison between models. Based on the results in Table C.2, we find that this closed-economy HANK implies aggregate effects of monetary shocks very similar to those in the baseline model, but it generates smaller distributional effects due to the absence of heterogeneity in households' international integration.

Table C.1: Recalibrated Parameters in the Closed-economy HANK

Parameter	Description	Value
Panel 1. Recalibrated Parameters Governing the Steady State		
B_{ss}	Government debt	0.95
$\underline{b}$	Borrowing constraint	-0.18
ψ	Disutility of labor	3.44
β	Discount factor	0.96
Panel 3. Recalibrated Parameters Governing the Aggregate Responses		
ϕ_π	Taylor rule, coefficient of inflation	1.10
ϕ_i	—, coefficient of lagged nominal interest rate	0.90
ρ_m	Domestic monetary shock, persistence	0.63
σ_m	—, std.	0.25%

Note: The values for B_{ss} and $\underline{b}$ are expressed in the unit of households' quarterly average labor income in steady state.

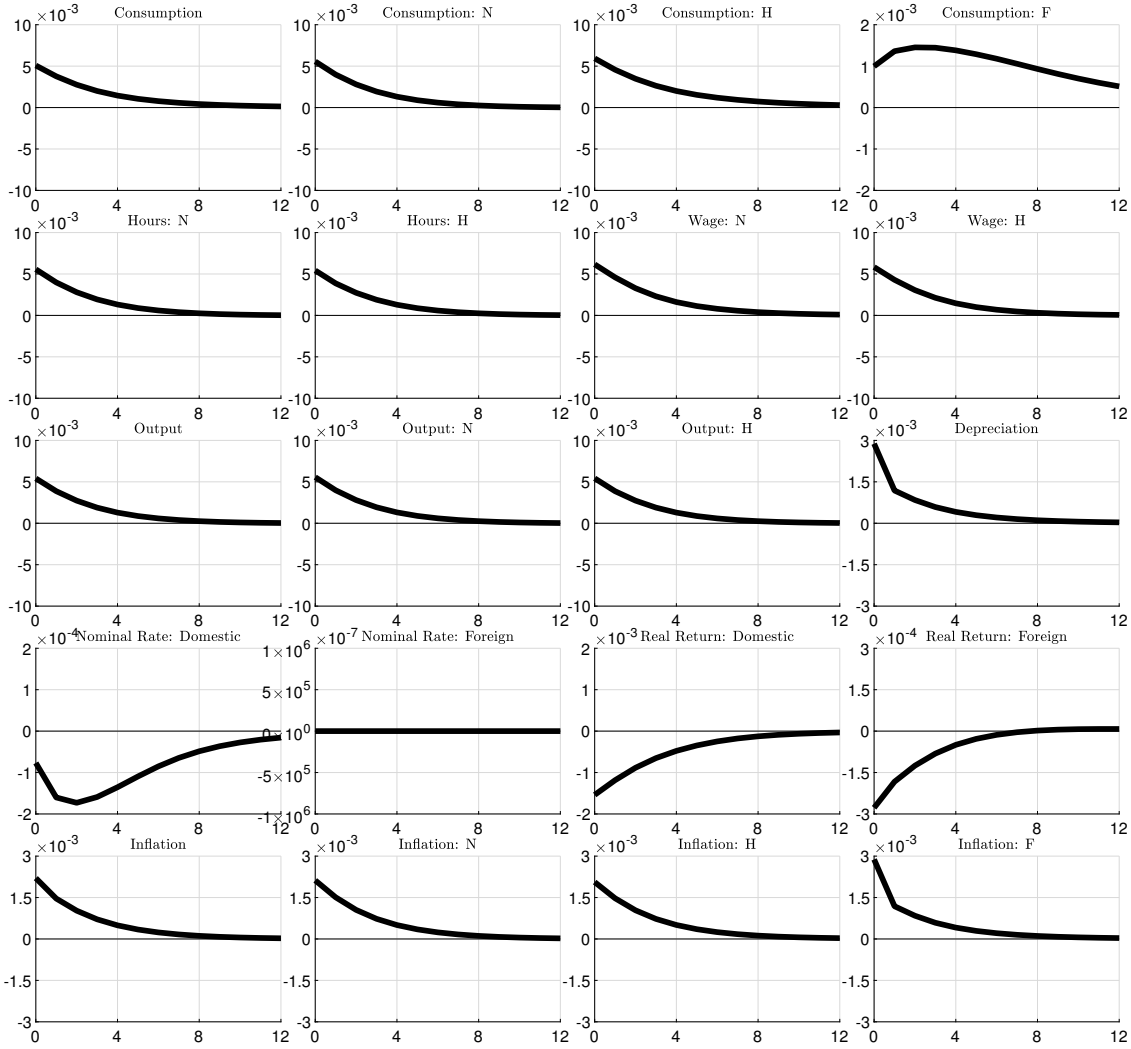
Table C.2: Consumption Responses to Domestic Monetary Shock in Alternative Types of Models

	Open-economy HANK	Closed-economy HANK	Open-economy RANK
Panel 1.Aggregate Effects (%)			
Inflation	0.88	0.77	1.16
Exchange Rate	0.29	-	0.53
Consumption	0.51	0.58	0.25
Panel 2. Distributional Effects on Consumption			
Std.	0.29	0.23	-
Gap by Net Wealth	0.38	0.29	-
Panel 3. Decomposition of Aggregate Consumption Response (%)			
Real Interest Rate	36	37	83
Labor Income	54	48	19
Others	10	15	-2

Notes: All aggregate responses here are the peak responses of each variable. All distributional effects on consumption are normalized by the peak aggregate consumption response.

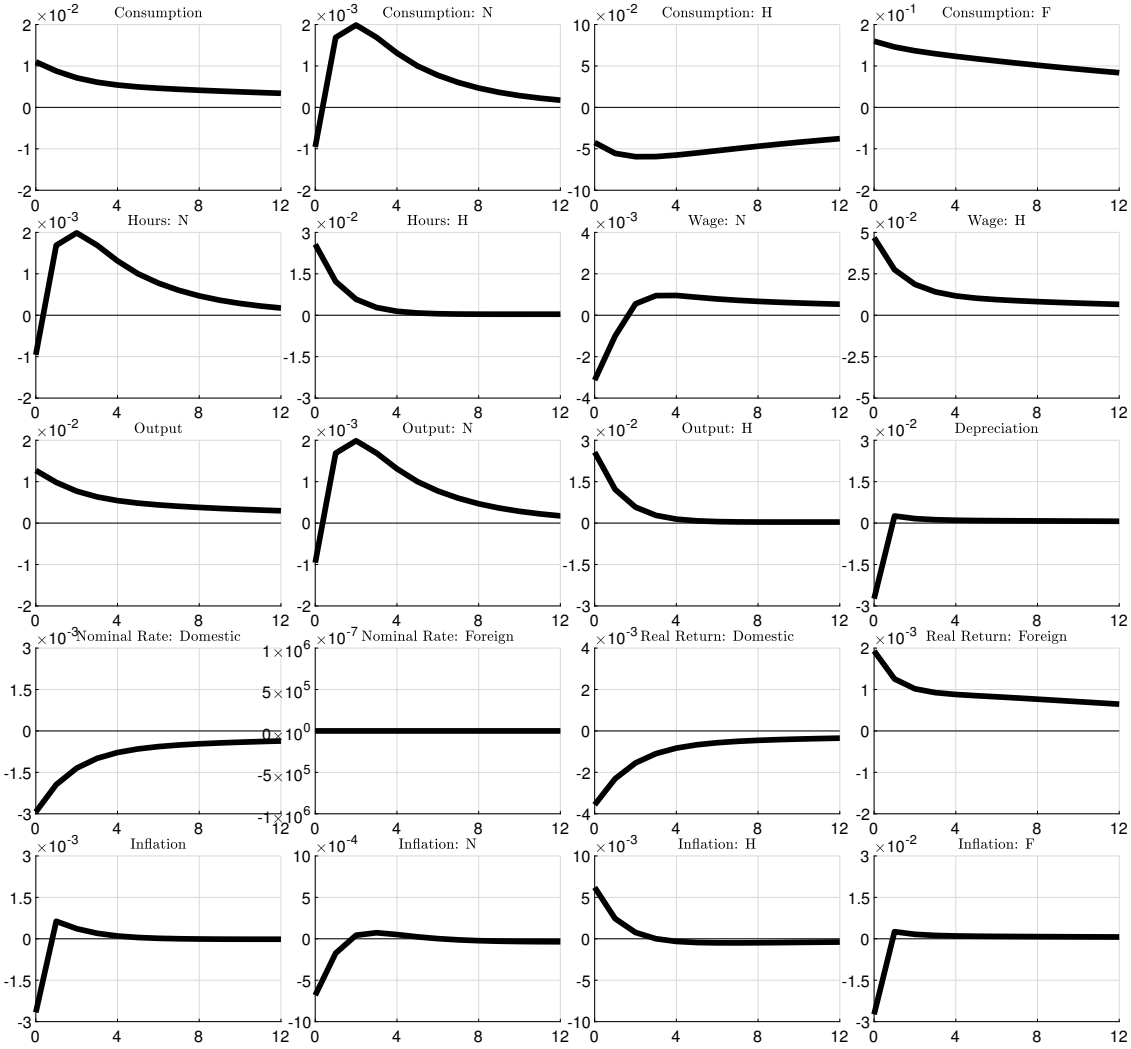
D. Additional Figures and Tables

Figure D.1: Aggregate Effects of a Monetary Policy Shock



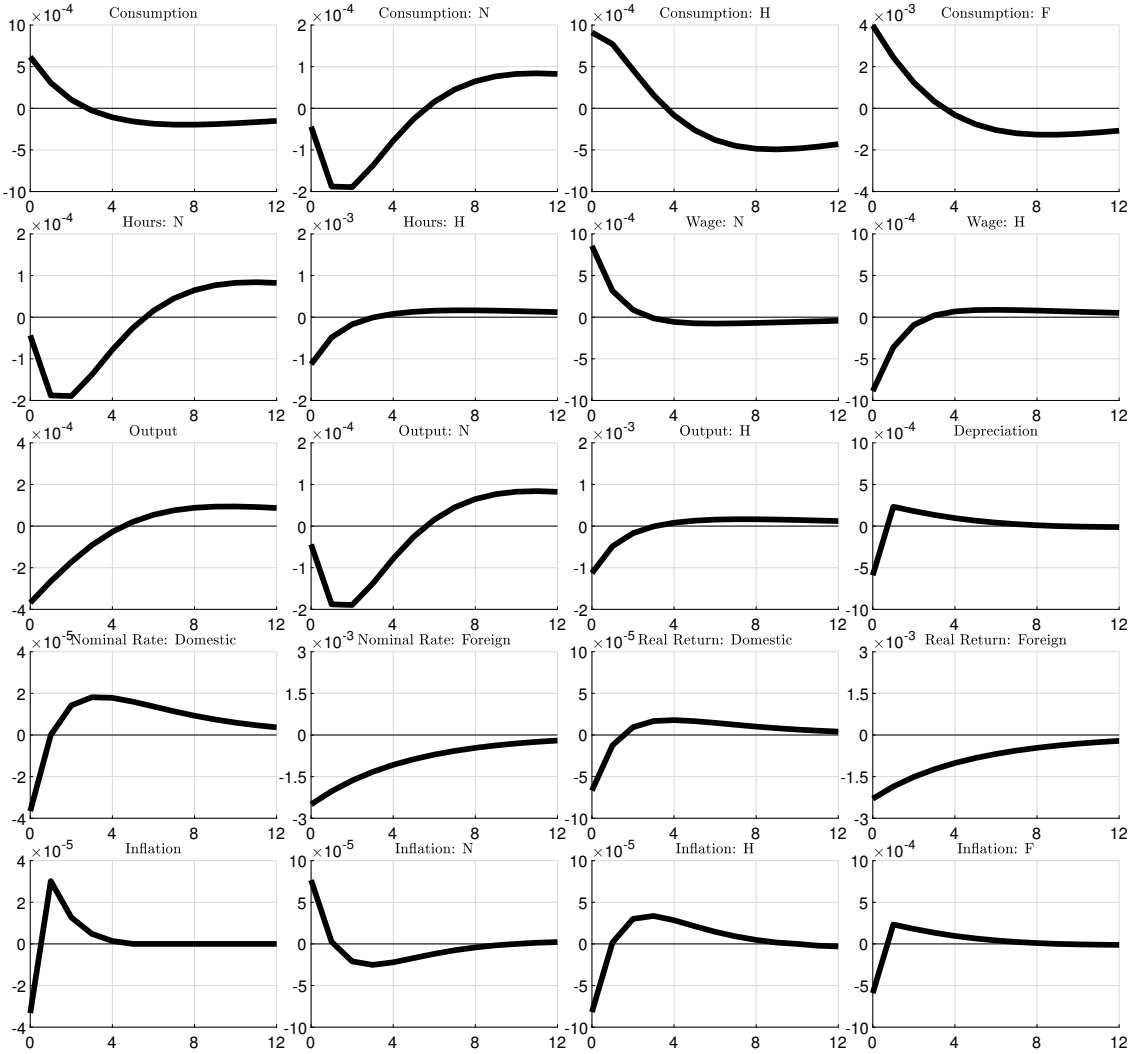
Notes: This figure shows impulse responses to a 25 b.p. expansionary monetary policy shock (i.e., an innovation to the Taylor rule $\epsilon_{m,t} = -0.0025$).

Figure D.2: Aggregate Effects of a Foreign Demand Shock



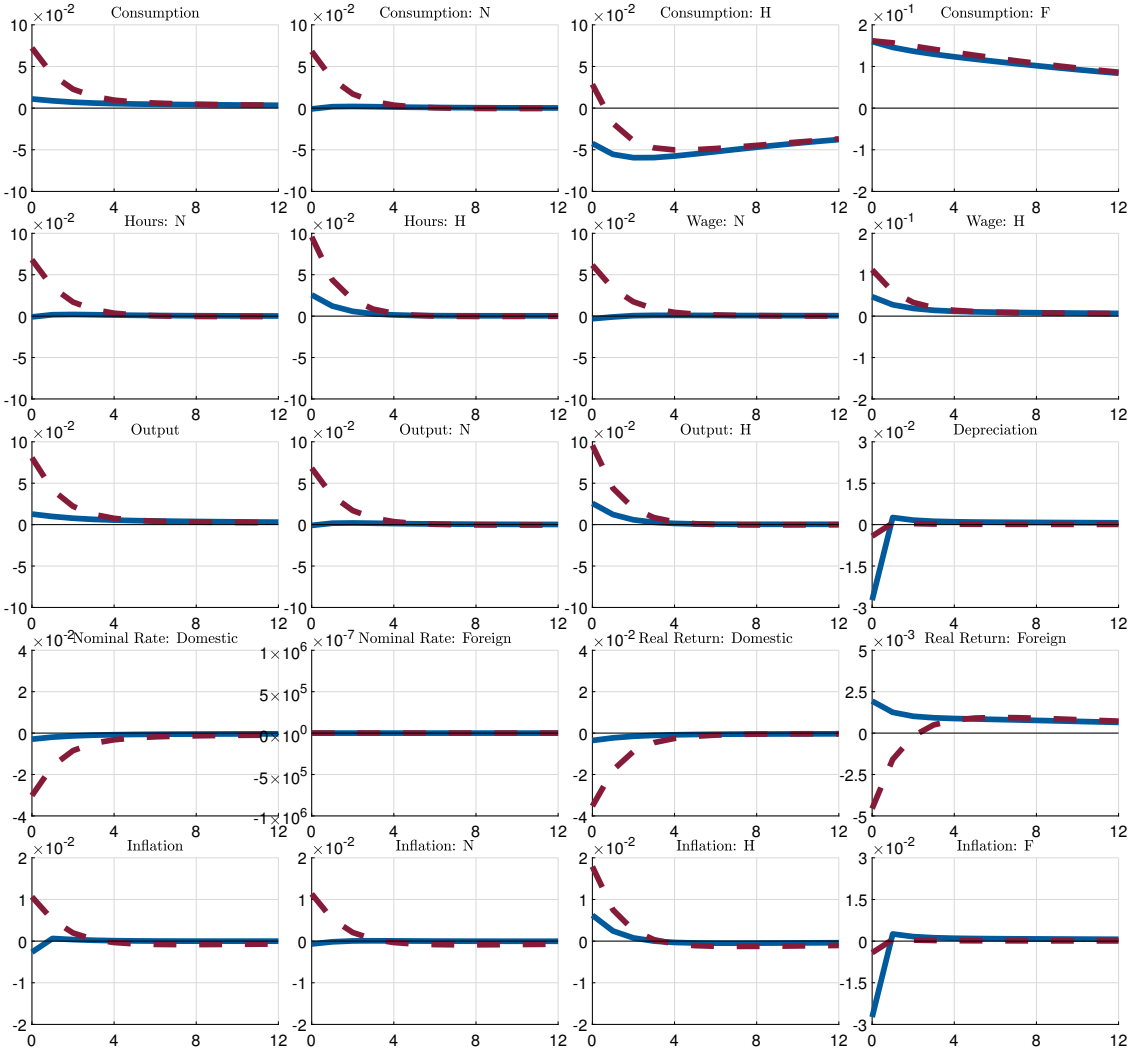
Note: This figure shows impulse responses to a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$).

Figure D.3: Aggregate Effects of a Foreign Monetary Policy Shock



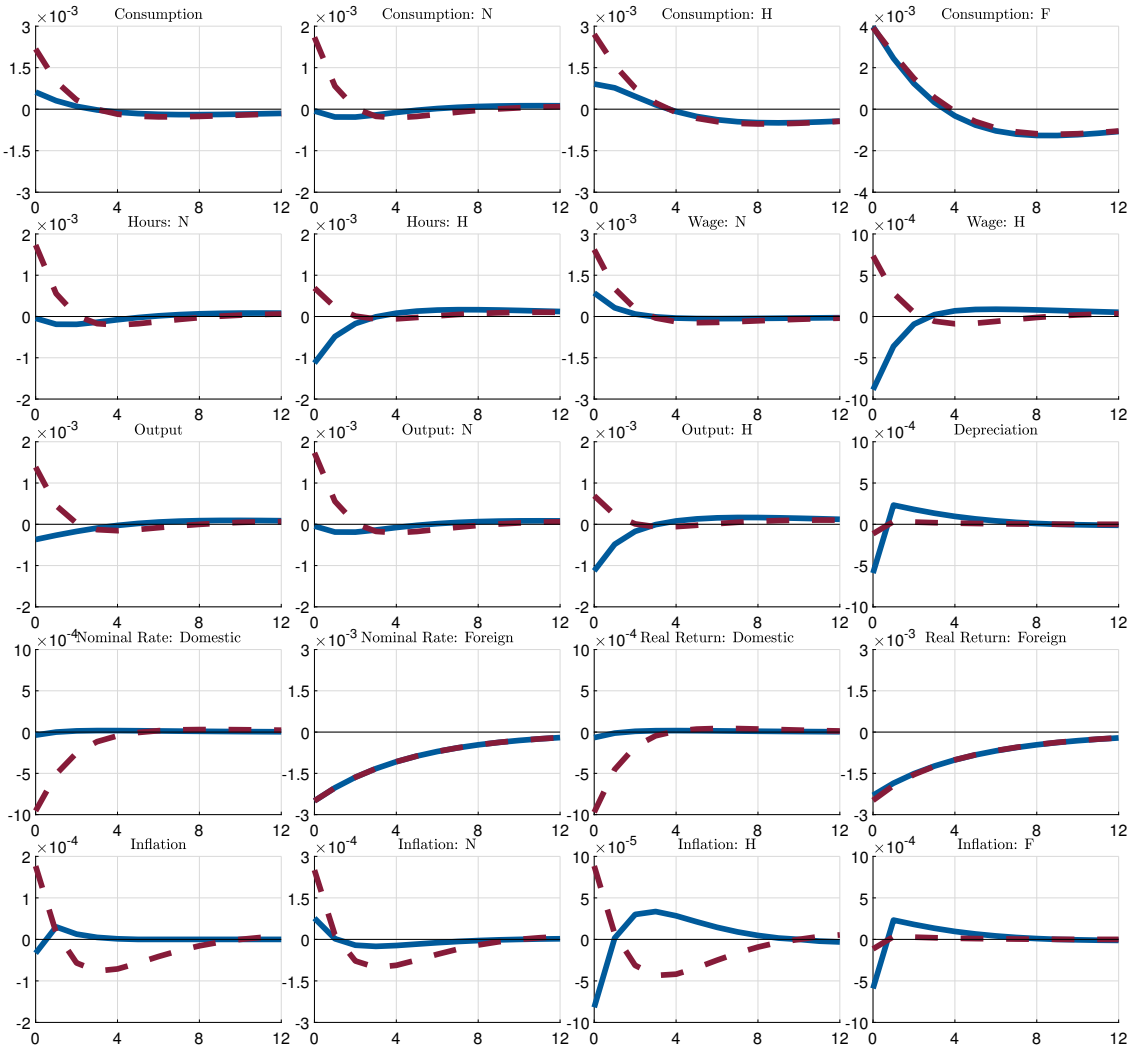
Note: This figure shows impulse responses to a 25 b.p. expansionary foreign monetary policy shock (i.e., an innovation to the foreign interest rate $\epsilon_{m^*,t} = -0.0025$).

Figure D.4: Aggregate Effects of a Foreign Demand Shock under Alternative Exchange-rate Regimes



Notes: This figure shows impulse responses to a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$), under different exchange-rate regimes. *Flexible exchange rate*, represented by the solid line, corresponds to the baseline model (described in Section 2); *Fixed exchange rate*, represented by the dashed line, corresponds to the equilibrium under which the monetary policy sets the nominal rate to target $\mathcal{E}_t = 1$ in all periods.

Figure D.5: Aggregate Effects of a Foreign Monetary Policy Shock under Alternative Exchange-rate Regimes

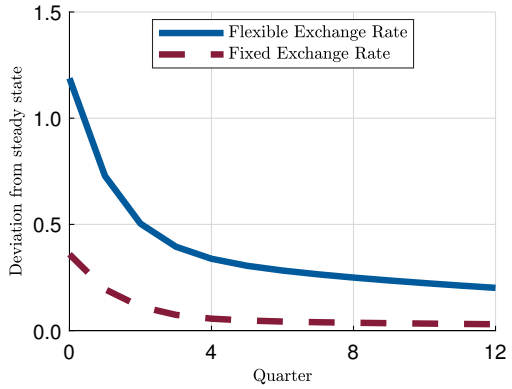


Note: This figure shows impulse responses to a 25 b.p. expansionary foreign monetary policy shock (i.e., an innovation to the foreign interest rate $\epsilon_{m^*,t} = -0.0025$) under different exchange rate regimes. *Flexible exchange rate*, represented by the solid line, corresponds to the baseline model (described in Section 2); *Fixed exchange rate*, represented by the dashed line, corresponds to the equilibrium under which the monetary policy sets the nominal rate to target $\mathcal{E}_t = 1$ in all periods.

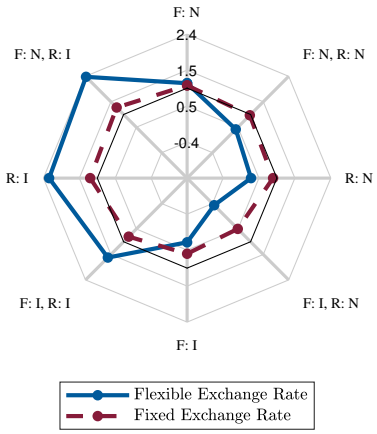
Figure D.6: Distributional Effects of External Shocks under Alternative Exchange Rate Regimes

Consumption Response to an Expansionary Foreign Demand Shock

(a) Dispersion

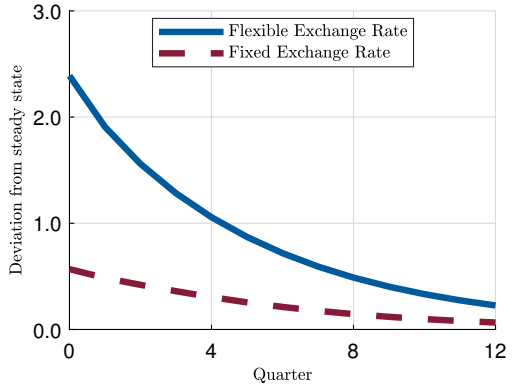


(b) by Real and Financial Integration

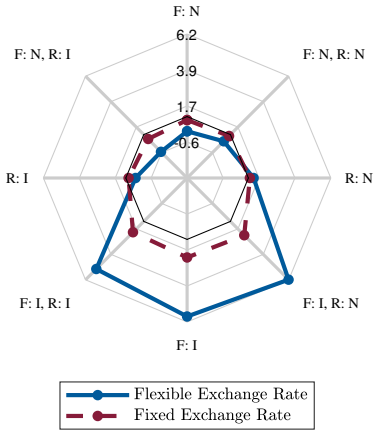


Consumption Response to an Expansionary Foreign Monetary Policy Shock

(c) Dispersion

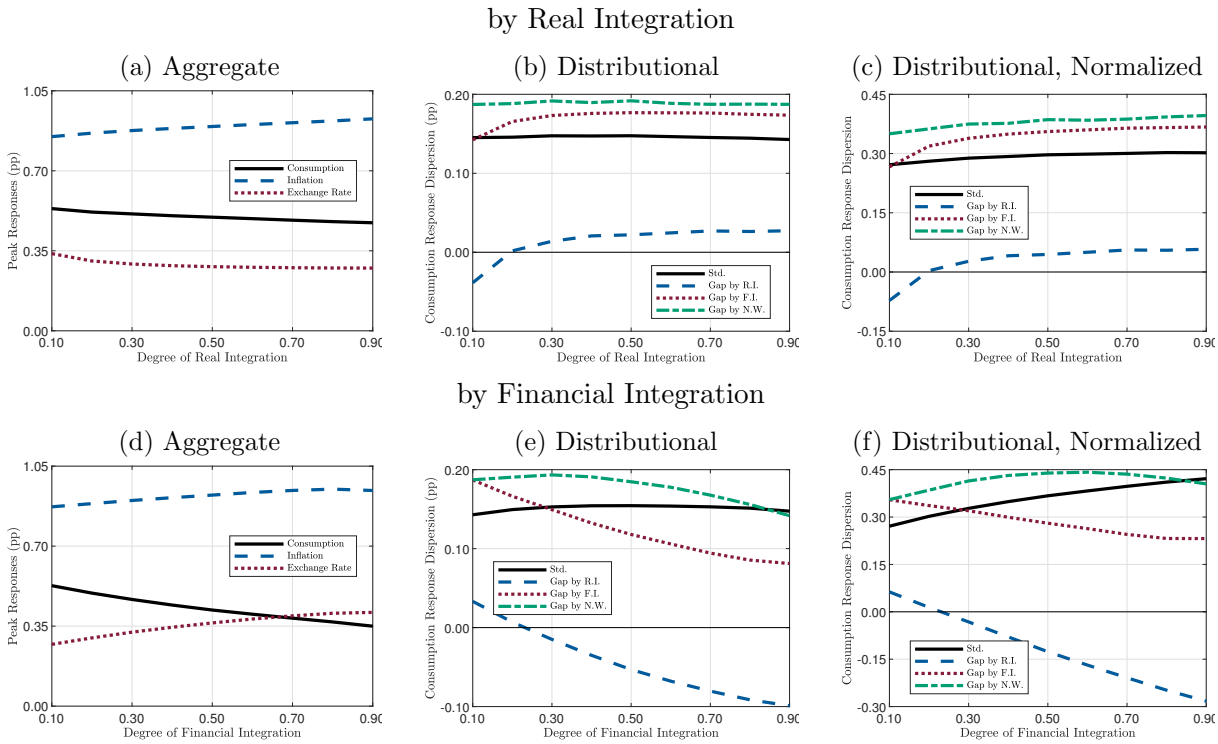


(d) by Real and Financial Integration



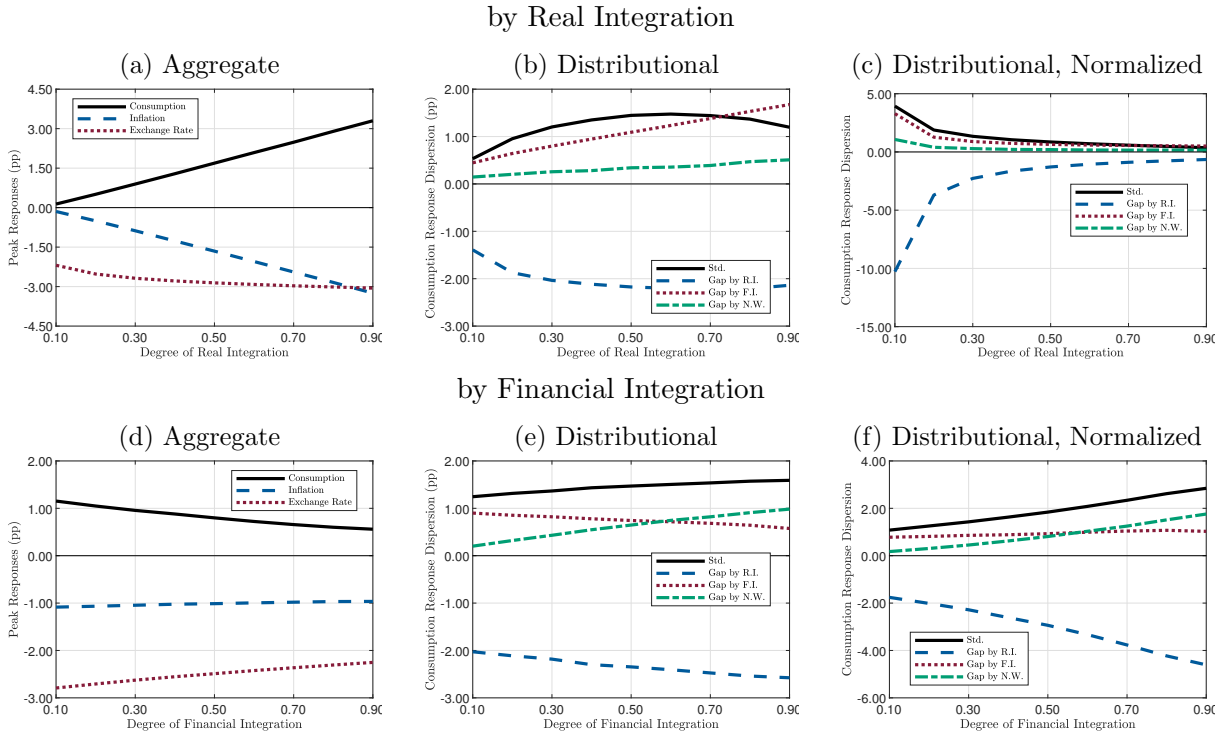
Notes: Panels (a)-(b) show the distributional effects of a 15% expansionary external demand shock (i.e., $\epsilon_{y^*,t} = 0.15$) on consumption. Panels (c)-(d) show the distributional effects of a 25 b.p. expansionary foreign monetary policy shock (i.e., $\epsilon_{m^*,t} = -0.0025$) on consumption. Panel (a) and (c) show the responses of the cross-sectional standard deviation of consumption responses scaled by the peak response of aggregate consumption. Panel (c) and (d) show the responses of the total consumption of different subgroups of households in the period when the aggregate consumption response reaches its peak. Households are categorized by their type of *real* and *financial* integration. For notationAL simplicity, we use "R" and "F" for real and financial integration and "I" and "N" to indicate *integrated* and *not integrated*. All responses are normalized by the peak response of aggregate consumption. To facilitate visual interpretation of the unevenness of consumption responses, we add a thin black solid line to depict the scenario in which different subgroups of households share homogeneous consumption responses. *Flexible-exchange-rate regime* corresponds to the baseline model (described in Section 2); *Fixed-exchange-rate regime* corresponds to the equilibrium under which the monetary policy sets the nominal rate to target $\mathcal{E}_t = 1$ in all periods.

Figure D.7: Effects of a Domestic Monetary Shock under Alternative Degrees of International Integration



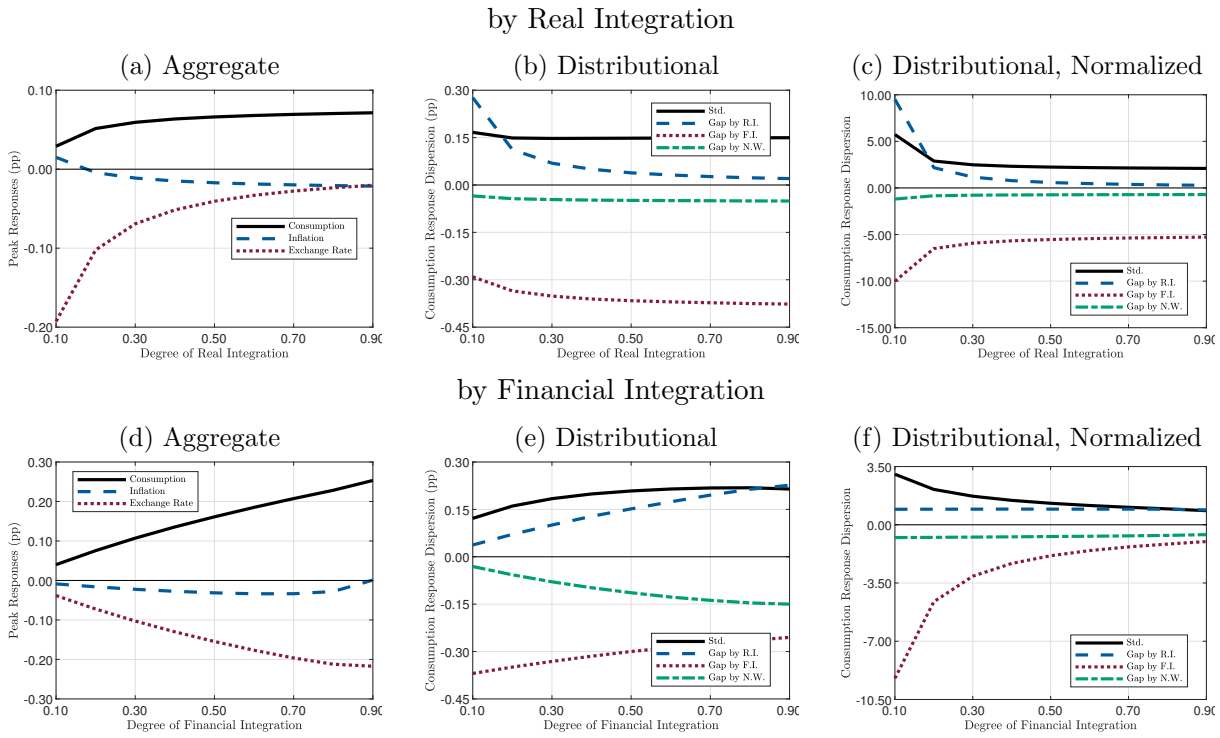
Notes: The above are the effects of a 25 b.p. expansionary monetary policy shock ($\epsilon_{m,t} = -0.0025$). The *degree of real integration* refers to the fraction of households working in the home tradable goods sector, and the *degree of financial integration* refers to the fraction of households with access to international financial markets. When we vary the degree of international integration, we calibrate the model to have the same wealth distribution across households. Panel (a) and (d) summarize peak consumption responses at different degrees of international integration. In panel (b) and (e), we compute the cross-sectional standard deviation of households' consumption responses and the response of groupwise consumption when the aggregate consumption response reaches its peak, and normalize it by the peak aggregate consumption response. Panel (c) and (f) show results similar to panels (b) and (d) but without normalization.

Figure D.8: Effects of a Foreign Demand Shock under Alternative Degrees of International Integration



Notes: The above are the effects of a 15% expansionary external demand shock ($\epsilon_{y^*,t} = 0.15$). The *degree of real integration* refers to the fraction of households working in the home tradable goods sector, and the *degree of financial integration* refers to the fraction of households with access to international financial markets. When we vary the degree of international integration, we calibrate the model to have the same wealth distribution across households. Panel (a) and (d) summarize peak consumption responses at different degrees of international integration. In panel (b) and (e), we compute the cross-sectional standard deviation of households' consumption responses and the response of groupwise consumption when the aggregate consumption response reaches its peak, and normalize it by the peak aggregate consumption response. Panel (c) and (f) show results similar to panels (b) and (d) but without normalization.

Figure D.9: Effects of a Foreign Monetary Shock under Alternative Degrees of International Integration



Note: The above are the effects of a 25 b.p. expansionary foreign monetary policy shock ($\epsilon_{m^*,t} = -0.0025$). The *degree of real integration* refers to the fraction of households working in the home tradable goods sector, and the *degree of financial integration* refers to the fraction of households with access to international financial markets. When we vary the degree of international integration, we calibrate the model to have the same wealth distribution across households. Panel (a) and (d) summarize the peak consumption responses at different degrees of international integration. In panel (b) and (e), we compute the cross-sectional standard deviation of households' consumption responses and the response of groupwise consumption when the aggregate consumption response reaches its peak, and normalize it by the peak aggregate consumption response. Panel (c) and (f) show results similar to panels (b) and (d) but without normalization.

Table D.1: Targeted moments for idiosyncratic income shock processes

Moment	Model	Data
1-year change in log annual earnings		
Variance	0.47	0.49
Skewness	−0.27	−0.81
Kurtosis	15.56	15.55
5-year change in log annual earnings		
Variance	0.71	0.69
Skewness	−0.29	−0.71
Kurtosis	13.33	10.33

Notes: Data moments from Bowlus, Gouin-Bonenfant, Liu, Lochner and Park (2020).

Table D.2: Target Moments: Aggregate Impulse Responses

	Data	Model
Response to Domestic Monetary Shock		
Consumption	$(0.5\%, 1.5\%)$	0.5%
Nominal Interest Rate	$(-0.5\%, -1.2\%)$	-0.1%
CPI	$(0\%, 1.2\%)$	0.9%
Response to Foreign Demand Shock		
Consumption	$(0.8\%, 1.6\%)$	1.1%
Exchange Rate	$(-4.0\%, -2.0\%)$	-2.7%
Export	$(8.0\%, 12.0\%)$	9.5%

Notes: Empirical responses to a domestic monetary shock are from Champagne and Sekkel (2018). Empirical responses to a foreign demand shock are from Charnavoki and Dolado (2014). Listed empirical moments are the 65% confidence interval of the peak impulse response. Listed moments in the model are the peak impulse responses of the corresponding variables.