The Transmission of Foreign Demand Shocks*

Jeppe Druedahl[†,‡] Søren Hove Ravn[†] Laura Sunder-Plassmann[§]
Jacob Marott Sundram[†] Nicolai Waldstrøm[†]

September 2024

Abstract

Introducing household heterogeneity into a New Keynesian model of a small open economy enables the model to fit a set of stylized empirical facts about the transmission of foreign demand shocks. In the absence of a strong labor income effect on consumption, the model produces a counterfactual increase in domestic consumption in response to a shortfall of foreign demand, as the domestic central bank responds to the shock by reducing the interest rate. With plausible marginal propensities to consume, the model instead delivers a decline in domestic consumption, including of both tradable and non-tradable goods, as observed in the data. This entails that foreign demand shocks are more important for domestic business cycles than implied by existing models that abstract from household heterogeneity. Moreover, we show that while monetary policy is well-suited to counteract foreign demand shocks, traditional fiscal policies are inadequate, as they provide insufficient stimulus to the tradable sector. This poses a particular challenge for countries with a fixed exchange rate or in a monetary union.

*We thank Hafedh Bouakez, Edouard Challe, Christian Hoeck, Christian Kastrup, John Kramer, Alaïs Martin-Baillon, Isabelle Mejean, Dima Mukhin, Haroon Mumtaz, Emil Partsch, Ivan Petrella, Omar Rachedi, Emiliano Santoro, Martin Souchier, Gianluca Violante, Christoffer Weissert, and seminar participants at the University of Copenhagen, Danmarks Nationalbank, Bank of Finland, National Bank of Slovakia, the 2022 European Winter Meeting of the Econometric Society, the 2023 Nordic Summer Symposium in Macroeconomics, the 2023 Oslo Macro Conference, the 2023 meeting of the European Economic Association, the 2024 Theories and Methods in Macroeconomics conference, and the 2024 meeting of the Society for Economic Dynamics for helpful comments. The authors are grateful for financial support from the Carlsberg Foundation (Grant CF20-0546) and from the Economic Policy Research Network (EPRN). Center for Economic Behavior and Inequality (CEBI) is a center of excellence at the University of Copenhagen, founded in September 2017, financed by a grant from the Danish National Research Foundation (Grant DNRF134). Druedahl: jeppe.druedahl@econ.ku.dk Ravn: soren.hove.ravn@econ.ku.dk Sunder-Plassmann: sunderplassmann.laura@gmail.com Sundram: jacob.sundram@econ.ku.dk Waldstrøm: nicolai.w@econ.ku.dk

[†]University of Copenhagen

[‡]CEBI

[§]University of Rostock

1 Introduction

In small open economies, external shocks are typically believed to be important drivers of domestic business cycles. Shocks to the foreign demand for domestic goods represent a prominent example. Yet, the existing open-economy business-cycle literature has not been able to produce a convincing account of the transmission mechanism of foreign demand shocks that can fit the data.

In this paper, we offer a detailed study of the transmission of such shocks. We first characterize and quantify the empirical effects of foreign demand shocks in 31 small open OECD economies. We use a pooled local projections design, and combine sign restrictions with a standard small open-economy assumption for identification. In response to a *negative* shock to foreign demand, we establish three key findings regarding the response of the domestic economy: *First*, we observe a drop in consumption, output, employment, and other aggregate variables. *Second*, consumption of both tradable and non-tradable goods displays a decline. *Third*, foreign demand shocks account for a substantial share ($20 - 25\%$) of domestic business fluctuations.

Our second and main contribution is to develop a structural business-cycle model that can account for these facts. Through the lens of this model, it becomes clear that a high average marginal propensity to consume (MPC) out of transitory income is a necessary ingredient in order to explain the decline in domestic consumption and its components, as well as the observed comovement patterns.

As a benchmark, we first show that open-economy representative-agent New Keynesian (RANK) models are hard to reconcile with the empirical facts above. The intuition is as follows: When foreign demand for domestic goods drops, an inflation-targeting domestic central bank reduces the nominal interest rate in response to the decline in domestic economic activity and inflation.[1] The real interest rate then declines, and the powerful intertemporal substitution effect present in RANK models implies an *increase* in domestic consumption, including of both tradable and non-tradable goods, contrasting with our empirical evidence. Furthermore, since the implied correlation between domestic output and consumption is negative, whereas the unconditional correlation between these two variables is strongly positive in the data, standard RANK models attribute a very small role to foreign demand shocks in

1. Likewise, under a fixed exchange rate, the uncovered interest rate parity (UIP) condition induces the domestic central bank to reduce the interest rate in tandem with the foreign central bank, assuming that foreign inflation also drops, as we observe in the data.

explaining domestic business fluctuations, as found, e.g., by Justiniano and Preston (2010), but in contrast to our empirical evidence.

To account for the empirical findings, we instead propose a small open economy heterogeneous-agent New-Keynesian (SOE-HANK) model featuring idiosyncratic income risk and borrowing constraints, a distinction between tradable and non-tradable goods, and cross-country input-output linkages in production. Our model implies a sizeable but realistic MPC. Consistent with the closed-economy HANK literature (e.g., Kaplan et al., 2018, or Auclert, 2019), the model features a strong direct income effect, which dominates the intertemporal substitution effect. In our SOE-HANK model, a decline in foreign demand induces an inward shift in domestic firms' labor demand curve, thus leading to a decline in wages and hours worked. This reduces households' labor income. With a high average MPC, this gives rise to a *drop* in domestic households' consumption spending, which more than offsets the intertemporal substitution effect described above. This is what enables the model to account for the observed decline in aggregate consumption. We first establish this insight analytically in a stylized version of our model, and then corroborate our point in a quantitative model calibrated to match the average small open OECD economy. We also confirm this finding under a fixed exchange rate, as well as in a model augmented with capital formation.[2] Moreover, we demonstrate that the presence of a strong, negative income effect is key to obtaining a simultaneous decline in consumption of both tradable and non-tradable goods, as in the data.

Finally, the fact that our HANK model reproduces the positive correlation between domestic output and consumption *conditional* on a foreign demand shock paves the way for such shocks to potentially account for a sizeable share of domestic business-cycle fluctuations. To substantiate this point, we conduct an exercise in which we allow for foreign and domestic shocks to be correlated, and back out the correlation required to perfectly match the response of domestic aggregate consumption in the data. We find that the required size of the correlation is much smaller in our calibrated HANK model (0.27) than in the corresponding RANK model (0.95). In other words, the HANK model is able to generate most of the required propagation of foreign shocks to domestic variables endogenously, while the RANK model is not.

We then turn our attention to the implications for macroeconomic policy. A negative foreign demand shock reduces income and consumption of households working in

2. However, accounting for the negative response of investment observed in the data turns out to be a challenge, both in a HANK and a RANK context.

both domestic sectors, although it affects those working in the tradable sector most strongly. Monetary policy is well-suited to counteract the effects of such shocks: A monetary expansion simultaneously stimulates the non-tradable sector and depreciates the real exchange rate and the terms of trade, which benefits the tradable sector. In contrast, expansionary fiscal policy leads to an appreciation of the terms of trade, consistent with the insights of the textbook Mundell-Fleming model. This aggravates the initial shortfall in foreign demand for domestic tradables. In other words, expansionary fiscal policy provides inadequate stimulus to the tradable sector. We show that this point holds under both fixed and floating exchange rates.

These results constitute an important challenge for countries that cannot set an independent monetary policy, such as those with a fixed exchange rate or in a monetary union (or countries where the zero lower bound on nominal interest rates is binding). This is especially relevant when foreign demand shocks are quantitatively important for domestic fluctuations, as we argue in this paper. We show that a fiscal devaluation (as studied by Farhi et al., 2014, among others) may represent a potential remedy. A fiscal devaluation—in the form of a reduction in the payroll tax combined with an increase in the value-added tax—successfully depreciates the terms of trade, and is therefore able to stabilize income and consumption in both domestic sectors.

1.1 Related Literature

Our work is closely related to three branches of the existing literature. First, we contribute to the empirical literature quantifying the effects of foreign demand shocks on small open economies. Studies in this vein typically utilize structural vector autoregression (VAR) models combined with a small open economy assumption and, in some cases, sign restrictions to identify foreign demand shocks, much like our work. Examples include Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016). The findings of these papers can be summarized as follows: Negative foreign demand shocks tend to reduce domestic GDP, consumption, wages, and often prices, while the effect on net exports is inconclusive. Our findings are consistent with these, though we also study the joint responses of foreign output, inflation, and interest rates, and add the findings of positive sectoral comovement and the quantitative importance of foreign demand shocks. Notably, most existing studies focus on one or a few countries, while we take a more comprehensive approach, drawing on data for 31 OECD countries.

Second, we contribute to the literature aimed at proposing structural models to explain these results. Early contributions to this literature typically constructed international Real Business Cycle (IRBC) models and focused on technology shocks.[3] In the last few decades, the literature has turned to models with nominal rigidities (e.g., Gali and Monacelli, 2005, Corsetti, 2007). The line of research on the relative importance of foreign shocks in explaining domestic business cycles, especially in small open economies, is closely related to our work. Estimated models in this tradition—even those of large scale—typically imply that foreign shocks are largely unimportant for domestic business cycles. Examples include Justiniano and Preston (2010) for Canada, Adolfson et al. (2007) and Christiano et al. (2011) for Sweden, and Bergholt (2015) for Norway. Strikingly, Justiniano and Preston (2010) find that—in an estimated representative-agent model—*all* shocks originating in the US explain less than 3% of the variation in Canadian output and other macroeconomic aggregates. This is strongly at odds with their own empirical findings, according to which U.S. shocks explain $40 - 80\%$ of business fluctuations in Canada. The small role attributed to foreign disturbances by RANK models is a reflection of the counterfactual responses of domestic variables to foreign shocks in some of these models. Christiano et al. (2011) and Adolfson et al. (2013) both obtain a positive response of domestic consumption to a negative foreign demand shock in estimated structural models, and the model of Bergholt (2015) features positive responses of both output and consumption to this type of shock. In the model of Lubik and Schorfheide (2007), a foreign recession causes domestic output to rise, implying that business cycles are negatively correlated across countries. In this respect, a key contribution of this paper is to show that our SOE-HANK model can account for the empirical response of the domestic economy, conditional on foreign demand shocks.

Finally, our work is related to the recent literature studying traditional business-cycle questions through the lens of models with heterogeneous agents. In general, the HANK literature has emphasized the importance of high MPCs for the transmission of shocks, see, e.g., Kaplan et al. (2018), Bayer et al. (2019), Hagedorn et al. (2019), and Auclert et al. (2020, 2024). We build on this work by focusing on the role of MPCs in the transmission of foreign demand shocks. A recently emerging

3. The seminal paper is Backus et al. (1992). In their model, the cross-country correlation of consumption was much higher than that of output, while the opposite is true in the data; the so-called *Backus–Kehoe–Kydland puzzle* (or *quantity anomaly*). A large, subsequent literature has studied this issue, stressing among other things the importance of non-traded goods and trade in intermediate production inputs; two features included in our model (see, among others, Backus and Smith, 1993, Obstfeld and Rogoff, 2000, Heathcote and Perri, 2002, Kose and Yi, 2006, and Burstein et al., 2008), and later nominal frictions, as in Huang and Liu (2007).

branch of this literature studies the open-economy dimensions of HANK models. De Ferra et al. (2020) study the macroeconomic and distributional implications of a current account reversal, and find that a revaluation of foreign-currency debt has larger aggregate ramifications when debt and leverage are concentrated among poor, high-MPC households. Hong (2020) studies the business cycle of an emerging economy through the lens of a HANK model. Zhou (2022) and Oskolkov (2023) focus on the cross-country transmission of monetary policy shocks and their distributional effects. Bellifemine et al. (2023) emphasize how a large non-tradable sector coupled with large MPCs amplify the effects of monetary policy on employment in a HANK model of a monetary union. Acharya and Challe (2024) study the optimal design of monetary policy in a SOE-HANK model. In a recent paper, we compare fiscal multipliers in open-economy HANK and RANK models (Druedahl et al., 2024).

The papers most closely related to ours are those by Auclert et al. (2021b) and Guo et al. (2023). The former emphasizes the role of the so-called *real income channel*, through which an increase in import prices reduces consumption of high-MPC households. This channel is at the core of the analysis of Auclert et al. (2021b), who focus on the effects of exchange-rate shocks, which work primarily through changes in relative prices. While a similar channel is operative in our setting, it turns out to be less important from a quantitative viewpoint in response to foreign demand shocks. Instead, we find that changes in labor income take centre stage. Guo et al. (2023) study different types of shocks originating abroad—an increase in demand for domestic tradables or a drop in foreign interest rates—in a SOE-HANK model. Their focus is on the interaction between business cycles and income inequality, which gives rise to a stabilization-inequality trade-off for monetary policy. They also show that in response to either shock, households' consumption response is shaped by their degree of integration in international product and financial markets. Our analysis is complementary to theirs, as we focus less on inequality, and more on the transmission channels of foreign demand shocks, including their empirical validation and their implications for business-cycle comovement across sectors and countries.

The papers mentioned above share the common assumption of a small open-economy structure. In contrast, Chen et al. (2023), Acharya and Pesenti (2024), and Bayer et al. (2024) employ two-country HANK models in order to study the positive and/or normative aspects of monetary policy spillovers across countries, and Giagheddu (2020) considers the distributional impact of fiscal devaluations in a two-country setting. Aggarwal et al. (2023) offer a reinterpretation of macroeconomic developments after the COVID-19 pandemic through the lens of a multi-country HANK model.

Structure The paper proceeds as follows. In the next section, we present our empirical findings. We establish our main points in a stylized model in Section 3, before proceeding to present the full model in Section 4. Section 5 provides the details about the calibration of the model. We present and discuss our model-based results in Section 6, while Section 7 is dedicated to policy analysis. We finally consider a model version with capital in Section 8. Section 9 concludes.

2 Empirical results

In this section, we estimate the effects of foreign demand shocks on small open economies and present our empirical findings.

2.1 Empirical strategy

We study the effects of a shock to foreign demand on various economic outcomes in a small open economy. To this end, we employ sign restrictions (Uhlig, 2005; Arias et al., 2018) to obtain identification, and pooled local projections (LP) (Jordà, 2005; Jordà and Taylor, 2016) to estimate impulse responses.

The empirical approach is as follows. We take the point of view of a small open economy, indexed by j. For each country j, we use trade weights to construct a country-specific measure of the foreign economy, consisting of foreign output ($Y^*_{j,t}$), foreign inflation ($\pi^*_{j,t}$), and the foreign nominal interest rate ($i^*_{j,t}$). Each of these are trade-weighted averages across the trading partners of country j. To be consistent with a "small open economy" assumption, we exclude those countries for which country j represents a significant trading partner. See Appendix A.2 for details.

Our aim is to project domestic economic outcomes in the small open economy onto identified foreign demand shocks. Specifically, we therefore estimate the following pooled local projections equation by OLS for $h = 1, \ldots, H$:

$$Z_{j,t+h} = \beta_h X_{j,t} + \sum_{k=1}^{p} \delta_{h,k} X_{j,t-k} + \varepsilon_{j,t,h}, \tag{2.1}$$

where $X_{j,t} = (Z_{j,t}, Y^*_{j,t}, \pi^*_{j,t}, i^*_{j,t})'$. The coefficients in β_h give the (reduced form) IRF of a given domestic variable $Z_{j,t}$ in response to shocks to the four variables in $X_{j,t}$. To identify a foreign demand shock, we impose sign restrictions on the responses of the *foreign* variables, leaving the responses of domestic variables unrestricted. This requires us to estimate equivalent regression equations for the three foreign variables:

$$Y^*_{j,t+h} = \beta^Y_h X_{j,t} + \sum_{k=1}^{p} \delta^Y_{h,k} X_{j,t-k} + \varepsilon^Y_{j,t,h}, \tag{2.2}$$

$$\pi^*_{j,t+h} = \beta^\pi_h X_{j,t} + \sum_{k=1}^{p} \delta^\pi_{h,k} X_{j,t-k} + \varepsilon^\pi_{j,t,h}, \tag{2.3}$$

$$i^*_{j,t+h} = \beta^i_h X_{j,t} + \sum_{k=1}^{p} \delta^i_{h,k} X_{j,t-k} + \varepsilon^i_{j,t,h}. \tag{2.4}$$

We then impose the following sign and zero restrictions: First, a foreign demand shock moves foreign output, inflation, and the nominal interest rate *in the same direction* on impact. Second, since the domestic economy is small, domestic shocks (that is, shocks to $Z_{j,t}$) do not affect foreign variables. The restrictions are implemented by drawing candidate "rotation matrices", and keeping only those rotations of impulse responses that satisfy the identifying assumptions. The details of this procedure are described in Appendix A.1. Note that we formally identify four separate shocks in the process: A foreign demand shock, a foreign supply shock, a foreign monetary policy shock, and a domestic shock. The identifying assumptions for each of these are summarized in Appendix Table A.1.

Our identification strategy thus proceeds in two steps: The first is the use of sign restrictions, which builds on previous literature studying the responses of small open economies to foreign shocks; see, e.g., Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016). The restriction that demand shocks induce a positive comovement between output, inflation, and the interest rate has also been employed in other contexts (see, e.g., Furlanetto et al., 2019). The combination of sign restrictions and local projections follows the methodology outlined by Plagborg-Møller and Wolf (2021) based on methods in Rubio-Ramírez et al. (2010) and Arias et al. (2018).[4] The second step is the "small open economy" assumption: The domestic economy is small compared to the foreign economy, and therefore does not affect it. In other words, there is a one-way interaction from the large foreign to the small domestic economy. This assumption is routinely made in both theoretical and empirical studies of small open economies.

4. To our knowledge, the only existing application of sign restrictions combined with local projections is by Alpanda et al. (2021) in the context of monetary policy shocks.

2.2 Data and estimation

We use data from all 38 OECD countries. Since the G7 countries can generally not be considered small open economies, these are used exclusively in the construction of the foreign variables, $Y^*_{j,t}, \pi^*_{j,t}, i^*_{j,t}$ (see Appendix A.2 for further details). This leaves us with a panel of 31 small open economies for the construction of domestic economic outcomes, $Z_{j,t}$ (Appendix A.3 contains the complete list of countries). These countries are generally very open to foreign trade, as reflected by an average ratio of exports to GDP of 44%. For each country, the sample ends in 2019:Q4, and begins between 1947 and 1996, depending on data availability for the country in question (with most countries starting in the latter part of this span). The effective number of countries and observations in the dataset therefore varies across outcome variables. We take logs of all variables where applicable, and detrend the data using a country-specific regression on $(1, t, t^2)$. A detailed description of the variables and the transformations we apply is provided in Appendix A.4.

2.3 Results

We first consider the effects of a foreign demand shock on the foreign economy itself. The results are reported in Figure 1. This highlights the nature of the shock faced by the small open economy: A prolonged contraction in output of its trading partners, alongside a persistent drop in foreign inflation, and an even more persistent decline in the nominal interest rate.

We then turn to our main focus; the effects of the foreign shock on the 31 small open ("domestic") economies. These responses are shown in Figure 2. The shock induces a statistically significant contraction across a range of domestic macroeconomic variables, including GDP and inflation, both of which display a decline largely similar in magnitude to that observed in the foreign economy. Moreover, two of the three main findings discussed in the introduction clearly emerge from the figure (second column): *First*, aggregate consumption in the small open economy drops. *Second*, the aggregate response is composed of reductions in consumption of both tradable and non-tradable goods. In addition to these findings, we also observe notable drops in employment, the real wage, and the nominal and real interest rates.[5] The real

5. We also observe a clear drop in investment, see Appendix Figure A.1. We return to this finding in Section 8, where we consider a model with capital formation.

exchange rate displays a modest appreciation. In general, the persistence of the responses of domestic variables is comparable to that in the foreign economy.[6]

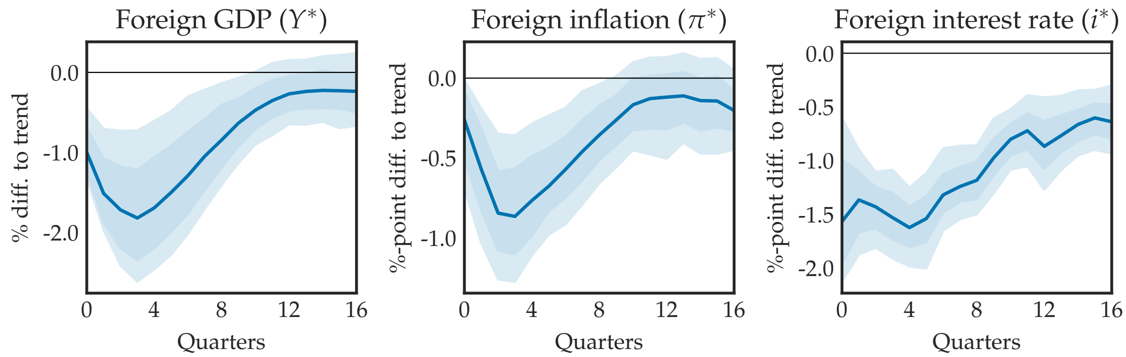


Figure 1: Effects of foreign demand shock in the foreign economy

Note: The figure reports impulse responses of $Y^*_{j,t}$, $\pi^*_{j,t}$, and $i^*_{j,t}$ to a negative foreign demand shock (when $Z_{j,t} = C_{j,t}$). The shaded areas indicate 95 and 68 pct. confidence bands. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

To establish the third of our main empirical findings, we turn next to quantifying the importance of foreign demand shocks for domestic macroeconomic fluctuations. To this end, we estimate the share of the forecast error variance of domestic variables accounted for by each of the four shocks. We do this on a country-by-country basis and then report the median across countries (see Appendix A.6 for details). The variance decomposition is reported in Figure 3. The main takeaway is that foreign demand shocks account for around $20-25\%$ of the variation in domestic macroeconomic variables at business-cycle frequencies.[7] In other words, such shocks account for a significant share of business fluctuations in small open economies, as anticipated in the introduction. Moreover, foreign demand shocks are the most important among the three foreign shocks we have identified. Altogether, foreign shocks account for around half of the observed variation in domestic variables. This finding is in line with existing studies, e.g., the VAR evidence of Justiniano and Preston (2010).

6. Note that we observe a larger drop in imports than in exports, implying a counterintuitive *rise* in net exports. This finding—alongside the observed appreciation of the real exchange rate—is in line with the empirical results of Fukui et al. (2023), who report an increase in imports in response to an exchange rate depreciation. Nonetheless, this result—combined with the fact that domestic output drops by almost as much as foreign output—could indicate that our identification strategy may not have been entirely successful in purging identified foreign demand shocks of a "global" component that affects both the foreign and the domestic economy directly. In Section 2.4 we discuss a specification where we attempt to control for this by including OECD-wide GDP in our regressions.

7. Appendix Table A.4 reports the exact numbers and corresponding confidence intervals at selected horizons.

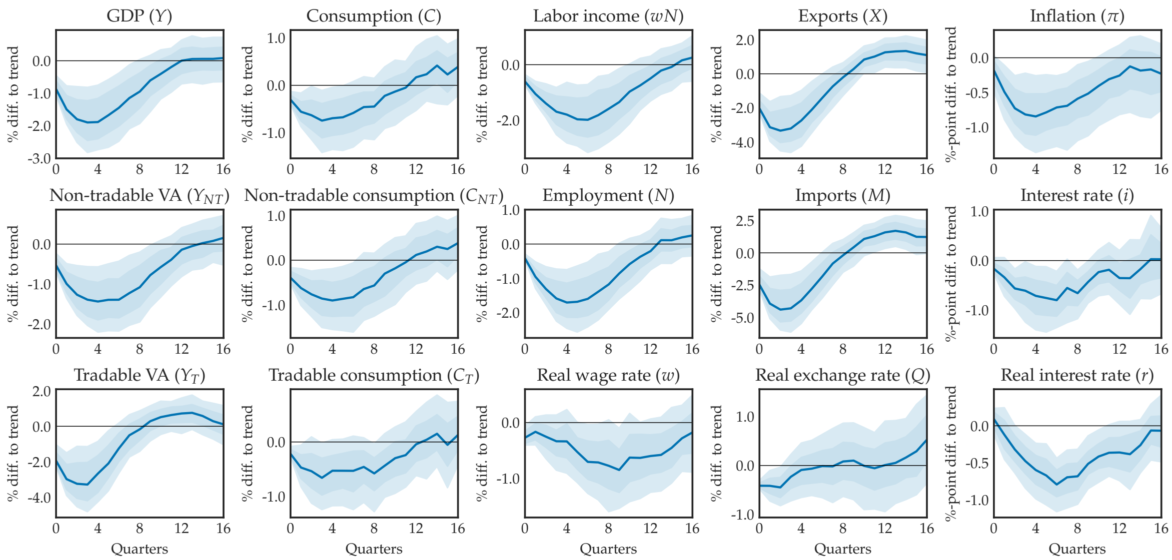


Figure 2: Effects of foreign demand shock in the small open economy

Note: The figure reports impulse responses of domestic outcome variables to a negative foreign demand shock. The shaded areas indicate 95 and 68 pct. confidence intervals. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

2.4 Robustness

We conduct a variety of sensitivity checks to confirm the robustness of our empirical findings. The results are reported in Appendix A.7. First and most importantly, we estimate separate responses for fixed and floating exchange-rate countries. In both cases, we obtain results that are very similar to those reported above, as seen in Appendix Figure A.3 and A.4. This shows that our empirical findings are not specific to one type of exchange rate regime. In Section 6, we show that our theoretical explanation also holds up, irrespective of this choice.

A potential concern may be that the system (2.1)-(2.4) is only *set-identified*, given our reliance on sign restrictions. That is, other types of shocks than what we think of as "pure" foreign demand shocks may satisfy the sign restrictions. In particular, this may be relevant for "global" shocks that hit a large number of countries simultaneously, such as financial crises, shifts in global sentiments, or pandemics. To address this concern, we include OECD-wide GDP as a control variable in order to capture time-varying global factors, following the approach of Cloyne et al. (2023). As seen from Appendix Figure A.5, this approach produces results that are substantially more noisy, though most of our results are still confirmed.

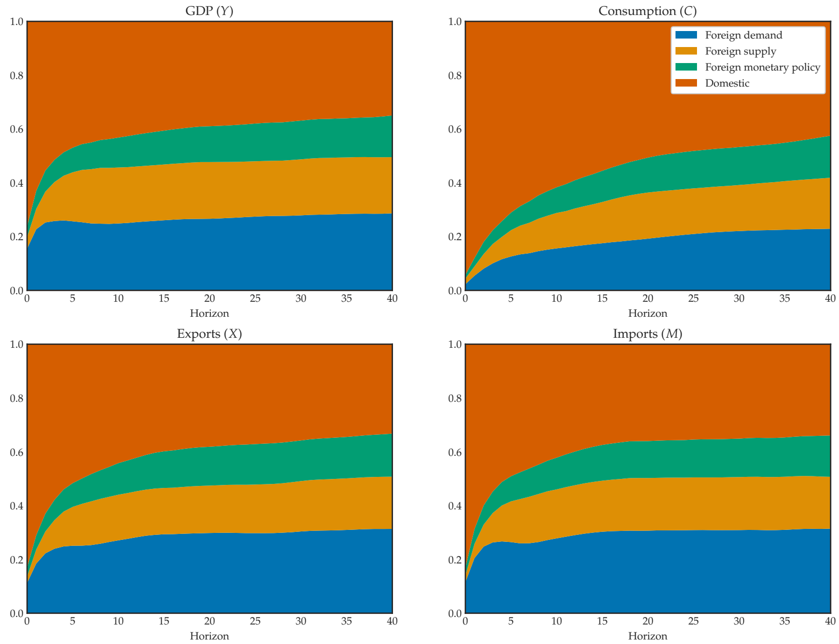


Figure 3: Forecast error variance decomposition

Note: The figure reports the forecast error variance decomposition of selected variables. The horizontal axis indicates the horizon, and the vertical axis indicates the share of variance explained.

We finally turn to a series of changes to the empirical specification and the construction of the variables. These include using a structural VAR model instead of local projections; applying different filtering methods or a different lag structure; employing a balanced sample of countries starting in 1996; using only the G7 economies to construct the foreign variables ($Y^*_{j,t}, \pi^*_{j,t}, i^*_{j,t}$); or using a common foreign economy based on shares of world GDP for all countries (i.e., $Y^*_{j,t} = Y^*_t, \forall j$, and similar for $\pi^*_{j,t}$ and $i^*_{j,t}$). We also consider a specification in which domestic outcome variables are projected directly onto country-specific foreign output $Y^*_{j,t}$, without relying on sign restrictions. The main takeaway from these exercises—which are reported in Appendix Figures A.6 through A.13—is that our main results are quite robust with respect to all the alterations we have considered.

3 A stylized model of foreign demand shocks

To understand the effects of foreign demand shocks on domestic variables, we first introduce a stylized New Keynesian model of a small open economy, which allows for an analytical characterization of the main transmission mechanisms at work in the fully-fledged model we present in the next section.

The stylized model builds on the canonical model of Gali and Monacelli (2005), extended to feature household heterogeneity and incomplete financial markets, as in Bewley (1986), Imrohoroğlu (1989), Huggett (1993), and Aiyagari (1994). Market incompleteness implies that there is no risk sharing across households, nor across countries. Our stylized model is essentially equivalent to that of Auclert et al. (2021b), except for the assumptions regarding monetary policy. For comparison, we also consider an otherwise identical representative-agent (RANK) version of the model, featuring complete domestic financial markets, but no international risk sharing.[8]

The model consists of domestic households that have CES preferences over bundles of home and foreign goods with a home bias of $1-\alpha \in (0,1)$; domestic firms that produce the home good under perfect competition, facing sticky wages, and using a linear production technology with domestic labor as the only input; and a domestic central bank that follows a Taylor rule targeting domestic price inflation. Foreign consumption demand is exogenous, and we treat it as the "foreign demand shock" in this stylized setting.

We consider the linearized perfect foresight impulse response in discrete time, and let boldface variables refer to the time path, i.e. $\boldsymbol{X} = \{X_0, X_1, \dots\}$. We are interested in the response of domestic consumption, $\boldsymbol{C}$, to a drop in foreign consumption demand, $\boldsymbol{C}^*$. We focus here on the overall intuition, while a detailed exposition is provided in Appendix B.

Denote the real exchange rate by $\boldsymbol{Q}$, and define the *total* trade elasticity as $\chi \equiv \eta(1-\alpha)+\eta^*$, where η is the domestic consumers' elasticity of substitution between home and foreign goods, and η^* is the corresponding elasticity abroad. Then the market clearing condition for domestic production, $\boldsymbol{Y}$, can be written in terms of linearized deviations from steady state, $dY_t = Y_t - Y_{ss}$, as follows:

$$d\boldsymbol{Y} = (1-\alpha)d\boldsymbol{C} + \alpha d\boldsymbol{C}^* + \frac{\alpha}{1-\alpha}\chi d\boldsymbol{Q}, \tag{3.1}$$

where the first two terms capture domestic and foreign income effects, respectively, and the third term captures the substitution effect from changes in the real exchange rate. Domestic household labor income, $\boldsymbol{Y}^{hh}$, can be written, also in deviations from

8. We do not treat the case of perfect international risk sharing. While a RANK model with this feature would be able to generate a positive co-movement between foreign and domestic consumption almost by construction, perfect international risk sharing is a very stark and empirically less plausible assumption, which creates other puzzles of its own (see, e.g., Corsetti et al., 2008).

steady state, as

$$d\boldsymbol{Y}^{hh} = d\boldsymbol{Y} - \frac{\alpha}{1-\alpha} d\boldsymbol{Q}. \tag{3.2}$$

From the household budget constraint, we can write domestic consumption deviations as:

$$d\boldsymbol{C} = \boldsymbol{M} d\boldsymbol{Y}^{hh} + \boldsymbol{M}^{r} d\boldsymbol{r}, \tag{3.3}$$

where $\boldsymbol{M}$ is the matrix of intertemporal marginal propensities to consume, and $\boldsymbol{M}^{r}$ is the matrix of intertemporal effects on consumption of real interest rate changes.

Finally, we assume free capital mobility, which gives rise to a UIP condition. We can write this in real terms to obtain a relationship between the domestic real interest rate and the real exchange rate:

$$d\boldsymbol{r} = -\boldsymbol{G}^{r,Q} d\boldsymbol{Q}. \tag{3.4}$$

We can combine (3.4) with the model's New Keynesian Phillips curve and the Taylor rule to obtain a relationship between domestic output and the real exchange rate:

$$d\boldsymbol{Q} = -\boldsymbol{G}^{Q,Y} d\boldsymbol{Y}. \tag{3.5}$$

The matrices $\boldsymbol{G}^{Q,Y}$ and $\boldsymbol{G}^{r,Q}$ are derived from the structural parameters of the model as shown in Appendix B. The implication of (3.4) is that high domestic real interest rates are associated with a future real exchange rate appreciation. Furthermore, we have found numerically that (3.5) implies a negative relationship between domestic output and the real exchange rate.

3.1 The response of aggregate consumption

Combining equations (3.1)–(3.5), we can show the following result:

Proposition 1. *The equilibrium response of domestic consumption ($d\boldsymbol{C}$) to a change in foreign consumption ($d\boldsymbol{C}^{*}$) is given by:*

$$d\boldsymbol{C} = \Big[\underbrace{\boldsymbol{M}}_{\textit{Labor income}} + \underbrace{\frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y}}_{\textit{Real income}} + \underbrace{\boldsymbol{M}^{r} \boldsymbol{G}^{r,Q} \boldsymbol{G}^{Q,Y}}_{\textit{Intertemporal sub.}} \Big] \boldsymbol{G}^{Y,C^{*}} d\boldsymbol{C}^{*}, \tag{3.6}$$

with $\boldsymbol{G}^{Y,C^{*}}$ a known function of the structural parameters of the model.

Proof. See Appendix B.

For realistic parametrizations of the model, the entries of the matrix $\boldsymbol{G}^{Y,C^*}$ are such that domestic output declines in response to a negative foreign demand shock. Proposition 1 thus states that the consumption response to a foreign demand shock is driven by three channels.

The first channel captures direct income and multiplier effects from lower labor income. Consumption drops because domestic households have less income due to the drop in foreign demand.

The second channel captures effects of real exchange rate movements on consumption via household income. This is the "real income channel" emphasized by Auclert et al. (2021b): The decline in domestic inflation is associated with a depreciation of the real exchange rate, which reduces the real income of domestic households, forcing them to spend less on relatively more expensive imports and shrink their overall consumption basket.[9]

The third channel captures intertemporal substitution effects from movements in the real interest rate: In the empirically plausible case where the substitution effect of changes in the interest rate is stronger than the income effect, the dominant entries in $\boldsymbol{M}^r$ are negative. This channel thus tends to drive up consumption, as the domestic central bank responds to the decline in domestic inflation by reducing the nominal interest rate, thus driving down also the real rate and inducing households to bring consumption forward in time.

Proposition 1 applies not only in our open-economy HANK model, but also in the RANK version of the model. When the marginal propensity to consume (MPC) out of current income is low, $\boldsymbol{M} \approx \boldsymbol{0}$, such as in representative-agent models which operate under the permanent income hypothesis, it holds that

$$d\boldsymbol{C} \approx \boldsymbol{M}^r \boldsymbol{G}^{r,Q} \boldsymbol{G}^{Q,Y} \boldsymbol{G}^{Y,C^*} d\boldsymbol{C}^*. \tag{3.7}$$

Since the dominant entries in each of the $\boldsymbol{G}$-matrices are positive, and those in $\boldsymbol{M}^r$ negative, as argued above, domestic consumption thus responds *positively* to a drop in foreign demand, in direct contrast to our empirical results. This reflects that intertemporal substitution plays a dominant role in the RANK model, as the low MPC

9. In the quantitative model we propose in the next section, the real income channel instead exerts a *positive* impact on the consumption response to a foreign demand shock. This happens since, in line with our empirical evidence in Section 2, the shock also affects the foreign interest rate and foreign inflation, leading instead to an *appreciation* of the real exchange rate. This indicates that the labor income channel is the key driver of the consumption response.

effectively switches off the two other channels.

In contrast, the presence of high-MPC households in our HANK model implies that $\boldsymbol{M} \approx \mathbf{0}$ no longer applies. Instead, the first and second channels will dominate, provided that the average MPC is sufficiently high. This paves the way for the model to generate a negative response of domestic consumption, in line with the data. Furthermore, as we show using the full model in the next section, the negative response of aggregate consumption turns out to be crucial in obtaining a drop in consumption of both tradable and non-tradable goods, as well as in accounting for the importance of foreign demand shocks for fluctuations in domestic output.

We find it insightful to briefly consider the case of a fixed exchange rate. Under a peg, the relationship between the domestic output gap and the real exchange rate turns positive (i.e., the matrix $\boldsymbol{G}^{Q,Y}$ flips sign; see Appendix B). This implies that the RANK version of the model (with $\boldsymbol{M} \approx \mathbf{0}$) actually generates the desired, negative response of domestic consumption, but for the "wrong" reason: With no changes in the foreign nominal interest rate, the domestic nominal interest rate also remains fixed, so the decline in domestic inflation leads to an increase in the real interest rate and a drop in consumption. In our full model in the next section—and in line with the data—foreign inflation also declines, and the foreign central bank responds by reducing the nominal interest rate, so that the negative responses of the nominal and real domestic interest rates are restored, and consumption in the RANK setup again displays a counterfactual increase.

4 Model

We now turn to a quantitative business-cycle model of a small open economy. Building on the stylized model considered in the previous section, we now account for production of both tradable and non-tradable goods in the domestic economy. Moreover, we extend the production structure to incorporate inputs of (domestic and foreign) intermediate goods, which is frequently employed in existing studies to obtain positive business-cycle comovement across sectors and countries (see e.g. Huang and Liu, 2007 and Bouakez et al., 2009). A public sector conducts fiscal policy by setting the levels of government spending, taxes, and transfers. We postpone an extension featuring capital formation to Section 8.

4.1 Households

The economy consists of a continuum of households of unit measure, indexed by i. Households are permanently heterogeneous along two dimensions: The sector in which they work (tradable or non-tradable), and the level of their discount factor, β. We index these two states by s and k, respectively, and generally leave out the i index. The average discount factor is $\bar{\beta}$. We include a mean-zero discount factor shock ϵ_t^{β}, common across households. The composite discount factor for a household with permanent subjective discount factor β^k is denoted by $\beta_t^k = \beta^k \exp\left\{\epsilon_t^{\beta}\right\}$.

In real terms, the recursive consumption-saving problem of a given household is:

$$V_t^{s,k}(e_t, a_{t-1}) = \max_{c_t, a_t} \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \nu \frac{L_{s,t}^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} + \beta_t^k \mathbb{E}_t \left[V_{t+1}^{s,k}(e_{t+1}, a_t) \right] \right) \tag{4.1}$$

s.t.

$$c_t + a_t = (1 + r_t^a)\, a_{t-1} + (1 - \tau_t)\, w_{s,t} L_{s,t} e_t + T_t, \tag{4.2}$$

$$a_t \geq 0, \tag{4.3}$$

$$\ln e_t = \rho_e \ln e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim \mathcal{N}\left(0, \sigma_e^2\right), \tag{4.4}$$

where σ is the inverse intertemporal elasticity of substitution, and φ is the Frisch elasticity of labor supply. Each period, households choose the consumption bundle (c_t) and the level of savings (a_t) to maximize the expected discounted sum of lifetime utility, subject to a period budget constraint (4.2) and a no-borrowing constraint (4.3). Households can save in an asset yielding the return r_t^a. They earn real sector-specific labor income $w_{s,t} L_{s,t} e_t$, where $w_{s,t}$ is the wage rate, $L_{s,t}$ is hours worked, and e_t captures the idiosyncratic part of earnings, which follows an AR(1) process in logs, as in (4.4). Note that labor supply is not chosen by the individual household, and thus not a choice variable in the consumption-saving problem. Instead, it is set by the labor union of which the household is a member, as described in Section 4.3. This ensures that all households within a given sector work the same number of hours, as is common in the HANK literature (see, e.g., De Ferra et al., 2020 or Auclert et al., 2024). Finally, T_t denotes lump-sum transfers from the government, and τ_t is a proportional labor income tax rate. Let $\mathcal{D}_t$ be the distribution of households over states

$\{a_{t-1}, e_t, \beta, s\}$. Denoting aggregate consumption and assets by C_t and A_t, we have:

$$C_t = \int \tilde{c}_t \left(a_{t-1}, e_t, \beta, s\right) d\mathcal{D}_t, \tag{4.5}$$

$$A_t = \int \tilde{a}_t \left(a_{t-1}, e_t, \beta, s\right) d\mathcal{D}_t, \tag{4.6}$$

where $\tilde{c}_t$ and $\tilde{a}_t$ denote the optimal consumption and savings choices.

4.1.1 Portfolio choice

Total assets A_t owned by households are invested in a mutual fund, which can invest in three types of financial assets, implying the following balance-sheet relation:

$$A_t = B_t + \int p^D_{j,t} v_{j,t} dj + B^*_t, \tag{4.7}$$

where B_t and B^*_t denote domestic and foreign government bonds, respectively, and $v_{j,t}$ denotes the equity shares of domestic firm j priced at $p^D_{j,t}$, with $\int v_{j,t} dj = 1$. Domestic bonds pay the nominal policy rate i_t set by the central bank, and generate the real return $r_t \equiv \frac{1+i_t}{1+\pi_{t+1}} - 1$, where π_{t+1} is the inflation rate. Firm shares pay dividends $D_{j,t}$ each period. Foreign bonds B^*_t pay the foreign interest rate i^*_t. $Q_t = E_t \frac{P^*_t}{P_t}$ is the real exchange rate, where P_t and P^*_t denote the domestic and foreign price levels, and E_t is the nominal exchange rate, defined as domestic currency units per foreign currency unit. The real return to foreign assets is then $(1 + r^*_t) \frac{Q_{t+1}}{Q_t}$. In the absence of aggregate uncertainty, and given that all assets are perfect substitutes, the real returns on each of the three assets will be equalized in equilibrium. Letting $r_t = \mathbb{E}_t r^a_{t+1}$ denote the ex-ante real return, we obtain the no-arbitrage conditions:[10]

$$1 + r_t = \frac{D_{j,t+1} + p^D_{j,t+1}}{p^D_{j,t}}, \tag{4.8}$$

$$1 + r_t = (1 + r^*_t) \frac{Q_{t+1}}{Q_t}. \tag{4.9}$$

10. In the initial period following an unexpected (MIT) shock, it is generally not the case that $r_t = r^a_{t+1}$, so the no-arbitrage condition fails. In this period, the returns to assets is:

$$r^a_t = \frac{p^D_{j,t} + D_{j,t} + \frac{i_{t-1}}{1+\pi_t} B_{t-1}}{A_{t-1}} - 1,$$

where we assume that households initially hold only domestic assets; $B^*_{ss} = 0$.

The first condition equates the return on domestic bonds and stocks, while the second is a real UIP condition, stating that the expected real return on foreign and domestic assets must be equalized.

4.1.2 Complete markets and risk sharing: The representative-agent case

In addition to the model with incomplete markets, we also consider a complete-markets benchmark case. The assumption of complete markets with perfect risk-sharing and no preference heterogeneity implies the existence of a representative household, with aggregate consumption determined by a standard Euler equation:

$$C_t^{-\sigma} = (1 + r_{t+1}^a)\bar{\beta}_t C_{t+1}^{-\sigma}.$$

As is well known, this type of small open economy model is not stationary. Thus, following Schmitt-Grohé and Uribe (2003) and much of the ensuing literature, we introduce a debt-elastic interest-rate premium $\iota_t = \iota(B_t^*)$ on foreign borrowing in order to ensure stationarity of the net foreign asset position. The real UIP condition then becomes: $1 + r_t = (1 + r_t^*)\frac{Q_{t+1}}{Q_t}\iota_t$.[11]

4.1.3 Consumption goods

Consumption is a CES aggregate of tradable ($C_{T,t}$) and non-tradable ($C_{NT,t}$) goods:

$$C_t = \left[\alpha_T^{\frac{1}{\eta_{T,NT}}} C_{T,t}^{\frac{\eta_{T,NT}-1}{\eta_{T,NT}}} + (1-\alpha_T)^{\frac{1}{\eta_{T,NT}}} C_{NT,t}^{\frac{\eta_{T,NT}-1}{\eta_{T,NT}}}\right]^{\frac{\eta_{T,NT}}{\eta_{T,NT}-1}}, \tag{4.10}$$

where the parameter $0 < \alpha_T < 1$ determines the expenditure share on tradable goods, and $\eta_{T,NT} > 0$ is the elasticity of substitution between the two goods. The CES formulation implies that the demand functions take the following forms:

$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\eta_{T,NT}} C_t, \tag{4.11}$$

$$C_{NT,t} = (1-\alpha_T) \left(\frac{P_{NT,t}}{P_t}\right)^{-\eta_{T,NT}} C_t, \tag{4.12}$$

11. Although this is not necessary in the HANK model, which is stationary by design, we include it in both models for ease of comparison. The functional form of $\iota(B_t^*)$ is reported in Appendix C.

where $P_t = \left[\alpha_T P_{T,t}^{1-\eta_{T,NT}} + (1-\alpha_T) P_{NT,t}^{1-\eta_{T,NT}}\right]^{\frac{1}{1-\eta_{T,NT}}}$ is the consumer price index (CPI), and $P_{T,t}$ and $P_{NT,t}$ are the prices of tradable and non-tradable goods. Tradables are, in turn, a composite made up of foreign and home goods, $C_{F,t}$ and $C_{H,t}$, bundled through a CES aggregator with share parameter $0 < \alpha_F < 1$, and elasticity of substitution $\eta_{H,F} > 0$, resulting in the corresponding standard demand functions for home and foreign tradables, respectively.

4.2 Firms

We now turn to the production sector of the economy. The domestic supply side is composed of two sectors: A tradable and a non-tradable goods sector, $s \in \{T, NT\}$. In each sector, perfectly competitive wholesalers aggregate the different varieties supplied by the producers into a single final good.

4.2.1 Wholesalers

The representative wholesaler in sector s uses a CES production technology with elasticity of substitution $\epsilon^P > 0$, so the demand for output from producer j in sector s is given by (with $Z_{s,t}$ denoting gross output of sector s):

$$Z_{s,t}^j = \left(\frac{P_{s,t}^j}{P_{s,t}}\right)^{-\epsilon^P} Z_{s,t}. \tag{4.13}$$

4.2.2 Producers

The sectoral good $Z_{s,t}$ is produced using inputs of labor, $L_{s,t}$, and an intermediate goods bundle, $X_{s,t}$. In anticipation of a symmetric equilibrium within sectors, we drop the superscript j. Production is given by:

$$Z_{s,t} = \mathcal{Z}_s X_{s,t}^{\alpha_s^X} L_{s,t}^{1-\alpha_s^X} - F_s, \tag{4.14}$$

where $\mathcal{Z}_s$ is TFP, $0 \leq \alpha_s^X \leq 1$ is the share parameter for intermediate goods, and F_s is a fixed cost introduced to ensure a realistic valuation of the firm, given conventional levels of the markup. Each sector is characterized by monopolistic competition between a continuum of firms facing the demand function of wholesalers, (4.13). Firms choose $X_{s,t}$, $L_{s,t}$, and $P_{s,t}$ to maximize real dividends. The first-order conditions for factor inputs are presented in Appendix C. Firms' price-setting is subject to a Rotemberg adjustment cost of size θ_s^P. This gives rise to a sector-specific New-Keynesian Phillips curve:

$$\pi_{s,t}\left(1+\pi_{s,t}\right)=\frac{\epsilon^P}{\theta_s^P}\left(mc_{s,t}-\frac{P_{s,t}}{P_t}\frac{1}{\mu_s}\right)+\frac{1}{1+r_t}\pi_{s,t+1}\left(1+\pi_{s,t+1}\right)\frac{Z_{s,t+1}}{Z_{s,t}}, \tag{4.15}$$

where $mc_{s,t}$ denotes the real marginal costs of firms in sector s.

4.2.3 Intermediate-good retailers

Within each sector $s \in \{T, NT\}$, the intermediate-good bundle $X_{s,t}$ is assembled by retailers operating in a perfectly competitive environment. The retailers have access to a CES technology:

$$X_{s,t}=\left[\Theta_{s\to s}^{\frac{1}{\eta_X}}X_{s\to s,t}^{\frac{\eta_X-1}{\eta_X}}+\Theta_{s'\to s}^{\frac{1}{\eta_X}}X_{s'\to s,t}^{\frac{\eta_X-1}{\eta_X}}+\Theta_{F\to s}^{\frac{1}{\eta_X}}X_{F\to s,t}^{\frac{\eta_X-1}{\eta_X}}\right]^{\frac{\eta_X}{\eta_X-1}}, \tag{4.16}$$

where $X_{s\to s,t}$ and $X_{s'\to s,t}$ denote input materials produced in sector s and s', respectively, and used as input for the intermediate-good bundle in sector s. The parameters $\Theta_{s\to s}$ and $\Theta_{s'\to s'}$ are the diagonal elements of a domestic input-output matrix. Likewise, $X_{F\to s,t}$ denotes intermediate inputs imported from the foreign economy (with weights $\Theta_{F\to s}$). $\eta_X > 0$ is the elasticity of substitution between input types.

4.2.4 Aggregates

Real value added (VA) in sector s (denoted $Y_{s,t}$) is defined as nominal VA deflated by the VA deflator $\mathcal{P}_t$:[12]

$$Y_{s,t}=\frac{P_{s,t}Z_{s,t}-P_{s,t}^X X_{s,t}}{\mathcal{P}_t}, \tag{4.17}$$

and aggregate VA (Y_t) as:

$$Y_t=\sum_s Y_{s,t}=Y_{T,t}+Y_{NT,t}. \tag{4.18}$$

12. The VA deflator is calculated as $\mathcal{P}_t=\frac{\sum_s Y_{s,t}P_{s,t}^Y}{\sum_s Y_{s,ss}P_{s,ss}^Y}$, where $P_{s,t}^Y$ is the sector-specific VA deflator.

4.3 Labor supply and wage setting

Labor supply is determined by unions. In each sector, there is a continuum of unions, and each household i in that sector provides $l^j_{i,s,t}$ hours of work to union j in sector s. Total labor supply of household i is then $l_{i,s,t} = \int l^j_{i,s,t} dj$. Each union assembles individual labor supply to a union-specific task, $L^j_{s,t} = \int e_{i,t} l^j_{i,s,t} di$, and aggregate labor supply is assembled from these union-specific tasks using a CES technology, with $\epsilon^W > 0$ denoting the elasticity of substitution between labor types. Union j in sector s maximizes the discounted stream of future utility of its members, net of a Rotemberg adjustment cost on nominal wages (see Appendix C for details). This problem yields a symmetric equilibrium in which all unions choose the same wage, and all households supply the same amount of labor. Thus, we obtain a sector-specific New Keynesian wage Phillips Curve:

$$\pi^w_{s,t}\left(1+\pi^w_{s,t}\right) = \frac{\epsilon^w}{\theta^w_s} L_{s,t} \left\{ \nu L^{\frac{1}{\varphi}}_{s,t} - \frac{\epsilon^w - 1}{\epsilon^w} \frac{(1-\tau_t) W_{s,t}}{P_t} U'\left(C_{s,t}\right) \right\} + \beta^U_t \pi^w_{s,t+1}\left(1+\pi^w_{s,t+1}\right), \tag{4.19}$$

where $U'\left(C_{s,t}\right) = \int e_i u'\left(c_{i,s,t}\right) d\mathcal{D}_t$ denotes the aggregate, productivity-weighted marginal utility of consumption, and β^U_t is the discount factor of the union, which we set to $\beta^U_t = \frac{1}{1+r_t}$, as in Hagedorn et al. (2019).

4.4 Monetary policy

As our baseline, we assume that the domestic economy maintains a floating exchange rate vis-a-vis the foreign economy. The domestic central bank conducts monetary policy according to a Taylor rule featuring interest rate smoothing:

$$i_t = \left(i_{ss} + \phi^\pi \pi^{PP}_{t+1}\right)(1-\rho^r) + \rho^r i_{t-1} + \epsilon^r_t, \tag{4.20}$$

where π^{PP}_t is the inflation rate of the the domestic producer price index (PPI), defined as the Laspeyres index over $C_{H,t}$ and $C_{NT,t}$.[13] We follow Galí (2015) in assuming that the central bank responds to movements in the PPI instead of the CPI. The policy rule features no output-gap response. None of our results depend on these choices.

We also consider the case where the domestic economy maintains a fixed exchange

13. $PPI_t = \frac{P_{H,t}C_{H,t}+P_{NT,t}C_{NT,t}}{P_{H,ss}C_{H,ss}+P_{NT,ss}C_{NT,ss}}$, where we use the steady state as the base period.

rate towards the foreign economy. In this case, we replace the Taylor rule (4.20) with the condition that the nominal exchange rate remains fixed at all times:

$$E_t = E_{ss}. \tag{4.21}$$

4.5 The public sector

The public sector finances public consumption (G_t), transfers (T_t), and debt service using new bond issuance (B_t) and labor income taxes, $\tau_t \sum_s w_{s,t} L_{s,t}$. The period real budget constraint (measured in terms of the CPI) is:

$$B_t + \tau_t \sum_s w_{s,t} L_{s,t} = T_t + \frac{P_t^G}{P_t} G_t + \frac{1 + i_{t-1}}{1 + \pi_t} B_{t-1}, \tag{4.22}$$

where P_t^G is the public consumption deflator, which reflects the share of government spending going to domestic tradables ($G_{H,t}$) and non-tradables ($G_{NT,t}$), which we discuss in Section 5. Public consumption and transfers are treated as exogenous. We obtain a balanced budget in steady state by adjusting the tax rate, τ_t. Outside of steady state, discretionary fiscal policy and changes in interest expenses require financing. In the spirit of Hagedorn et al. (2019), we assume that the government finances deficits by issuing bonds for the first t_B quarters after a shock. From period t_B and onwards, the government smoothly adjusts the tax rate τ_t to ensure that the level of public debt converges to the steady-state level. See Appendix C for details.

4.6 The foreign economy

The domestic economy is affected by foreign economic activity (through demand for domestic exports), prices (through international relative prices), and interest rates (through the UIP condition). Hence, we summarize the foreign economy as a sequence of foreign imports, foreign inflation, and the foreign nominal interest rate, $\left\{M_t^*, \pi_{F,t}^*, i_t^*\right\}$, which enter the set of domestic equilibrium conditions. This approach allows us to feed an estimated foreign demand shock, as studied in Section 2, directly into the model.[14]

The law of one price for foreign and domestic tradables implies that $P_{H,t} = E_t P_{H,t}^*$

14. A slightly more structural approach would be to model the foreign economy as a standard three-equation small open economy, as in Galí (2015). We have found that this yields similar results.

and $P_{F,t} = E_t P^*_{F,t}$, where $P^*_{H,t}$ denotes the price of domestic tradables in foreign currency, and $P^*_{F,t}$ is the price of the foreign good in foreign currency. Foreign demand for domestic tradables is given by an Armington-type relation:

$$C^*_{H,t} = \alpha^* \left(\hat{p}^*_t\right)^{-\eta^*} M^*_t, \tag{4.23}$$

where $\alpha^* \in [0, 1]$ is a scaling parameter, and $\eta^* > 0$ is the Armington elasticity. Following Drozd et al. (2021) and Boehm et al. (2023), we incorporate a dynamic export elasticity, which we obtain via a smoothed adjustment in the international relative price, $\hat{p}^*_t$:

$$\hat{p}^*_t = \left(\hat{p}^*_{t-1}\right)^{\rho^*} \left(\frac{P^*_{H,t}}{P^*_{F,t}}\right)^{1-\rho^*}, \text{ where } \hat{p}^*_{ss} = \frac{P^*_{H,ss}}{P^*_{F,ss}}. \tag{4.24}$$

When $\rho^* > 0$, the initial response of foreign demand to a change in relative prices is dampened, implying a smaller elasticity in the short run than in the long run, in line with the empirical evidence of Boehm et al. (2023).

4.7 Domestic market clearing

Equilibrium in the domestic economy is characterized by the two goods market clearing conditions:

$$Z_{NT,t} = C_{NT,t} + G_{NT,t} + X_{NT\to T,t} + X_{NT\to NT,t} + \Xi_{NT,t}, \tag{4.25}$$

$$Z_{T,t} = C_{H,t} + G_{H,t} + C^*_{H,t} + X_{T\to T,t} + X_{T\to NT,t} + \Xi_{T,t}, \tag{4.26}$$

where $\Xi_{s,t}$ collects all types of adjustment costs in sector s. We define net exports and the net foreign asset position as:

$$NX_t \equiv \frac{\mathcal{P}_t}{P_t} Y_t - C_t - G_t, \tag{4.27}$$

$$NFA_t \equiv B^*_t = A_t - p^D_t - B_t. \tag{4.28}$$

The latter implies that we are abstracting from foreign investment in domestic assets. Asset market clearing holds by Walras' law, and implies the following balance of payments relation between net exports and the net foreign asset position (i.e., the current account):

$$NFA_t = NX_t + (1 + r_t^a)\, NFA_{t-1}.$$

4.8 Shocks and equilibrium

We consider only perfect-foresight shocks in the model.[15] As discussed above, we are interested in foreign demand shocks consisting of the sequences $\left\{M_t^*, \pi_{F,t}^*, i_t^*\right\}$ obtained from our empirical analysis in Section 2. Later, we will also consider a domestic preference (or demand) shock ϵ_t^β, as well as shocks to the policy variables G_t, T_t, and ϵ_t^i. From the perspective of the domestic economy, the exogenous sequences are thus $\{M_t^*, \pi_{F,t}^*, i_t^*, \epsilon_t^\beta, G_t, T_t, \epsilon_t^i\}$, where the first three are those associated with foreign demand shocks.

Definition 1 (Domestic equilibrium)**.** *Given sequences for* $\{M_t^*, \pi_{F,t}^*, i_t^*, \epsilon_t^\beta, G_t, T_t, \epsilon_t^i\}$*, an initial household distribution over assets, earnings, discount factors and sectors* $\mathcal{D}_0(a, e, \beta, s)$*, and an initial portfolio allocation between foreign and domestic assets, a competitive equilibrium in the domestic economy is a path of household policies* $\{c_t\,(a, e, s)\,, a_t\,(a_{t-1}, e, s)\}$*, distributions* $\mathcal{D}_t(a, e, s)$*, prices:*

$$\left\{E_t, Q_t, P_{s,t}, P_{H,t}, P_{F,t}, W_{s,t}, P_{s,t}^X, p_t^D, i_t, r_t, r_t^a\right\},$$

and quantities:

$$\{C_t, C_{s,t}, C_{H,t}, C_{F,t}, A_t, Z_{s,t}, Y_{s,t}, X_{s,t}, L_{s,t}, D_{s,t}, NFA_t, Y_t, T_t, \tau_t, G_t, B_t\},$$

such that all households and firms optimize, monetary and fiscal policies satisfy their respective rules/constraints, and the goods markets, (4.25) *and* (4.26)*, clear.*

4.9 Solution method

We solve the households' dynamic programming problem using the endogenous grid method of Carroll (2006). We use the "fake news algorithm" from Auclert et al. (2021a) to efficiently compute the Jacobian of the household problem around the

15. Since we only study small shocks, the dynamics of the model are approximately linear, and the impulse responses are identical to those from a model with aggregate risk (Boppart et al., 2018).

deterministic steady state. We then proceed to solve for the full non-linear transition paths to each shock using Broyden's method.[16]

5 Calibration and model fit

We now describe our calibration and the fit of the model with the empirical evidence.

5.1 Calibration

The model is calibrated at a quarterly frequency. Our target is the average small open economy in our sample of OECD countries employed in Section 2. We calibrate the HANK and RANK models as similarly as possible. All parameters except those describing households' income and preferences are therefore identical across the two models. The parameter values are summarized in Appendix Table D.1 and Table D.2.

Preferences We set the elasticity of intertemporal substitution ($1/\sigma$) to 0.4. This value is well within the range of estimates commonly used in the literature. The implied interest-rate sensitivity of consumption in our HANK model is consistent with the two-asset HANK model of Kaplan et al. (2018), c.f. Appendix D.1. The Frisch elasticity of labor supply, φ, is set to a standard value of 0.5, consistent with the literature review by Chetty et al. (2011). These two parameters are the same in the RANK and HANK models.

We calibrate the average discount factor, $\bar{\beta}$, to obtain asset market clearing at a steady-state real interest rate of 2% annually. In the RANK model, the discount factor (β) is directly pinned down by our choice of the steady-state real interest rate. In both models, we calibrate the steady-state asset demand to match a quarterly wealth-to-income ratio of 10, which corresponds to the average among OECD countries over the period 1996-2019. We introduce discount-factor heterogeneity in the HANK model in order to match the large MPCs estimated in micro studies. We assume that discount factors are uniformly distributed on $\left[\overline{\beta} - \Delta\beta, \overline{\beta} + \Delta\beta\right]$, where $\Delta\beta$ is the discount-factor dispersion. We calibrate $\Delta\beta$ to match an annual first-year MPC of 0.51, following the estimates from Fagereng et al. (2021), c.f. Appendix D.1.

16. The code is written in Python and based on the GEModelTools package.

Income process For the idiosyncratic income process, we set the standard deviation of innovations (σ_e) to 0.13, and the persistence (ρ_e) to 0.966, following the estimates in Floden and Lindé (2001). This yields an income process which is similar to the ones commonly used in the HANK literature (e.g., McKay et al., 2016, Guerrieri and Lorenzoni, 2017). We approximate the AR(1) process with a discrete Markov process using the method of Rouwenhorst (1995).

Domestic consumption baskets The CES share parameters α_F and α_T are based on OECD data on the composition of consumption. We fix the steady-state share of tradables in the consumption basket to match the average ratio across OECD countries, where we take consumption of non-durables to be tradables and consumption of services to be non-tradables. We find that tradables make up 41% of the consumption basket; $\alpha_T = 0.41$. We set α_F (the share of foreign tradables in the tradable consumption basket of domestic households) to match the OECD average share of imports going to final consumption (29%). This yields $\alpha_F = 0.64$.

The elasticities of substitution, $\eta_{T,NT}$ and $\eta_{H,F}$, are less easily disciplined by the data. Evidence on the elasticity between tradable and non-tradable goods is sparse. Estimates of the elasticity of substitution between different varieties of goods are often around 3 to 5 (e.g., Feenstra et al., 2018), but given that the data used in these studies typically reflects tradable goods more than non-tradables, these estimates do not carry over to our case. Ostry and Reinhart (1992) and Akinci (2011) estimate the elasticity between tradables and non-tradables directly, and find it to be in the range of 0.5 to 1.5. We set $\eta_{T,NT} = 0.5$ as our baseline, and then consider a higher value as a robustness check. Regarding the elasticity of substitution between home and foreign tradables, we follow Boehm et al. (2023), who find a long-run elasticity of 2. We conduct robustness checks also for this parameter value.

Foreign economy The foreign interest rate is set to 2% per year. We set the size of the export market, α^*, to match the average of imports and exports to GDP across OECD countries, which is 42%. We set the export elasticity, η^*, to 2 and the export rigidity, ρ^*, to 0.9. These numbers imply a first-year elasticity of around 0.75, rising to a long-run elasticity of about 2, in line with the empirical evidence reported by Boehm et al. (2023).

Government For the monetary policy rule, we set a Taylor rule coefficient of 1.5 and an interest-rate smoothing parameter of 0.9. Regarding public consumption and debt, we set $\frac{G}{GDP} = 0.2$ and $\frac{B}{GDP} = 0.58$ annualized, as these are the average values in our data sample. For the debt dynamics in response to transitory shocks, we assume fully debt-financed fiscal policy for the first $t_B = 50$ quarters, with gradually increasing taxation afterwards to ensure that the public debt level returns to the steady state level. The functional form for the tax rate, τ_t, is reported in Appendix C. Regarding the composition of government spending, we assume that 80% goes to the non-tradable sector, with the remaining 20% going to the domestic tradable sector, as documented by Cardi and Restout (2023).[17]

Production structure The supply side of our model is characterized by extensive input-output (IO) linkages. We discipline these using the OECD IO tables and the OECD STAN database, targeting average moments over the period 1990-2021. We proxy the non-tradable sector by the service sector, and the tradable sector by the industries in the STAN database. We calibrate the share of intermediate goods in production, α_T^X and α_{NT}^X, such that the expenditure share of intermediate goods is 81% and 57%, respectively, which are the averages across the countries in the STAN database. Finally, we assume that 30% of households are employed in the tradables sector to match the average *Trade-in-Employment* shares in the STAN database.

The input-output matrix of the model is given by:

$$\mathbf{\Theta} = \begin{array}{c} \\ T \\ NT \\ F \end{array} \begin{array}{c} \begin{array}{cc} T & NT \end{array} \\ \begin{bmatrix} 0.29 & 0.29 \\ 0.49 & 0.51 \\ 0.22 & 0.20 \end{bmatrix} \end{array},$$

where columns represent inputs, and rows output. According to the STAN database, the non-tradable sector obtains 51% of intermediate inputs from itself, while the corresponding number for the tradables sector is 29%. We use these numbers as the diagonal in $\mathbf{\Theta}$. We calibrate the share of imports in each sector ($\mathbf{\Theta}_{F,T}$, $\mathbf{\Theta}_{F,NT}$) to match i) a total import-to-GDP ratio of 41%; and ii) the ratio of imports in the tradable sector to imports in the non-tradable sector ($\frac{X_{F\to T}}{X_{F\to NT}} = 1.26$). The remaining two parameters in $\mathbf{\Theta}$ are then obtained residually. Finally, we fix the elasticity of substitution

17. Considering a sample of 18 OECD countries, these authors report an average non-tradable share of public spending of 80%, and a domestic tradable share of 18%, while 2% is directed towards imports. We assume for simplicity that the public sector does not purchase foreign tradables.

between intermediate goods from different sectors, η_X, at 0.5, which is in the middle of the range found in the literature (e.g., Atalay, 2017; Boehm et al., 2019).

Markups and nominal rigidities We set the markup on final goods to 20% in both sectors, implying elasticites of substitution for final goods of $\epsilon_T^P = \epsilon_{NT}^P = 6$. We pick the Rotemberg price adjustment costs $(\theta_T^P, \theta_{NT}^P)$ to match a Phillips curve slope of 0.1 in the non-tradable sector, and 0.2 in the tradable sector, following Nakamura and Steinsson (2008). For the wage Phillips curve, we set the markups equal to the final goods markups, $\epsilon_T^w = \epsilon_{NT}^w = 6$, as is common in the literature. We set the Rotemberg adjustment cost on wages to match a slope of 0.05, implying that wages are more sticky than prices. This allows the model to match the empirical observation that firm profits are procyclical, as emphasized by Broer et al., 2020. We calibrate the fixed costs F_T, F_{NT} such that the total supply of domestic assets equals the demand from households, and such that each sector's share of total profits matches its share of value-added.

5.2 Model fit

We are now ready to evaluate the ability of the calibrated model to account for the empirical effects of a foreign demand shock. To this end, we feed the model with smoothed versions of the estimated paths for foreign demand for domestic goods (i.e., foreign imports), foreign inflation, and the foreign nominal interest rate (these are reported in Appendix Figure D.3). Figure 4 reports the responses to a foreign demand shock in the HANK and RANK models alongside our empirical results for the domestic economy from Section 2. Both models are able to account relatively well—qualitatively as well as quantitatively—for the responses of most variables, such as output, employment, exports, inflation, and nominal and real interest rates.[18] This picture changes significantly, however, when we consider the response of consumption, including of both tradables and non-tradables (second column): While the HANK model can largely match the negative responses observed in the data for consumption and its components, the RANK model displays a counterfactual *increase* in each of these variables.

18. The jump in inflation one year after the shock is due to the fact that we are reporting annual inflation rates to be consistent with the data.

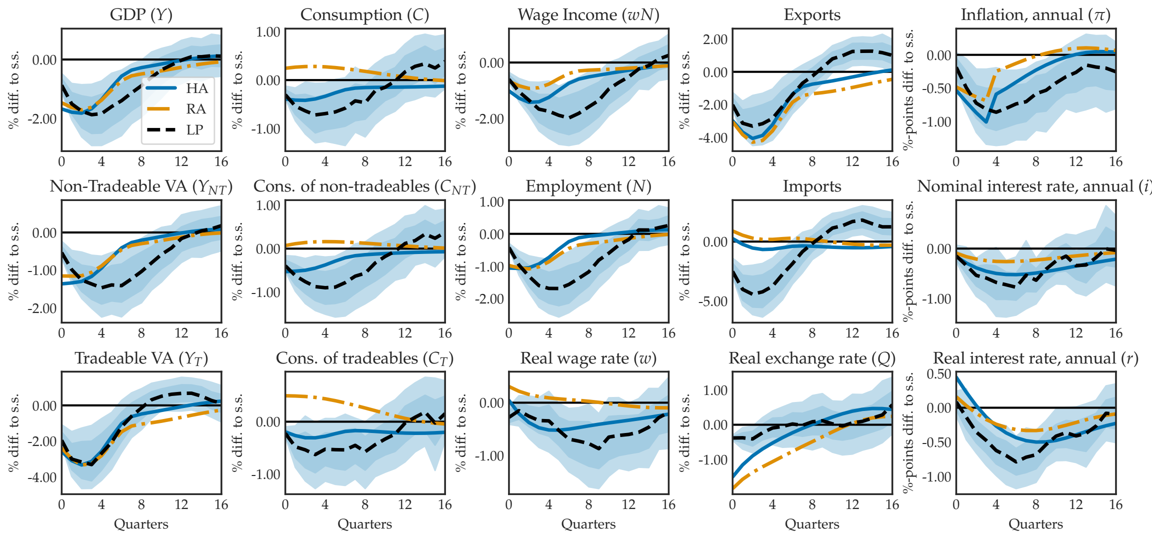


Figure 4: Response of the domestic economy to a foreign demand shock

Note: The figure shows the response of domestic variables to a foreign demand shock in the HANK and the RANK model, alongside our empirical LP-based results from Section 2.

To understand this difference, it is important to recall the analytical insights from Section 3: In the RANK model, the representative household raises current consumption via intertemporal substitution, whereas the presence of high-MPC households in the HANK model leads to a decline in consumption. We shed further light on this result in the next section. Finally, we observe that the real exchange rate appreciates in both models, and more so than in the data. This is a reflection of the fact that the domestic real interest rate declines by less than its foreign counterpart.[19] All else equal, this pushes up the response of imports, which helps explain why both models fail to deliver the big drop in imports observed in the data.

5.2.1 Fixed nominal exchange rate

Our empirical investigation yielded no evidence that the transmission of foreign demand shocks differs markedly across exchange-rate regimes. We therefore find it worthwhile to evaluate the fit of our theoretical model also under a fixed nominal exchange rate. In Appendix Figure E.1, we report the results of a similar exercise as the one conducted above, i.e., where we feed the estimated paths of foreign vari-

19. Note that the real UIP condition (4.9) can be solved forward to yield $Q_t = \prod_{k=0}^{\infty} \frac{1+r^*_{t+k}}{1+r_{t+k}} Q_{ss}$.

ables into a version of our model with a currency peg.[20] We note that all of our main findings are confirmed, although the observed differences in consumption and its components between the HANK and RANK models are of a smaller magnitude. Consumption drops by less in the HANK model, since this model underestimates the drop in employment and labor income, whereas it increases by less in the RANK model, since the real interest rate path is shifted up. For the remaining variables, the model entails a relatively good fit of the data, although the real exchange rate displays an almost flat response, in this case.

6 Transmission of foreign demand shocks

We now return to our three main empirical findings from Section 2, assessing and explaining the ability of the HANK and RANK models to account for these facts.

6.1 The response of aggregate consumption

To analyze the drivers of the aggregate consumption response in more detail, we decompose it using the linearized consumption function studied in Section 3. In the fully fledged model, the analogue to equation (3.3) is given by:

$$d\boldsymbol{C} = \underbrace{\boldsymbol{M} d\boldsymbol{Y}^{hh}}_{\text{Disp. income}} + \overbrace{\boldsymbol{M}^r d\boldsymbol{r}}^{\text{Interest rate}} + \underbrace{\boldsymbol{M}^v \left(d\boldsymbol{r}^{\boldsymbol{a}} - d\boldsymbol{r}\right)}_{\text{Revaluation}}. \tag{6.1}$$

Recall that the first term represents the effects on consumption of disposable labor income, while the second term measures the effects of future expected real interest rates, thus primarily capturing intertemporal substitution effects. The third term represents the asset revaluation effect occurring in period 0 due to the fact that the ex-ante and ex-post returns on assets are not equalized for MIT shocks, as discussed by Auclert (2019).[21] $\boldsymbol{M}^v$ denotes the matrix of intertemporal effects on consump-

20. We use the same smoothed series for foreign demand for domestic goods and foreign inflation as above. Since the UIP condition implies that foreign and domestic nominal interest rates are equalized under a peg, we simply use the estimated path for the *domestic* nominal interest rate in this case. In practice, these two series are not identical, since no country j in our sample has a fixed exchange rate towards *all* of the countries used in the construction of $i^*_{j,t}$.

21. This effect was absent in the stylized model of Section 3, since that model featured a zero net supply of bonds and no firm profits.

tion from this channel. While this decomposition applies in both the HANK and the RANK model, the relative importance of the channels differs markedly across models. This is shown in Figure 5, which plots the three components from (6.1) following a foreign demand shock.

In the RANK model, the response of consumption is driven predominantly by the interest rate channel, with a lower real rate inducing the household to engage in intertemporal substitution to raise current consumption. In the HANK model, instead, the consumption response is driven predominantly by the decline in disposable labor income, which passes through to consumption in the presence of a large aggregate MPC. This confirms the insights from Section 3.

Note that the intertemporal substitution channel is also operative in the HANK model, with the lower real interest rate exerting a positive effect on aggregate consumption, though this channel is clearly dominated by the labor income channel. Likewise, the latter is also present in the RANK model, where it exerts a small but very persistent contribution, reflecting the extensive consumption smoothing present in permanent-income models. The distinction between intertemporal substitution in RANK models and the labor income channel in HANK models plays a key role in the HANK literature; see, e.g., Kaplan et al. (2018), who offer a reinterpretation of the aggregate effects of monetary policy through the lens of a HANK model. Finally, the revaluation effect is practically non-existent in the RANK model, while it exerts a small but persistent, positive effect in the HANK model.[22]

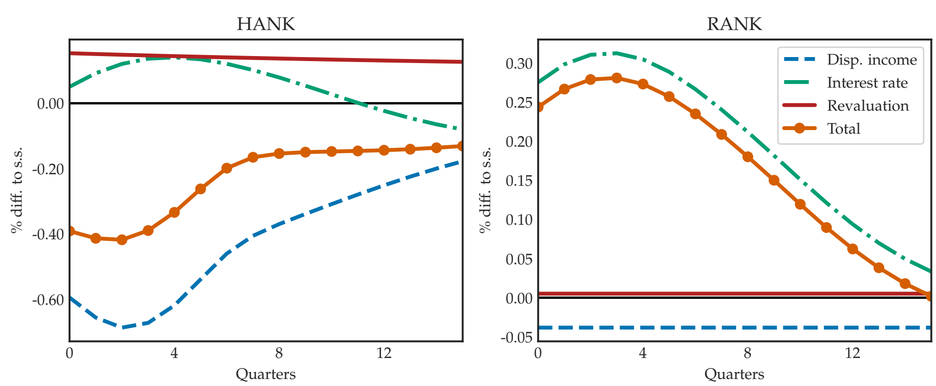


Figure 5: Decomposed consumption response to a foreign demand shock

Note: The figure shows the decomposed response of domestic consumption to a foreign demand shock according to (6.1).

22. Note that because the revaluation effect primarily affects households at the top of the wealth distribution (who act in a Ricardian manner and display low MPCs), the impact on consumption exhibits almost perfect smoothing even in the HANK model.

6.2 Consumption of tradables and non-tradables

To understand the consumption of tradables and non-tradables in more detail, we consider the linearized decomposition of the responses of these variables:

$$dC_T = \underbrace{-\eta_{T,NT}\alpha_T d\left(\frac{P_T}{P}\right)}_{\text{Substitution effect}} + \underbrace{\alpha_T dC}_{\text{Scale effect}}, \tag{6.2}$$

$$dC_{NT} = \underbrace{-\eta_{T,NT}(1-\alpha_T) d\left(\frac{P_T}{P}\right)}_{\text{Substitution effect}} + \underbrace{(1-\alpha_T)dC}_{\text{Scale effect}}. \tag{6.3}$$

The substitution effect in these equations refers to changes in the consumption of tradables and non-tradables induced by relative price changes. The scale (or income) effect represents consumption changes due to movements in the level of total consumption, as studied above. We report this decomposition in Figure 6.

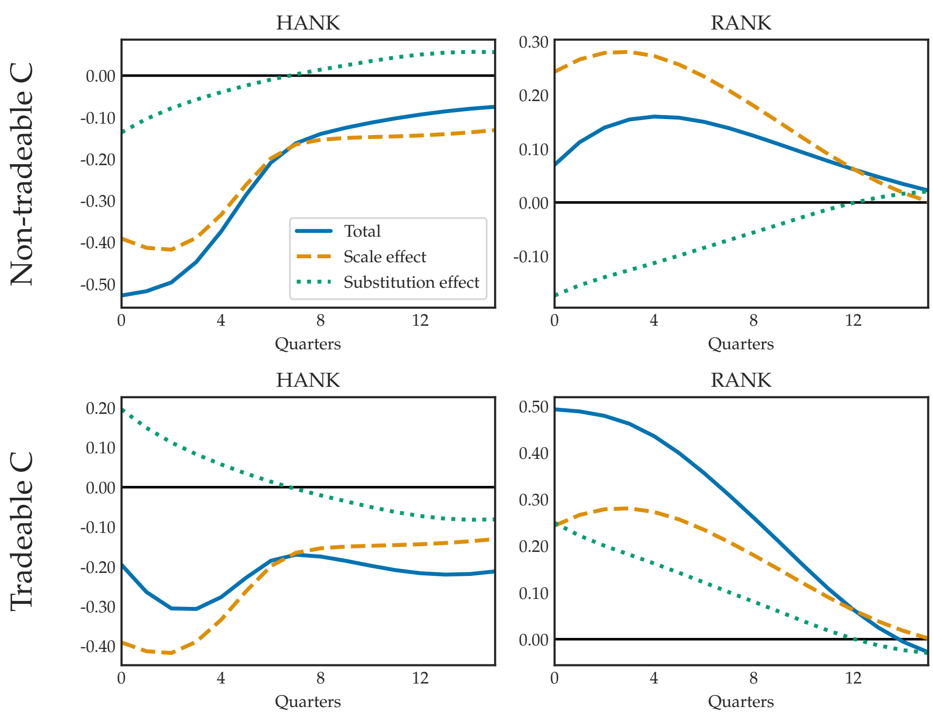


Figure 6: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock

Note: The figure shows the decomposition of the responses of tradable and non-tradable consumption following a foreign demand shock according to equations (6.2) and (6.3).

The key message from the figure is that the different responses in the two models can largely be ascribed to the scale effect, as the blue and dashed orange lines tend to follow each other closely. In the HANK model, this effect is large and negative, thus inducing the empirically observed drop in both tradable and nontradable consumption. The opposite is true in the RANK model, with the scale effect pushing both consumption types up. In both models, this effect dominates the substitution effect arising from the drop in the relative price of domestic tradable goods observed in response to the decline in foreign demand.

6.3 Can foreign demand shocks drive the business cycle?

We turn next to the third and final of our main empirical findings, the fact that—in the data—foreign demand shocks account for a large share of business-cycle fluctuations in output and other aggregate variables. We have documented above that the RANK model exhibits a negative correlation between domestic output and consumption, conditional on a foreign demand shock. Yet, the *unconditional* correlation of aggregate output and consumption is strongly positive in the data. For the 31 small open economies considered in Section 2, the average unconditional correlation between output and consumption is 0.69.[23] Effectively, this property rules out foreign demand shocks as potentially important drivers of business cycles in RANK models, consistent with the puzzling results of Justiniano and Preston (2010) and other estimated small open economy models. In our HANK model, in contrast, foreign demand shocks give rise to a positive comovement between output and consumption, in accordance with the unconditional observation.

Comovement of output and consumption Some key covariances from the data and the model can be considered to document these facts. In the first row of Table 1, we report the unconditional covariance of output and aggregate consumption in the data, as well as those of output with tradable and non-tradable consumption.[24] In the second row, we report the same covariances, but now *conditional* on identified foreign demand shocks. We then report the corresponding covariances—conditional on foreign demand shocks—from the HANK and RANK models in the bottom panel of the table. These numbers document that while the RANK model gets the sign

23. A similar argument applies to the correlation between domestic and foreign consumption, which in the RANK model is negative, conditional on a foreign demand shock, while, unconditionally, it is clearly positive in the data (0.40 in our sample).

24. We choose to focus here on covariances rather than correlations, since the former are informative of not just the sign, but also the magnitude of the comovement between two variables.

wrong, the HANK model can match the sign of the covariance between output and aggregate consumption, and account for roughly 40% of its magnitude. By bringing the conditional covariance of output and consumption in line with its unconditional counterpart in the data, the HANK model thus paves the way for foreign demand shocks to play a quantitatively important role for domestic business cycles.

	$\text{Cov}(C, Y)$	$\text{Cov}(C_{NT}, Y)$	$\text{Cov}(C_T, Y)$
Data			
Unconditional	9.71	8.89	9.07
Conditional	7.96	9.75	7.30
Model			
HANK	4.02	4.80	2.91
RANK	-3.05	-1.62	-5.11

Table 1: Covariances

Note: The table reports the covariances of domestic output with domestic consumption or either of its sectoral components.

Correlated shocks To further substantiate this point, we consider an experiment in which we allow for shocks in the model to be correlated across countries. This is a common feature in calibrated open-economy models in the RANK tradition to obtain positive cross-country comovement of macroeconomic variables; see, e.g., Backus et al. (1992) or Kose and Yi (2006). We then back out the degree of correlation between foreign and domestic demand shocks that is required to match the empirical evidence. This exercise offers a quantification of the amount of endogenous propagation of foreign demand shocks inherent in the model. To this end, we consider a *domestic* demand shock in the form of a shock to the exogenous component of households' discount factor (ϵ_t^β). We then assume that a negative foreign demand shock coincides with a negative realization of this shock, scaled such that the response of domestic aggregate consumption in the model exactly matches that in the data during the first ten quarters. We do this for each of the HANK and RANK models, and compute the correlation between the implied series for foreign and domestic GDP in each case. In the HANK model, this number is 0.27, whereas the RANK model requires a correlation of 0.95. In other words, the HANK model is able to generate most of the required propagation of foreign shocks onto domestic variables endogenously, while the RANK model requires a high degree of exogenous correlation to match the data. Thus, we conclude that the puzzling lack of comovement between domestic and foreign business cycles found by Justiniano and Preston (2010) is confirmed in the RANK model, whereas our HANK model can resolve this issue.

6.4 Fixed exchange rate

We have seen above that the responses of the domestic nominal and real interest rates play a crucial role in the RANK model. The counterfactual increase in aggregate consumption in that model can be attributed to the decline in the real interest rate, which in turn arises from the monetary policy response of the domestic central bank obeying the Taylor principle. This latter mechanism does not apply under a fixed exchange rate. We therefore revisit this case, as studied briefly at the end of the previous section, and evaluate whether this affects our results.

Under a peg, with $E_t = E_{ss}$ for all t, domestic monetary policy is dictated by the UIP condition, and the domestic real interest rate is therefore given by $dr_t = di_t^* - d\pi_{t+1}$. Thus, for the domestic real rate to decline, the foreign nominal interest rate needs to drop by more than domestic inflation. In Appendix Figure E.1, we document that this condition is satisfied in both the HANK and the RANK model, as both models display a decline in the real interest rate in response to a negative foreign demand shock, except for a short-lived initial increase. As a result, the positive response of consumption in the RANK model is confirmed under a fixed exchange rate.

This highlights the importance of modelling the foreign demand shock in line with the empirical evidence: Had we considered only a shift in the foreign demand component, M_t^*, keeping the remaining foreign variables fixed, we would have not captured the resulting decline in the foreign nominal interest rate i_t^*. This would have flipped the sign of the response of domestic consumption in the RANK model. When accounting for the empirical observation that also foreign inflation and the foreign interest rate drop, our HANK model can replicate the main empirical findings also under a fixed exchange rate, while the RANK model cannot.[25]

6.5 Robustness

Our main findings are robust to a range of modelling choices and parameter values. We first compare the household specification in our baseline model to a two-

25. In Appendix E.1, we report a complete set of results from our model with a fixed exchange rate. All main takeaways are similar to those reported above for a floating rate.

asset HANK model and a two-agent (TANK) model. We describe the details of these models and report the associated responses of output and consumption in Appendix Figure E.4. As seen from the figure, the main conclusions are unchanged under each of these specifications, both of which feature a drop in aggregate consumption of a magnitude roughly similar to our baseline model.

We have also considered an alternative specification of the financing of public expenditures, with a tax rule as in Auclert et al. (2020), according to which the government adjusts the tax rate continuously: $\tau_t - \tau = \epsilon^B \frac{B_{t-1} - B_{ss}}{Y_{ss}}$. The responses of output and consumption are reported in Appendix Figure E.5. Unsurprisingly, when the government relies more on higher taxes than on debt issuance to cover the shortfall of tax revenues after a negative foreign demand shock, the drop in consumption becomes somewhat larger in the HANK model, whereas this difference is inconsequential in the RANK model due to the presence of Ricardian equivalence. Thus, our main findings are unaffected.

We report the results of a further set of robustness checks in Appendix Figures E.6 through E.8. Notably, we show that having the central bank respond to consumer prices instead of producer prices does not change our findings, since foreign inflation also declines, thus reducing the domestic CPI. Likewise, since output drops, adding an output response to the Taylor rule does not change the sign of the interest-rate response. We also assess the robustness of our findings with respect to the values of the trade elasticities in the model, which are subject to some discussion in the existing literature. Since our findings generally emphasize income over substitution effects, they are not particularly sensitive to variations of these parameter values.

7 Implications for Stabilization Policy

When foreign demand shocks play an important role for business-cycle fluctuations in small open economies, as we have argued, it becomes relevant to study the implications of such shocks for stabilization policies. We therefore now turn to this question. Our analysis starts from the observation that for any given shortfall of foreign demand, the domestic government or central bank can always provide sufficient fiscal or monetary stimulus to stabilize *aggregate* domestic consumption. Against this backdrop, we study the ability of various policy tools to stabilize consumption of households working in each of the two domestic sectors. Our argument is that, all else equal, symmetric policies that stabilize consumption for households in the tradable and the non-tradable sectors roughly equally should be preferable.[26]

	Floating				Fixed			
	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$
Foreign demand	-1.00	-1.27	-0.91	1.40	-1.00	-1.04	-0.99	1.05
Domestic demand, β	-1.00	-0.83	-1.06	0.79	-1.00	-0.84	-1.05	0.80
Public transfers, T	1.00	0.64	1.12	0.57	1.00	0.68	1.11	0.62
Public spending, G	1.00	0.08	1.32	0.06	1.00	0.19	1.28	0.15
Monetary policy, i	1.00	1.01	1.00	1.01	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.24	0.92	1.36
Fiscal devaluation	-	-	-	-	1.00	1.16	0.95	1.22

Table 2: Cumulative effects of demand shocks and policy instruments.

Note: The domestic demand shock and all policy instruments follow AR(1) processes with a persistence of 0.75. Both demand shocks are scaled to generate a cumulative 1% *decrease* in aggregate consumption, and the policy instruments are scaled to exactly offset this. C is aggregate consumption and C_T^{hh} and C_{NT}^{hh} denote consumption of households employed in the tradable and non-tradable sectors, respectively. For all variables we report the cumulative effect over the first 16 quarters. The fiscal devaluation combines an increased VAT with a reduced payroll tax. Details are in Appendix E.4.

In the first row of Table 2, we consider the effects of a negative foreign demand shock scaled to generate a 1% cumulative drop in aggregate consumption. We then report the implied drop in consumption of households working in the tradable (C_T^{hh}) and non-tradable sector (C_{NT}^{hh}), respectively (columns 2-3), and the ratio between these two (column 4).[27] These numbers indicate that households in the tradable sector suffer the biggest drop in consumption, which is not too surprising, given that this sector is most directly affected by a reduction in foreign demand.

In comparison, the second row of Table 2 reports the corresponding numbers for a negative *domestic* demand shock (i.e., a shock to the discount factor, ϵ_t^{β}), which is assumed to follow an AR(1) process with a persistence of 0.75. This shock is seen to affect the non-tradable sector most strongly, in part because the tradable sector is less sensitive to domestic demand, and partly because the fall in domestic demand

26. We leave an analysis of the optimal policy response to foreign demand shocks for future study. For a characterization of optimal fiscal and/or monetary policies in HANK models, see Acharya and Challe (2024) and Waldstrøm (2024) for open-economy analyses in one-sector models with a focus on different types of shocks, and Le Grand et al. (2021), McKay and Wolf (2022), Acharya et al. (2023), or Dávila and Schaab (2023) for closed-economy analyses.

27. See also Appendix E.4, where we report a table corresponding to Table 2, but focused on the responses of labor income instead of consumption. This does not alter the main message.

causes a decline in domestic inflation, which leads to a depreciation of the real exchange rate, and therefore an increase in foreign demand for domestic tradables.[28]

7.1 Policy instruments under a floating exchange rate

We now consider three traditional policy instruments that may be used to offset foreign demand shocks: i) *Public transfers*, T_t, which are distributed equally among households in the two sectors; ii) *Government spending*, G_t, which flows predominantly to the non-tradable sector, as discussed in Section 5.1; iii) *Monetary policy*, implemented via changes in the exogenous component of the Taylor rule (4.20), ϵ_t^r. All three instruments are assumed to follow AR(1) processes with a persistence of 0.75, and are scaled to offset the cumulative drop in aggregate consumption entirely.

The effects are reported in rows 3 to 5 of Table 2. The effects of public transfers (row 3) largely mirror those of a domestic demand shock, making this a well-suited policy to combat such shocks. However, in the face of foreign demand shocks, transfers fail to stimulate consumption of households in the tradable sector sufficiently. The same is true—to a much larger extent—for government spending (row 4), due to the sectoral composition of G_t. Both fiscal instruments lead to an *appreciation* of the real exchange rate (see Appendix Figure E.12), which—instead of stabilizing—exacerbates the shortfall of foreign demand via expenditure switching.

In contrast, we find that monetary policy (row 5) is more successful at stabilizing consumption of households in both sectors, in large part because a monetary expansion leads to a *depreciation* of the real exchange rate and the terms of trade (see Appendix Figure E.12). This stimulates foreign demand for domestically produced tradables. Domestic demand for non-tradables is also stimulated, partly due to income and multiplier effects of higher foreign demand, and partly because of intertemporal substitution effects. Altogether, expansionary monetary policy therefore stimulates income and consumption of households in both sectors. In other words, of the tools considered here, monetary policy appears to be the most appropriate for combating foreign demand shocks.

28. The effects of foreign demand shocks are significantly more symmetric across sectors than in the model of Guo et al. (2023), who find that households in the tradable sector are much more strongly affected. Importantly, they consider a foreign demand shock only in the form of a change in foreign demand for domestic goods, whereas we also account for the changes in foreign inflation and the foreign interest rate. Furthermore, their model does not feature input-output linkages in production.

7.2 Policy instruments with a fixed exchange rate

When we turn to the case of a fixed exchange rate (columns 5-8 of Table 2), the insights from above are largely confirmed: Foreign demand shocks affect households in the tradable sector more strongly (although the difference is smaller in this case), while domestic demand shocks weigh more strongly on households in the non-tradable sector. Furthermore, while public transfers appear well-suited to combat domestic demand shocks, we observe that both T_t and (especially) G_t provide inadequate stimulus to the tradables sector (rows 3 and 4) when faced with foreign demand shocks. This shortcoming can again be attributed to the fact that expansionary fiscal policies lead to an appreciation of the real exchange rate and the terms of trade, as discussed above (see Appendix Figure E.13).

The absence of an independent monetary policy under a currency peg therefore leaves domestic policymakers without any conventional instruments to offset foreign demand shocks. As shown in row 6 of Table 2, a devaluation of the nominal exchange rate would represent a way to provide adequate stimulus to both sectors, similarly to a monetary expansion under a floating rate (see also Appendix Figure E.13). However, these results emerge under the unlikely assumption that full and immediate commitment to a one-off nominal devaluation is possible. In practice, there are a range of reasons why this type of policy may be infeasible or undesirable.

Fiscal devaluation A possible remedy discussed in the literature is to conduct a fiscal devaluation. In a representative-agent setup, Farhi et al. (2014) find that a fiscal devaluation—in the form of an increase in value-added taxes (VAT) and a reduction of payroll taxes—may successfully mimic the real effects of a nominal exchange rate devaluation. To investigate the effectiveness of a fiscal devaluation in our context, we introduce a VAT and a payroll subsidy into our baseline HANK model (see Appendix E.4 for details). We then conduct a fiscal devaluation scaled to fully offset the effect of a negative foreign demand shock on aggregate consumption.

The results are reported in the bottom row of Table 2. We find that a fiscal devaluation successfully stimulates consumption of households in both sectors, especially those in the tradables sector. The explanation is the following: A fiscal devaluation entails an increase in the payroll subsidy, which reduces the domestic cost of production. At the same time, a higher VAT affects international relative prices. This is because the VAT is levied on imported goods from the foreign country, whereas domestic exports are not subject to the VAT. Altogether, this leads to expenditure switching from foreign to domestic tradables by domestic and foreign consumers.

The left panel of Appendix Figure E.13 shows that a fiscal devaluation leads to a substantial *appreciation* of the real exchange rate, reflecting the increase in the domestic consumer price index directly resulting from a higher VAT at home. However, as indicated in the right panel of the figure, the introduction of a VAT breaks the proportionality between the real exchange rate and the terms of trade: the latter—which is defined as the ratio of the prices of imports and exports, $S_t = \frac{(1-\tau_t^v)P_{F,t}}{P_{H,t}^* E_t}$, with τ_t^v denoting the value-added tax rate, and therefore the relevant measure for expenditure switching—*depreciates* substantially, as the VAT makes domestic tradables cheaper relative to foreign tradables. In addition, the price of domestic non-tradables relative to tradables declines, thus stimulating economic activity also in the former sector. The bottom line, therefore, is that a fiscal devaluation may be an effective way to offset a shortfall of foreign demand in countries without an independent monetary policy.

8 Capital Formation

As a final step in our analysis, we now extend the model to account for capital formation, in order to assess whether this affects our main findings. To this end, we assume that—in addition to intermediate goods—production requires inputs of a CES aggregate of capital and labor. The details are described in Appendix C. The first-order conditions characterizing the optimal choices of capital ($K_{s,t}$) and investment ($I_{s,t}$) are given by:

$$Q_{s,t}^I = \beta_t^I \left(r_{s,t+1}^K + (1-\delta_K) Q_{s,t+1}^I \right), \tag{8.1}$$

$$1 + g\left(\frac{I_{s,t+1}}{I_{s,t}}\right) + g'\left(\frac{I_{s,t+1}}{I_{s,t}}\right)\frac{I_{s,t+1}}{I_{s,t}} = \beta_{t+1}^I g'\left(\frac{I_{s,t+2}}{I_{s,t+1}}\right)\left(\frac{I_{s,t+2}}{I_{s,t+1}}\right)^2 + Q_{t+1}, \tag{8.2}$$

where $Q_{s,t}^I$ is the Lagrange multiplier associated with the law of motion for capital, $r_{s,t}^K$ is the real rental rate of capital, and $g(\cdot)$ denotes investment adjustment costs. Future profits are discounted by $\beta_t^I \equiv \frac{1}{1+r_t+\epsilon_t^{INV}}$, with ϵ_t^{INV} capturing an investment wedge, to be discussed below. We set the investment adjustment cost to 10, in line with the estimated value in Auclert et al. (2020). The depreciation rate of capital (δ_K) is set to 2.5% per quarter, as is standard in the literature. The elasticity of substitution between capital and labor in production is set to 0.5, consistent with the meta-study of Gechert et al. (2022).[29]

We then turn to the quantitative results. The responses of most variables are largely unaffected by the introduction of capital (see Appendix Figure E.9). However, turning to the response of investment, we encounter the problem that the observed drop in the real interest rate leads to an *increase* in investment in both the HANK and RANK models, whereas investment displays a large *decline* in the data. Obtaining a positive comovement between consumption and investment in response to demand shocks is a well-known issue in business-cycle models (e.g., Barro and King, 1984), including those with heterogeneous agents (e.g., Auclert et al., 2020; or Bilbiie et al., 2022). While some structural remedies have been proposed in the existing literature, we opt for a reduced-form approach and introduce an *investment wedge* in the spirit of Chari et al. (2007), which takes the form of a wedge between the value of installed capital and the return on investment. Specifically, we let this wedge be given by ϵ_t^{INV}, which is assumed to follow an AR(1)-process with a persistence of 0.75. We then select the impact value of the wedge to minimize the distance between the response of investment in the model and in the data for the first ten quarters.[30]

The responses of the HANK and RANK model augmented with capital and the investment wedge are reported in Figure 7, along with our empirical results. By design, the response of investment is now consistent with the empirical evidence. Notably, the decline in investment entails a further reduction in employment and labor income, leading to a significant amplification of the drop in consumption (and its components) in the HANK model, in line with the insights of Auclert et al. (2020). In the RANK model, instead, the additional monetary stimulus implemented by the central bank determines an even larger increase in consumption via a lower path for the real interest rate. The latter also enables the model to deliver a better match of the response of the real exchange rate and, in turn, of imports, as compared to the model without capital. On the other hand, the implied drop in inflation is now overestimated. Overall, we conclude that the introduction of capital does not alter the main takeaways from our analysis, although our model can only account for the response of investment when the investment wedge is active.

29. The capital share in the CES production input is calibrated to match sector-specific expenditure shares. We also recalibrate the expenditure shares of intermediate goods to account for the use of capital in production. See Appendix D.1 for details.

30. We also considered introducing much higher adjustment costs or some form of financial friction, but found that this may change the shape of the investment response, but not its sign.

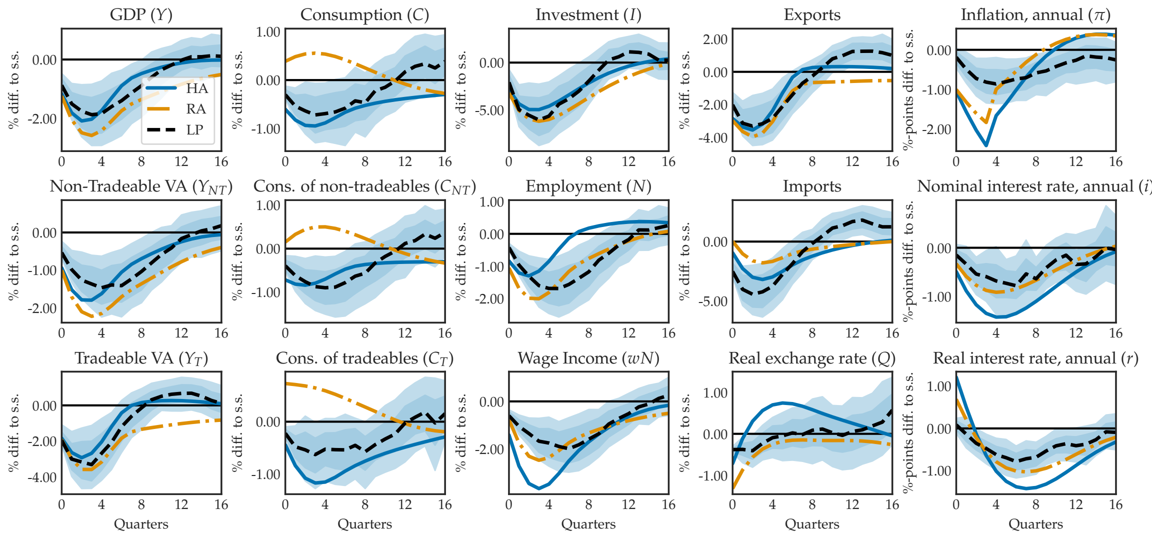


Figure 7: Response of the domestic economy to a foreign demand shock (with capital formation and investment wedge)

Note: The figure shows the response of domestic variables to a foreign demand shock in the HANK and the RANK model after the introduction of capital and an investment wedge.

9 Concluding remarks

In this paper, we have proposed a HANK model of a small open economy, and documented that this model can account for a set of empirical facts regarding the domestic response to a negative foreign demand shock. The key insight is that a strong direct labor income effect allows the model to match the observed negative response of aggregate consumption and its components. In contrast, in the absence of high-MPC households, a corresponding RANK model entails a counterfactual increase in domestic consumption, driven by intertemporal substitution. Since the HANK model implies a positive conditional comovement of output and consumption, in line with the unconditional comovement observed in the data, this model paves the way for foreign demand shocks to play a significant role in domestic business fluctuations, consistent with our empirical evidence.

The importance of foreign demand shocks poses a challenge for stabilization policies. Traditional fiscal policy tools such as public spending and transfers provide insufficient stimulus to the tradable sector. Monetary policy therefore plays a crucial role because of its ability to depreciate the terms of trade and stimulate both the tradable and non-tradable sector. These results constitute an important challenge for countries who cannot set monetary policy independently. We show that a fiscal devaluation may represent a good "substitute" for monetary policy.

Our findings call for further research in a number of directions. An important next step would be to obtain a micro-founded response of investment that can match the data, thus enabling the model to produce a positive comovement between consumption and investment. Furthermore, it would be interesting to consider a full palette of shocks to both demand and supply. An obvious candidate would be technology shocks, which are widely studied in the existing open-economy literature. This would pave the way for further insights on the international transmission of business cycles, and the relative importance of various shocks. Introducing a search-and-match labor market would enable a new transmission mechanism where foreign demand shocks affect domestic unemployment and therefore idiosyncratic uncertainty. This would likely strengthen the overall transmission. On the other hand, a more detailed specification of the labor market with workers moving across sectors might make it less challenging to stabilize foreign demand shocks, as workers would choose to relocate. In ongoing work, we are exploring these and other avenues.

References

Acharya, Sushant, and Edouard Challe. 2024. "Inequality and Optimal Monetary Policy in the Open Economy." *CEPR Discussion Paper No. DP19075.*

Acharya, Sushant, Edouard Challe, and Keshav Dogra. 2023. "Optimal Monetary Policy According to HANK." *American Economic Review* 113 (7): 1741–1782.

Acharya, Sushant, and Paolo Pesenti. 2024. "Spillovers and Spillbacks." *NBER Working Paper 32245.*

Adolfson, Malin, Stefan Laséen, Lawrence J. Christiano, Mathias Trabandt, and Karl Walentin. 2013. "Ramses II—Model Description." *Sveriges Riksbank Occasional Paper Series No. 12.*

Adolfson, Malin, Stefan Laséen, Jesper Lindé, and Mattias Villani. 2007. "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-through." *Journal of International Economics* 72 (2): 481–511.

Aggarwal, Rishabh, Adrien Auclert, Matthew Rognlie, and Ludwig Straub. 2023. "Excess Savings and Twin Deficits: The Transmission of Fiscal Stimulus in Open Economies." *NBER Macroeconomics Annual 2022* 37:325–412.

Aiyagari, S. R. 1994. "Uninsured Idiosyncratic Risk and Aggregate Saving." *The Quarterly Journal of Economics* 109 (3): 659–684.

Akinci, Ozge. 2011. "A Note on the Estimation of the Atemporal Elasticity of Substitution between Tradable and Nontradable Goods." *Working Paper.*

Alpanda, Sami, Eleonora Granziera, and Sarah Zubairy. 2021. "State Dependence of Monetary Policy across Business, Credit and Interest Rate Cycles." *European Economic Review* 140:103936.

Arias, Jonas E., Juan F. Rubio-Ramírez, and Daniel F. Waggoner. 2018. "Inference Based on Structural Vector Autoregressions Identified With Sign and Zero Restrictions: Theory and Applications." *Econometrica* 86 (2): 685–720.

Atalay, Enghin. 2017. "How Important are Sectoral Shocks?" *American Economic Journal: Macroeconomics* 9 (4): 254–80.

Auclert, Adrien. 2019. "Monetary Policy and the Redistribution Channel." *American Economic Review* 109 (6): 2333–2367.

Auclert, Adrien, Bence Bardóczy, Matthew Rognlie, and Ludwig Straub. 2021a. "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models." *Econometrica* 89 (5): 2375–2408.

Auclert, Adrien, Matthew Rognlie, Martin Souchier, and Ludwig Straub. 2021b. "Exchange Rates and Monetary Policy with Heterogeneous Agents: Sizing up the Real Income Channel." *NBER Working Paper 28872.*

Auclert, Adrien, Matthew Rognlie, and Ludwig Straub. 2020. "Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model." *NBER Working Paper 26647.*

———. 2024. "The Intertemporal Keynesian Cross." *Journal of Political Economy,* forthcoming.

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland. 1992. "International Real Business Cycles." *Journal of Political Economy* 100 (4): 745–775.

Backus, David K., and Gregor W. Smith. 1993. "Consumption and Real Exchange Rates in Dynamic Economies with Non-traded Goods." *Journal of International Economics* 35 (3): 297–316.

Barro, Robert J., and Robert G. King. 1984. "Time-separable Preferences and Intertemporal-substitution Models of Business Cycles." *The Quarterly Journal of Economics* 99 (4): 817–839.

Bayer, Christian, Alexander Kriwoluzky, Gernot J. Müller, and Fabian Seyrich. 2024. "A $HANK^2$ Model of Monetary Unions." *Journal of Monetary Economics,* forthcoming.

Bayer, Christian, Ralph Lütticke, Lien Pham-Dao, and Volker Tjaden. 2019. "Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk." *Econometrica* 87 (1): 255–290.

Bellifemine, Marco, Adrien Couturier, and Rustam Jamilov. 2023. "The Regional Keynesian Cross." *Working Paper.*

Bergholt, Drago. 2015. "Foreign shocks." *Norges Bank Working Paper 2015/15.*

Bewley, Truman. 1986. "Stationary Monetary Equilibrium with a Continuum of Independently Fluctuating Consumers." *Contributions to Mathematical Economics in Honor of Gérard Debreu,* 79–102.

Bilbiie, Florin O., Diego Känzig, and Paolo Surico. 2022. "Capital and Income Inequality: An Aggregate-demand Complementarity." *Journal of Monetary Economics* 126:154–169.

Boehm, Christoph E., Aaron Flaaen, and Nitya Pandalai-Nayar. 2019. "Input Linkages and the Transmission of Shocks: Firm-level Evidence from the 2011 Tōhoku Earthquake." *Review of Economics and Statistics* 101 (1): 60–75.

Boehm, Christoph E., Andrei A. Levchenko, and Nitya Pandalai-Nayar. 2023. "The Long and Short (Run) of Trade Elasticities." *American Economic Review* 113 (4): 861–905.

Boppart, Timo, Per Krusell, and Kurt Mitman. 2018. "Exploiting MIT Shocks in Heterogeneous-agent Economies: The Impulse Response as a Numerical Derivative." *Journal of Economic Dynamics and Control* 89:68–92.

Bouakez, Hafedh, Emanuela Cardia, and Francisco J. Ruge-Murcia. 2009. "The Transmission of Monetary Policy in a Multisector Economy." *International Economic Review* 50 (4): 1243–1266.

Broer, Tobias, Niels-Jakob Harbo Hansen, Per Krusell, and Erik Öberg. 2020. "The New Keynesian Transmission Mechanism: A Heterogeneous-agent Perspective." *The Review of Economic Studies* 87 (1): 77–101.

Burstein, Ariel, Christopher Kurz, and Linda Tesar. 2008. "Trade, Production Sharing, and the International Transmission of Business Cycles." *NBER Working Paper 13731.*

Canova, Fabio. 2005. "The Transmission of US Shocks to Latin America." *Journal of Applied Econometrics* 20 (2): 229–251.

Cardi, Olivier, and Romain Restout. 2023. "Sectoral Fiscal Multipliers and Technology in Open Economy." *Journal of International Economics* 144:103789.

Carroll, Christopher D. 2006. "The Method of Endogenous Gridpoints for Solving Dynamic Stochastic Optimization Problems." *Economics Letters* 91 (3): 312–320.

Chari, Varadarajan V., Patrick J. Kehoe, and Ellen R. McGrattan. 2007. "Business Cycle Accounting." *Econometrica* 75 (3): 781–836.

Charnavoki, Valery, and Juan J. Dolado. 2014. "The Effects of Global Shocks on Small Commodity-Exporting Economies: Lessons from Canada." *American Economic Journal: Macroeconomics* 6 (2): 207–237.

Chen, Sihao, Michael B. Devereux, Kang Shi, and Juanyi Xu. 2023. "Consumption Heterogeneity and Monetary Policy in an Open Economy." *Journal of Monetary Economics* 140:1–15.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber. 2011. "Are Micro and Macro Labor Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins." *American Economic Review* 101 (3): 471–75.

Christiano, Lawrence J., Mathias Trabandt, and Karl Walentin. 2011. "Introducing Financial Frictions and Unemployment into a Small Open Economy Model." *Journal of Economic Dynamics and Control* 35 (12): 1999–2041.

Cloyne, James, Òscar Jordà, and Alan M. Taylor. 2023. "State-dependent Local Projections: Understanding Impulse Response Heterogeneity." *NBER Working Paper 30971.*

Corsetti, Giancarlo. 2007. "New Open Economy Macroeconomics." *CEPR Discussion Paper No. DP6578.*

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc. 2008. "International Risk Sharing and the Transmission of Productivity Shocks." *Review of Economic Studies* 75 (2): 443–473.

Dávila, Eduardo, and Andreas Schaab. 2023. "Optimal Monetary Policy with Heterogeneous Agents: Discretion, Commitment, and Timeless Policy." *NBER Working Paper 24280.*

De Ferra, Sergio, Kurt Mitman, and Federica Romei. 2020. "Household Heterogeneity and the Transmission of Foreign Shocks." *Journal of International Economics* 124:103303.

Driscoll, John C., and Aart C. Kraay. 1998. "Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data." *Review of Economics and Statistics* 80 (4): 549–560.

Drozd, Lukasz A., Sergey Kolbin, and Jaromir B. Nosal. 2021. "The Trade-Comovement Puzzle." *American Economic Journal: Macroeconomics* 13 (2): 78–120.

Druedahl, Jeppe, Søren Hove Ravn, Laura Sunder-Plassmann, Jacob Marott Sundram, and Nicolai Waldstrøm. 2024. "Fiscal Multipliers in Small Open Economies With Heterogeneous Households." *Working Paper.*

Eickmeier, Sandra. 2007. "Business Cycle Transmission from the US to Germany—A Structural Factor Approach." *European Economic Review* 51 (3): 521–551.

Fagereng, Andreas, Martin B. Holm, and Gisle J. Natvik. 2021. "MPC Heterogeneity and Household Balance Sheets." *American Economic Journal: Macroeconomics* 13 (4): 1–54.

Farhi, E., G. Gopinath, and O. Itskhoki. 2014. "Fiscal Devaluations." *The Review of Economic Studies* 81 (2): 725–760.

Feenstra, Robert C., Philip Luck, Maurice Obstfeld, and Katheryn N. Russ. 2018. "In Search of the Armington Elasticity." *Review of Economics and Statistics* 100 (1): 135–150.

Feldkircher, Martin, and Florian Huber. 2016. "The International Transmission of US Shocks—Evidence from Bayesian Global Vector Autoregressions." *European Economic Review* 81:167–188.

Floden, Martin, and Jesper Lindé. 2001. "Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance?" *Review of Economic Dynamics* 4 (2): 406–437.

Fukui, Masao, Emi Nakamura, and Jón Steinsson. 2023. "The Macroeconomic Consequences of Exchange Rate Depreciations." *NBER Working Paper 31279.*

Furlanetto, Francesco, Francesco Ravazzolo, and Samad Sarferaz. 2019. "Identification of Financial Factors in Economic Fluctuations." *The Economic Journal* 129 (617): 311–337.

Gali, Jordi, and Tommaso Monacelli. 2005. "Monetary Policy and Exchange Rate Volatility in a Small Open Economy." *Review of Economic Studies* 72 (3): 707–734.

Galí, Jordi. 2015. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications.* Princeton University Press.

Galí, Jordi, J. David López-Salido, and Javier Vallés. 2007. "Understanding the Effects of Government Spending on Consumption." *Journal of the European Economic Association* 5 (1): 227–270.

Gechert, Sebastian, Tomas Havranek, Zuzana Irsova, and Dominika Kolcunova. 2022. "Measuring Capital-labor Substitution: The Importance of Method Choices and Publication Bias." *Review of Economic Dynamics* 45:55–82.

Giagheddu, Marta. 2020. "The Distributional Implications of Fiscal Devaluations." *SSRN Working Paper 3651258.*

Guerrieri, Veronica, and Guido Lorenzoni. 2017. "Credit Crises, Precautionary Savings, and the Liquidity Trap." *The Quarterly Journal of Economics* 132 (3): 1427–1467.

Guo, Xing, Pablo Ottonello, and Diego Perez. 2023. "Monetary Policy and Redistribution in Open Economies." *Journal of Political Economy Macroeconomics* 1 (1): 191–241.

Hagedorn, Marcus, Iourii Manovskii, and Kurt Mitman. 2019. "The Fiscal Multiplier." *NBER Working Paper 25571.*

Hamilton, James D. 2018. "Why You Should Never Use the Hodrick-Prescott Filter." *The Review of Economics and Statistics* 100 (5): 831–843.

Heathcote, Jonathan, and Fabrizio Perri. 2002. "Financial Autarky and International Business Cycles." *Journal of Monetary Economics* 49 (3): 601–627.

Hodrick, Robert J., and Edward C. Prescott. 1997. "Postwar U.S. Business Cycles: An Empirical Investigation." *Journal of Money, Credit and Banking* 29 (1): 1–16.

Hong, Seungki. 2020. "Emerging Market Business Cycles with Heterogeneous Agents." *Working Paper.*

Huang, Kevin X.D., and Zheng Liu. 2007. "Business Cycles with Staggered Prices and International Trade in Intermediate Inputs." *Journal of Monetary Economics* 54 (4): 1271–1289.

Huggett, Mark. 1993. "The Risk-free Rate in Heterogeneous-agent Incomplete-insurance Economies." *Journal of Economic Dynamics and Control* 17 (5): 953–969.

Ilzetzki, Ethan, Carmen M. Reinhart, and Kenneth S. Rogoff. 2019. "Exchange Arrangements Entering the Twenty-first Century: Which Anchor Will Hold?" *The Quarterly Journal of Economics* 134 (2): 599–646.

Imrohoroğlu, Ayşe. 1989. "Cost of Business Cycles with Indivisibilities and Liquidity Constraints." *Journal of Political Economy* 97 (6): 1364–1383.

Jordà, Òscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–182.

Jordà, Òscar, and Alan M. Taylor. 2016. "The Time for Austerity: Estimating the Average Treatment Effect of Fiscal Policy." *The Economic Journal* 126 (590): 219–255.

Justiniano, Alejandro, and Bruce Preston. 2010. "Can Structural Small Open-economy Models Account for the Influence of Foreign Disturbances?" *Journal of International Economics* 81 (1): 61–74.

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante. 2018. "Monetary Policy According to HANK." *American Economic Review* 108 (3): 697–743.

Kose, M. Ayhan, and Kei-Mu Yi. 2006. "Can the Standard International Business Cycle Model Explain the Relation Between Trade and Comovement?" *Journal of International Economics* 68 (2): 267–295.

Le Grand, François, Alaïs Martin-Baillon, and Xavier Ragot. 2021. "Should Monetary Policy Care About Redistribution? Optimal Fiscal and Monetary Policy with Heterogeneous Agents." *Working Paper.*

Lubik, Thomas A., and Frank Schorfheide. 2007. "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation." *Journal of Monetary Economics* 54 (4): 1069–1087.

McKay, Alisdair, Emi Nakamura, and Jón Steinsson. 2016. "The Power of Forward Guidance Revisited." *American Economic Review* 106 (10): 3133–58.

McKay, Alisdair, and Christian K. Wolf. 2022. "Optimal Policy Rules in HANK." *Working Paper.*

Mumtaz, Haroon, and Paolo Surico. 2009. "The Transmission of International Shocks: A Factor-Augmented VAR Approach." *Journal of Money, Credit and Banking* 41:71–100.

Nakamura, Emi, and Jón Steinsson. 2008. "Five Facts About Prices: A Reevaluation of Menu Cost Models." *The Quarterly Journal of Economics* 123 (4): 1415–1464.

Obstfeld, Maurice, and Kenneth Rogoff. 2000. "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?" *NBER Working Paper 7777.*

Oskolkov, Aleksei. 2023. "Exchange Rate Policy and Heterogeneity in Small Open Economies." *Journal of International Economics* 142:103750.

Ostry, Jonathan D., and Carmen M. Reinhart. 1992. "Private Saving and Terms of Trade Shocks: Evidence from Developing Countries." *IMF Economic Review* 39 (3): 495–517.

Plagborg-Møller, Mikkel, and Christian K. Wolf. 2021. "Local Projections and VARs Estimate the Same Impulse Responses." *Econometrica* 89 (2): 955–980.

Rouwenhorst, K. Geert. 1995. "10 Asset Pricing Implications of Equilibrium Business Cycle Models." *Frontiers of Business Cycle Research,* 294–330.

Rubio-Ramírez, Juan F., Daniel F. Waggoner, and Tao Zha. 2010. "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference." *Review of Economic Studies* 77 (2): 665–696.

Schmitt-Grohé, Stephanie, and Martın Uribe. 2003. "Closing Small Open Economy Models." *Journal of International Economics* 61 (1): 163–185.

Smets, Frank, and Raf Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1 (5): 1123–1175.

Uhlig, Harald. 2005. "What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure." *Journal of Monetary Economics* 52 (2): 381–419.

Waldstrøm, Nicolai. 2024. "Supply Shocks and Household Heterogeneity in Open Economies: Implications for Optimal Monetary Policy." *Working Paper.*

Zhou, Haonan. 2022. "Open Economy, Redistribution, and the Aggregate Impact of External Shocks." *SSRN Working Paper 3902121.*

Appendix: Contents

A Empirical Appendix

This appendix contains various details about our empirical approach, data selection and transformation, and a battery of robustness checks of our empirical findings.

A.1 Sign restrictions

We begin by providing additional details about our identification strategy.

A.1.1 Method

We define the 4×4 matrix of horizon-h (reduced form) impulse responses as:

$$C_h \equiv \begin{pmatrix} \beta_{1,h} & \beta^Y_{1,h} & \beta^\pi_{1,h} & \beta^i_{1,h} \\ \beta_{2,h} & \beta^Y_{2,h} & \beta^\pi_{2,h} & \beta^i_{2,h} \\ \beta_{3,h} & \beta^Y_{3,h} & \beta^\pi_{3,h} & \beta^i_{3,h} \\ \beta_{4,h} & \beta^Y_{4,h} & \beta^\pi_{4,h} & \beta^i_{4,h} \end{pmatrix},$$

for $h = 1, \ldots, H$ and $C_0 = I$. As in Rubio-Ramírez et al. (2010), the structural horizon-h impulse-response matrix is

$$\Theta_h = C_h B Q,$$

where Q is a 4×4 orthogonal matrix, and BB' is the Cholesky decomposition of the covariance matrix of the Wold innovation $\varepsilon_{t,h} = (\varepsilon_{t,1}, \varepsilon^y_{t,1}, \varepsilon^\pi_{t,1}, \varepsilon^i_{t,1})'$, such that B has strictly positive diagonal elements, c.f. Plagborg-Møller and Wolf (2021). Sign restrictions can then be imposed as follows, for each $n = 1, 2, ..., N$:

1. Draw $Q^{(n)}$ from the subspace of a uniform distribution of 4×4 orthogonal matrices consistent with the relevant zero restrictions (i.e., the "small open economy assumption"), following Arias et al. (2018).
2. Draw $C_h^{(n)}$ from a normal distribution with mean C_h and standard deviation given by the estimated standard errors of C_h, for all h.
3. Compute $\Theta_h^{(n)} = C_h^{(n)} B Q^{(n)}$, for all h.
4. If the following condition is satisfied, keep the draw of $Q^{(n)}$:

$$S_m \Theta^{(n)} e_m \geq 0, \quad m = 1, 2, 3, 4,$$

where $\Theta^{(n)} \equiv (\Theta_0^{(n)'}, \Theta_1^{(n)'}, \ldots, \Theta_H^{(n)'})'$, and S_m is a matrix set to impose the sign restrictions (see details below), as in Rubio-Ramírez et al. (2010). e_m denotes column m of a 4×4 unit matrix.

5. If the number of accepted draws of Q exceeds a given threshold (which we set to 500), stop. Otherwise set $n = n + 1$, and return to step 1.

The impulse responses reported in Figures 1 and 2 (as well as those in the robustness checks below) represent the median of the accepted impulse responses, while the confidence bands reflect the percentiles of the distribution of these.

Table A.1 presents a complete summary of the sign and zero restrictions we impose. All of these are imposed only on impact. We have checked that our findings are robust when we impose the restrictions for several quarters after the shock. As discussed in the main text, all of these assumptions are in line with existing work.

	Domestic	Foreign demand	Foreign supply	Foreign mon. pol.
Z	+	*	*	*
Y^*	0	+	+	+
π^*	0	+	-	+
i^*	0	+	-	-

Table A.1: Structural restrictions

Note: Rows indicate variables, and columns indicate structural shocks. "+" indicates a positive sign restriction (i.e., a positive response of a given variable to a *positive* shock of a given type), and "-" a negative one. "0" indicates a zero restriction, while "*" indicates that the response is not restricted.

Implementing the restrictions in Table A.1 requires setting the matrices S_m as follows:

$$S_1 = \begin{pmatrix} 1 & 0 & 0 & 0 \end{pmatrix}, \qquad S_2 = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix},$$

$$S_3 = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}, \qquad S_4 = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}.$$

The entire procedure can also be carried out using a structural VAR model instead of local projections. To do this, we simply replace the 4×4 matrix of horizon-h impulse responses C_h by the equivalent SVAR impulse responses.

A.2 Data description: Foreign variables

We compute a country-specific foreign variable for country j at time t, $z^*_{j,t}$, based on data for all 38 OECD countries over time, $z_{j,t}$, as follows (for example, $z_{j,t}$ could denote detrended log output):

1. **Compute raw weights.** Compute the raw weights based on exports:

$$w^{\text{raw}}_{j,p} = \frac{X_{j,p}}{\sum_{p=1}^{38} X_{j,p}} \quad \text{for } j, p = 1, \ldots, 38,$$

   where $X_{j,p}$ denotes country j's exports to country p.

2. **Adjust weights for interdependencies between small open economies.** To make sure that our "small open economy assumption" remains valid, we exclude from the construction of $z^*_{j,t}$ those countries for which country j represents a significant trading partner. Formally, if country p's exports to country j exceeds some cutoff ε, we set country p's weight in $z^*_{j,t}$ to 0:

$$\tilde{w}_{j,p} = \begin{cases} 0 & \text{if} \quad w^{\text{raw}}_{p,j} > \varepsilon \\ w^{\text{raw}}_{j,p} & \text{otherwise} \end{cases},$$

   and re-scale the resulting weights to add up to 1 for each country:

$$w_{i,j} = \frac{\tilde{w}_{i,j}}{\sum_{j=1}^{38} \tilde{w}_{i,j}}.$$

   In practice, we use a cutoff of $\varepsilon = 0.03$. To understand this step, consider Sweden as an example: Both Germany and Finland are important trading partners for Sweden. From the viewpoint of Germany, however, Sweden is not a quantitatively important trading partner, so we can safely assume that the German business cycle is exogenous to the Swedish economy. From the viewpoint of Finland, instead, Sweden is a significant trading partner, and the exogeneity assumption is violated. Hence, we include Germany in the computation of $z^*_{j,t}$ for Sweden, but exclude Finland.

   To make sure our results are not too sensitive to this approach, we consider two alternatives. The first is to use only the G7 countries (appropriately weighted) in the construction of the country-specific foreign variables. The second is to use the same foreign economy for all countries, i.e., $z^*_{j,t} = z^*_t, \forall j$.

The results from these exercises—which are reported in Figures A.11 and A.12—are very similar to those obtained with our baseline specification.

3. **Compute time-varying weights.** For each point in time, denote the set of countries for which data is available by $\mu(t)$. Define the weight at time t as the weight over these countries:

$$w_{j,p,t} = \begin{cases} \frac{w_{j,p}}{\sum_{p \in \mu(t)} w_{j,p}} & \text{if} \quad p \in \mu(t) \\ 0 & \text{otherwise.} \end{cases}$$

4. **Construct the foreign variable.**

   (a) Set the initial value of $z^*_{j,t}$ to the weighted average of the variable in question across the trading partners for which data is available in the first period:

$$z^*_{j,0} = \sum_{p=1}^{38} w_{j,p,0} z_{p,0}.$$

   (b) Update $z^*_{j,t}$ at time $t = 1, \ldots, T$ using the weighted average of the difference in the variable in question across trading partners:

$$z^*_{j,t} = z^*_{j,t-1} + \sum_{p=1}^{38} w_{j,p,t} \Delta z_{p,t}$$

When we consider a balanced panel of countries, step 3 becomes irrelevant, as the weights will be constant over time ($w_{j,p,t} = w_{j,p}$ for all t), so that $z^*_{j,t}$ is simply a weighted average of the relevant variable across trading partners at all points in time:

$$z^*_{j,t} = \sum_{p=1}^{38} w_{j,p} z_{p,t}.$$

As shown in Figure A.10, our empirical findings are largely unaltered when we use a balanced panel of countries (starting in 1996).

A.3 List of countries

Table A.2 contains a complete list of the countries we consider, and the classification we apply. We consider the G7 countries as large economies, and the remaining 31 OECD members as small open economies.[31]

Large countries	Canada, France, Germany, Italy, Japan, United Kingdom, United States of America.
Small countries	Australia, Austria, Belgium, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Ireland, Israel, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey.

Table A.2: List of countries

31. Some existing studies have considered Canada as a small open economy, e.g., Justiniano and Preston (2010). All our results are confirmed if we include Canada in the panel of small open economies.

A.4 Variable description

Symbol	Variable	Description	Measurement	Log
Y_T	Tradable value added	Gross value added in manufacturing	Chained, SA	Yes
Y_{NT}	Non-tradable value added	Gross value added in services	Chained, SA	Yes
C_T	Consumption of tradables	HH cons. of non-durable goods	Chained, SA	Yes
C_{NT}	Consumption of non-tradables	HH cons. of services	Chained, SA	Yes
I	Investment	Gross capital formation	Chained, SA	Yes
X	Exports	Exports of goods and services	Chained, SA	Yes
M	Imports	Imports of goods and services	Chained, SA	Yes
N	Employment	Total employment	Hours, SA	Yes
Q	Real exchange rate	Real CPI effective exchange rate	Index	Yes
Y	Value added	$Y = Y_T + Y_{NT}$	—	Yes
C	Consumption	$C = C_T + C_{NT}$	—	Yes
wN	Real labor compensation	See Section A.4.1		Yes
w	Real wage rate	See Section A.4.2		Yes
π	Annual CPI inflation	See Section A.4.3		No
i	Nominal annual interest rate	See Section A.4.4		No
r	Real annual interest rate	See Section A.4.5		No

Table A.3: Variable description

Note: All data is taken from the OECD database and is quarterly. All variables are detrended by a country-specific regression on $(1, t, t^2)$ after they have been transformed. "SA" indicates that a variable is seasonally adjusted. When constructing Y and C, we make sure to not simply add the underlying components, since these are chained, but to aggregate them appropriately.

A.4.1 Real labor compensation

Real labor compensation, $(wN)_t$, is computed as

$$(wN)_t = \frac{(WN)_t}{P_t^{\text{GDP}}},$$

where

- $(WN)_t$ is the total compensation of employees in current prices taken from OECD quarterly national accounts.
- P_t^{GDP} is computed as

  $$P_t^{\text{GDP}} = \frac{\text{PGDP}_t}{\text{GDP}_t},$$

  where PGDP_t and GDP_t are nominal and chained volume estimates of GDP, respectively, taken from the OECD quarterly national accounts.

A.4.2 Real wage rate

The real wage rate, w_t, is computed as

$$w_t = \frac{(wN)_t}{N_t}.$$

A.4.3 Annual CPI inflation

Annual CPI inflation, π_t, is computed as

$$\pi_t = \frac{P_t}{P_{t-4}} - 1,$$

where P_t is the quarterly consumer price index taken from the OECD CPI database.

A.4.4 Nominal annual interest rate

The nominal annual interest rate, i_t, combines two short interest rate series, both taken from the OECD Monthly Monetary and Financial Statistics (MEI):

- Immediate interest rates, Call Money, Interbank Rate.

- Short-term interest rate.

The two series are very closely correlated: Across country-years for which both are available, the correlation between them is 0.96. Thus, for each country, we simply use the longest series available.

A.4.5 Real annual interest rate

The real annual interest rate, r_t, is computed as

$$r_t = \frac{1 + i_t}{1 + \pi_{t+4}} - 1.$$

A.5 Investment

We now consider the impulse response and the variance decomposition of investment following a foreign demand shock, otherwise employing our the main specification.

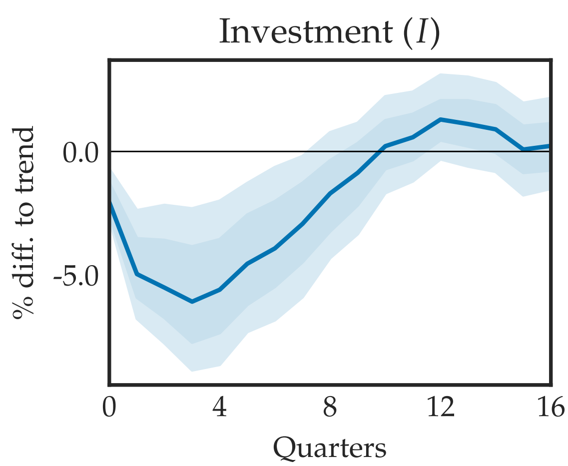


Figure A.1: LP results for investment

Note: See Figure 2.

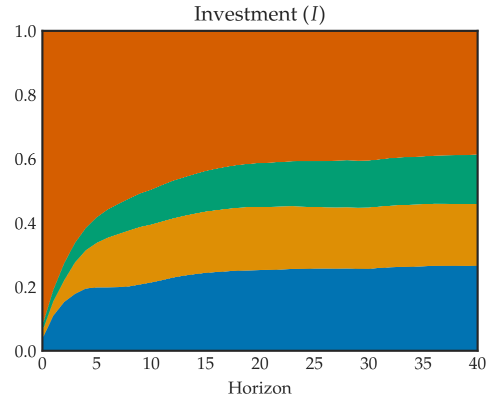


Figure A.2: Variance decomposition for investment

Note: See Figure 3.

A.6 Details of the variance decomposition

In order to compute the Forecast Error Variance Decomposition (FEVD), we take the simple approach of following the SVAR literature, which provides a mapping from structural impulse responses to the FEVD. This facilitates comparison between our results and the existing literature, which builds mostly on SVAR models.

To account for the fact that our data is pooled across several countries, we estimate the FEVD separately for each country, and then report quantiles over the set of FEVDs across all countries. We do this because otherwise the estimator of the FEVD can be severely (downward) biased. Intuitively, the IRF recovered using the pooled estimator represents an average IRF across countries. However, using the average IRF for all countries to measure the FEVD may understate the average FEVD, because the "true" IRF is different for each country. A similar issue arises when estimating the R^2 in a standard pooled linear regression.

Table A.4 sheds additional light on the variance decomposition. In the table, we report the FEVD of each variable at selected horizons alongside quantiles across the distribution of countries.

h	Y	C	I	X	M
4	25.7 (3.3,49.1)	6.1 (0.6,16.1)	13.4 (1.7,36.1)	19.9 (2.2,45.3)	22.8 (3.8,51.9)
16	27.2 (11.7,42.8)	15.0 (5.3,31.7)	23.5 (9.5,38.7)	30.8 (9.6,44.8)	30.5 (11.9,49.0)
∞	28.9 (16.4,39.5)	22.7 (11.5,34.9)	26.9 (10.5,37.7)	33.2 (14.1,44.9)	31.7 (16.3,40.6)

Table A.4: Forecast error variance decomposition (FEVD) of foreign demand shocks

Note: $h \to \infty$ refers to $h = 40$. Parentheses indicate 2.5% and 97.5% quantiles across countries.

A.7 Empirical robustness checks

We now turn to the results from a series of empirical sensitivity checks.

A.7.1 Fixed and floating exchange rates.

We estimate the IRFs separately for fixed and floating exchange rate countries. We follow the classification of country-episodes into exchange rate regimes of Ilzetzki et al. (2019). In particular, we use their monthly coarse classification, and collapse this to the quarterly frequency by averaging. We then denote a country as having a fixed exchange range in a given quarter if the value of the classification is below 2.5, and a floating exchange rate otherwise. The results for each sample are shown in Figures A.3 and A.4.

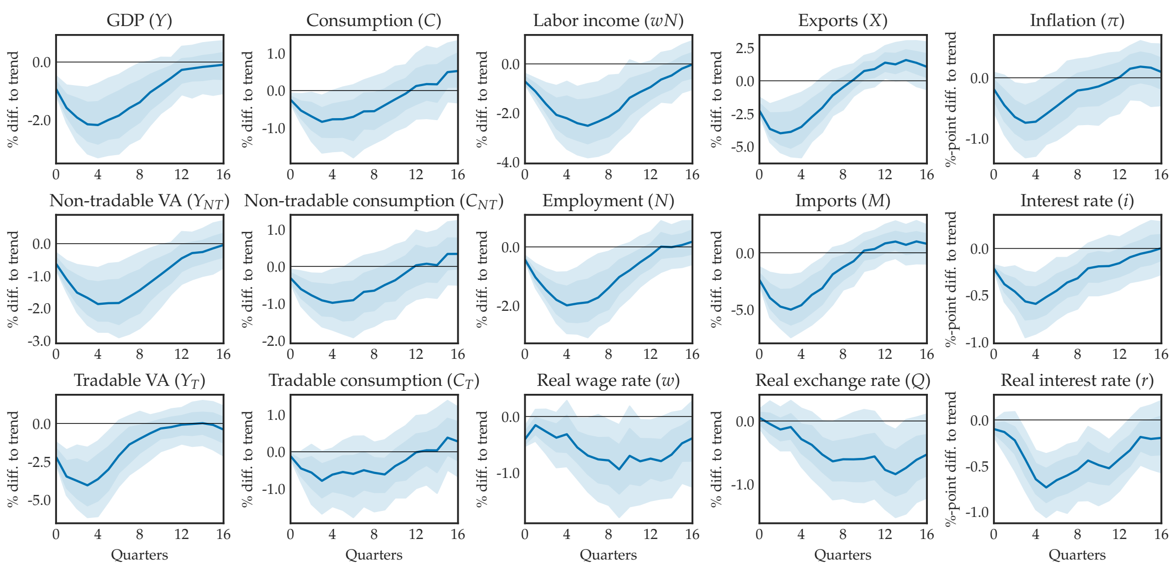


Figure A.3: LP results with fixed exchange rate countries only

Note: See Figure 2.

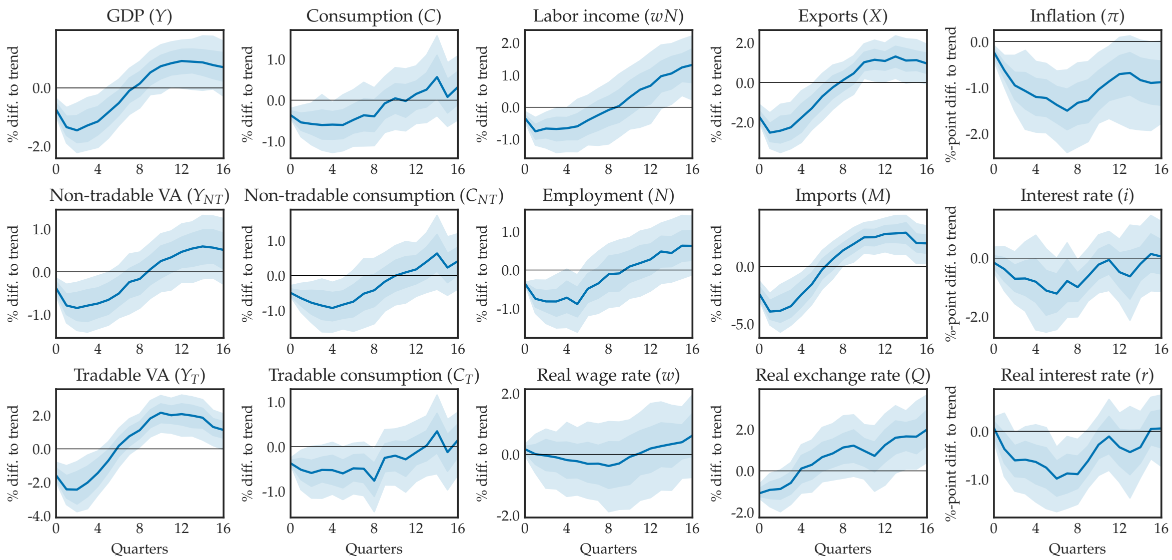


Figure A.4: LP results with floating exchange rate countries only

Note: See Figure 2.

A.7.2 Controlling for OECD-wide GDP

We consider adding OECD-wide GDP as a control variable to the main regressions. The IRFs are shown in Figure A.5.

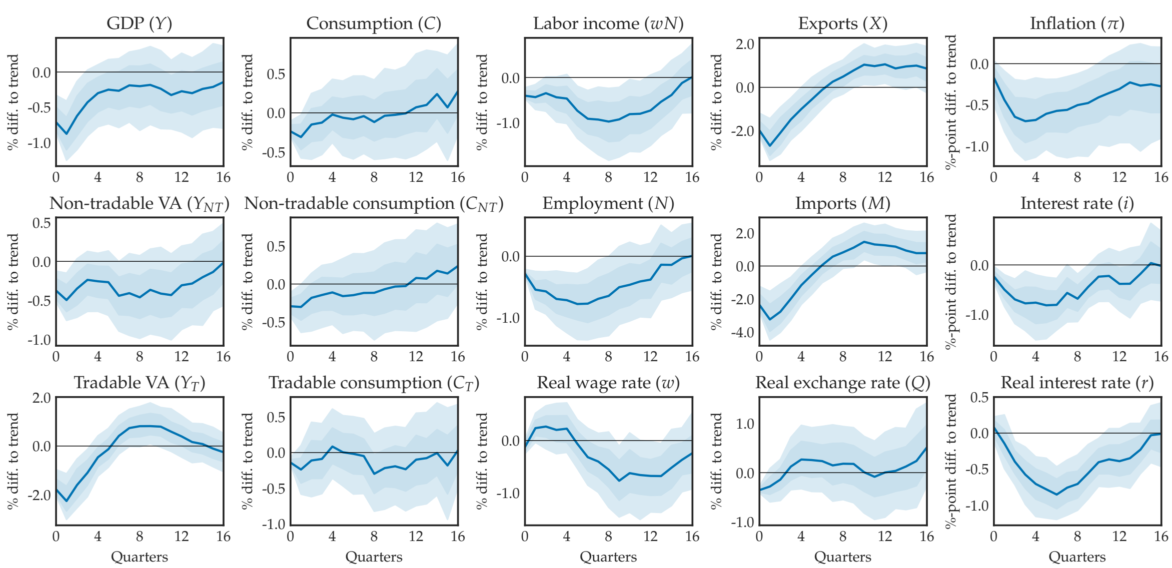


Figure A.5: LP results controlling for OECD GDP.

Note: See Figure 2.

A.7.3 Structural Vector Autoregression

We consider using a structural VAR model instead of local projections. The results are reported in Figure A.6 (solid blue lines). As seen from the figure, this produces results that largely appear like smoothed versions of our main results obtained using LP (dashed black lines), consistent with the insights of Plagborg-Møller and Wolf (2021).

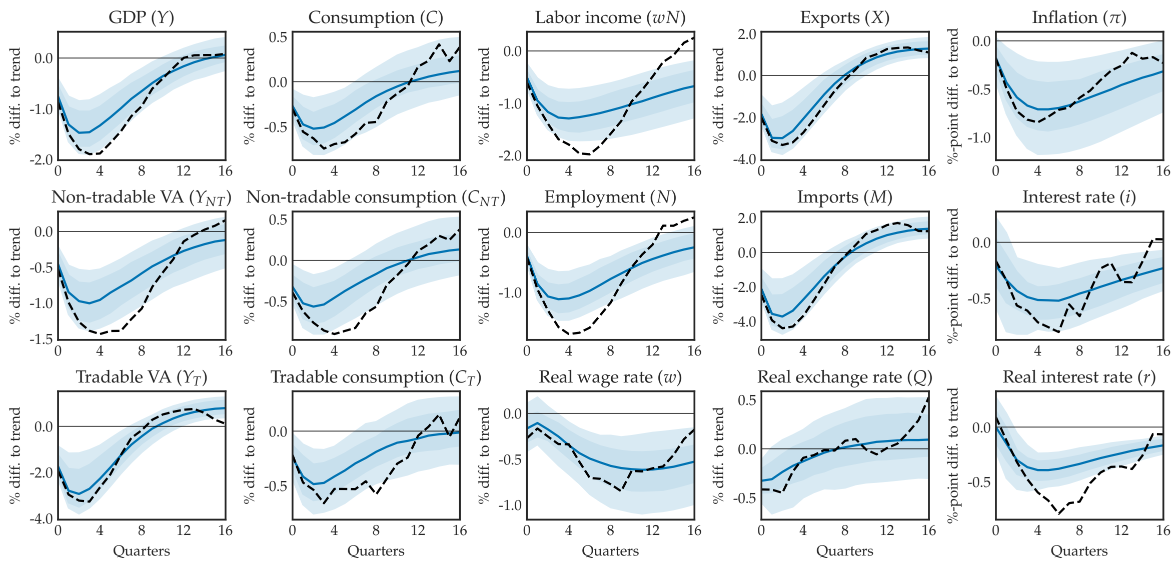


Figure A.6: SVAR IRFs

Note: The figure plots SVAR-based IRFs (solid blue lines) alongside the associated 95 and 68 pct. confidence intervals. For ease of comparison, the figure also reports our baseline LP results presented in Figure 2 (dashed black lines).

A.7.4 HP filter.

We filter the data using the HP filter (Hodrick and Prescott, 1997) instead of a regression on time trends. We use the standard quarterly smoothing parameter of $\lambda = 1600$. The IRFs are shown in Figure A.7.

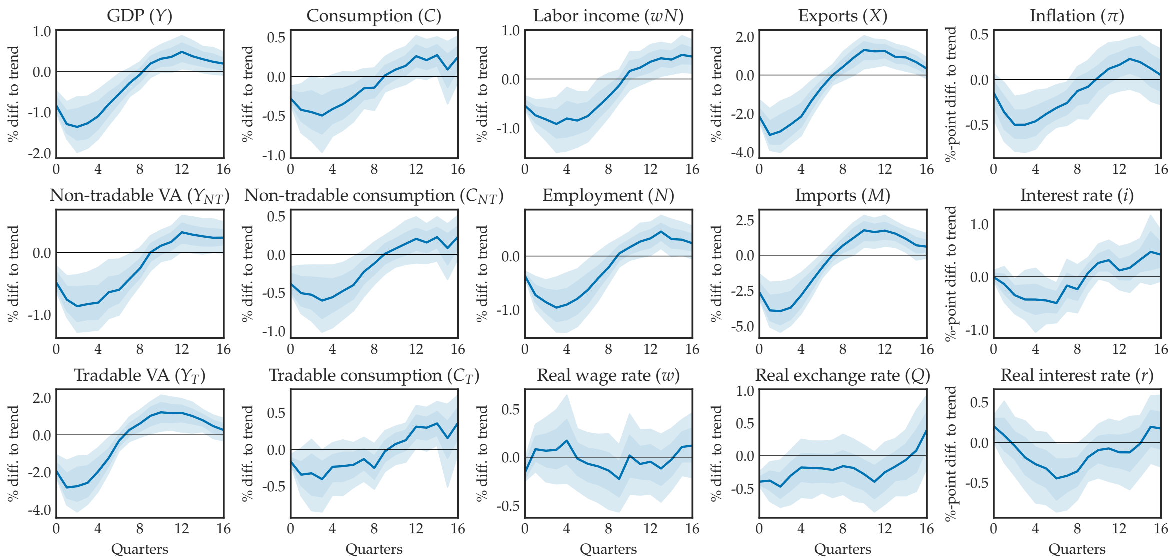


Figure A.7: LP results with HP filter

Note: See Figure 2.

A.7.5 Hamilton filter.

We filter the data using the Hamilton filter (Hamilton, 2018) instead of a regression on time trends. We use the suggested parameters of $h = 8$ and $p = 4$ (in the notation of Hamilton, 2018). The IRFs are shown in Figure A.8.

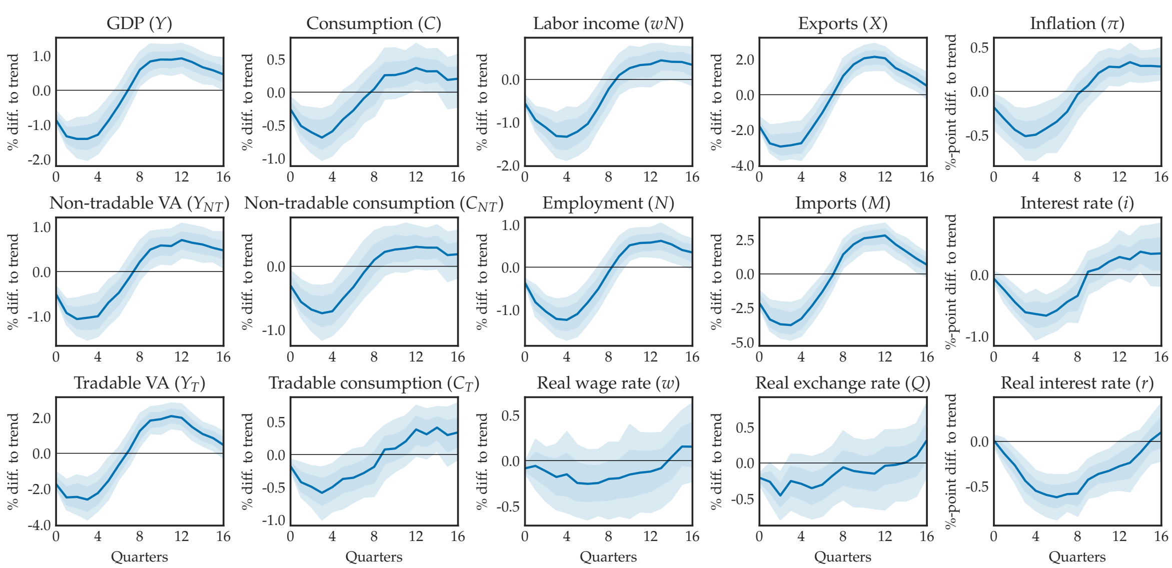


Figure A.8: LP results with Hamilton filter

Note: See Figure 2.

A.7.6 More lags.

We use $p = 4$ lags instead of $p = 2$. The IRFs are shown in Figure A.9.

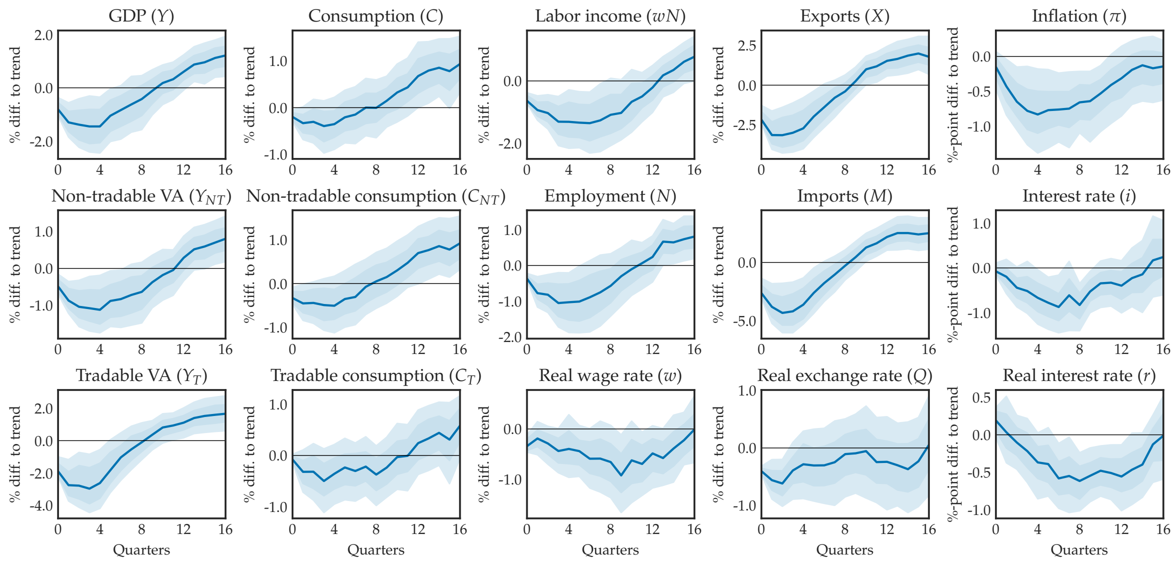


Figure A.9: LP results with 4 lags

Note: See Figure 2.

A.7.7 Balanced sample

We restrict the sample to a balanced panel starting in 1996. The IRFs are shown in Figure A.10.

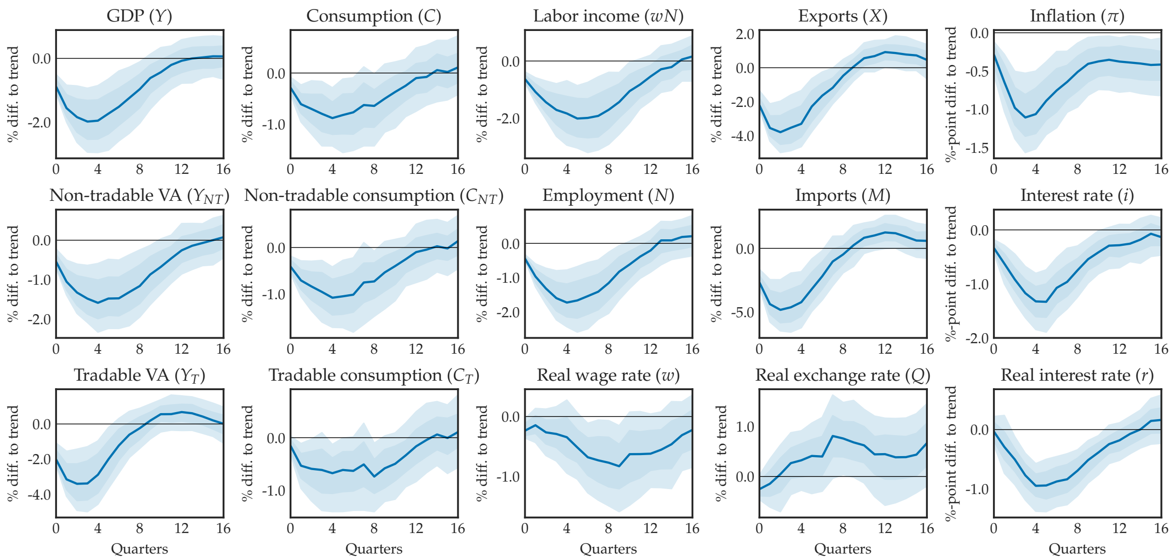


Figure A.10: LP results with balanced panel starting in 1996

Note: See Figure 2.

A.7.8 Only large economies on right-hand side.

We consider constructing $Y^*_{j,t}$ using only large economies. For the list of large economies, see Table A.2. The IRFs are shown in Figure A.11.

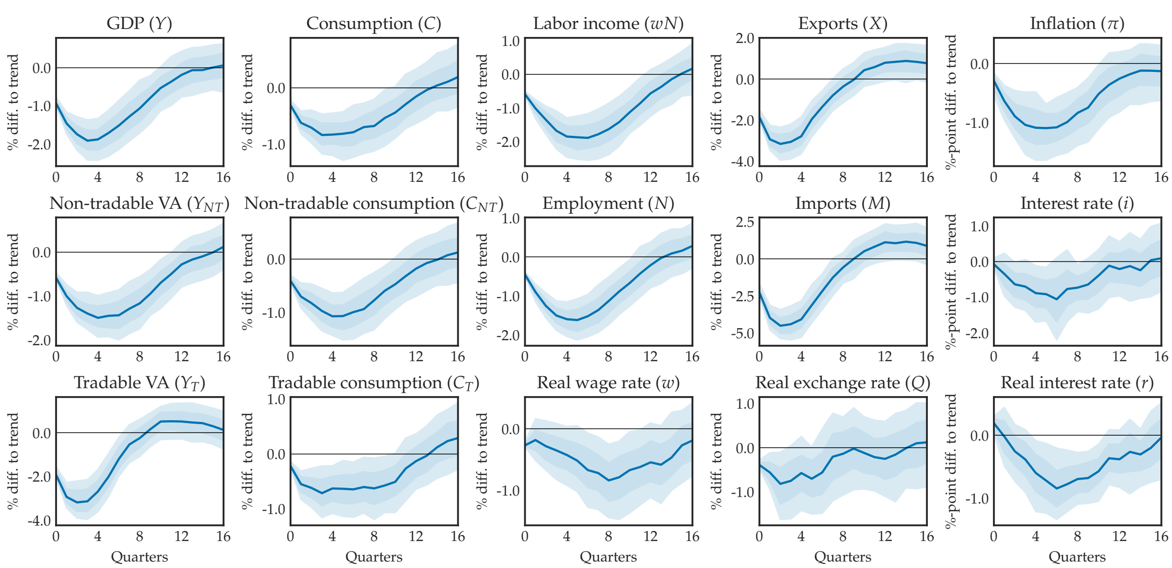


Figure A.11: LP results with only large economies used in the construction of $Y^*_{j,t}$.

Note: See Figure 2.

A.7.9 Common foreign economy

We consider constructing a common foreign economy using GDP weights, such that $Y^*_{j,t} = Y^*_t, \forall j$. The IRFs are shown in Figure A.12.

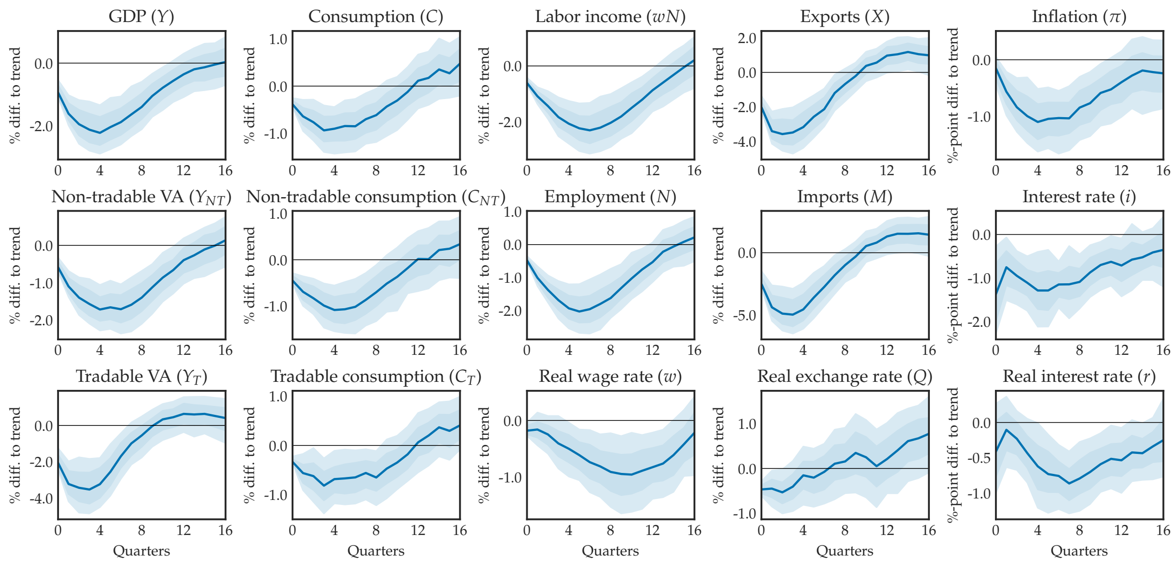


Figure A.12: LP results with a common foreign economy.

Note: See Figure 2.

A.7.10 No sign restrictions

We consider estimating IRFs without sign restrictions, i.e. simply estimating

$$Z_{j,t+h} = \beta_h Y^*_{j,t} + \sum_{k=1}^{p} \delta^Z_{h,k} Z_{j,t-k} + \sum_{k=1}^{p} \delta^{Y^*}_{h,k} Y^*_{j,t-k} + \varepsilon_{j,t,h}, \tag{A.1}$$

The IRFs are shown in Figure A.13.

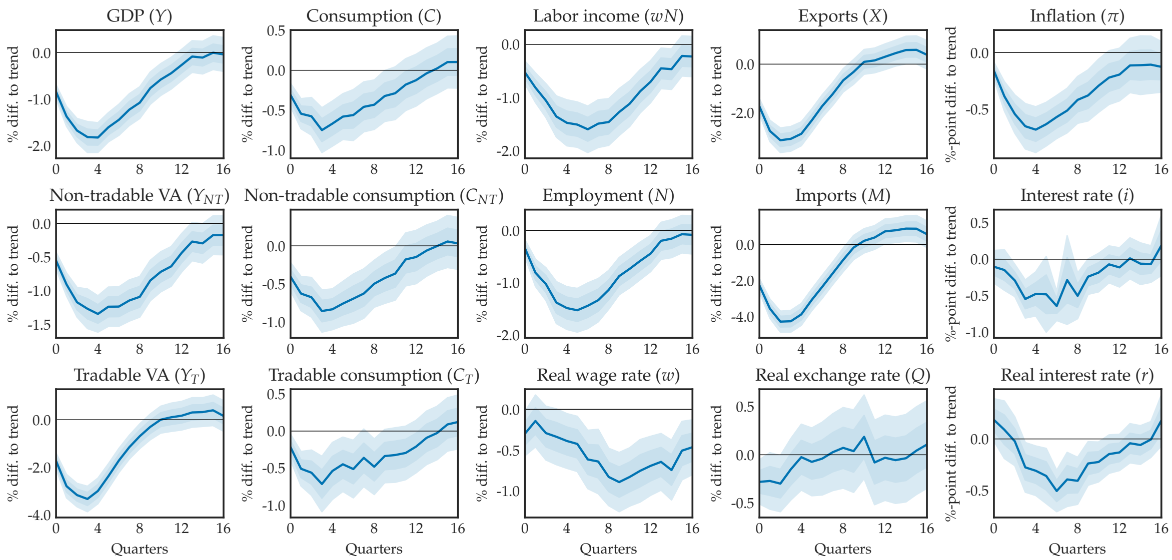


Figure A.13: LP results without sign restrictions.

Note: See Figure 2.

B Model Appendix: Stylized model

This appendix contains further details on the model presented in Section 3.

B.1 Stylized model

The following set of equations characterizes the equilibrium in a version of the canonical Gali and Monacelli (2005) small open economy model with sticky wages instead of sticky prices and with incomplete markets.

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t, \tag{B.1}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t, \tag{B.2}$$

$$C^*_{H,t} = \alpha\left(\frac{P^*_{H,t}}{P^*}\right)^{-\eta^*} C^*_t, \tag{B.3}$$

$$C_t + A_t = (1+r_{t-1})\,A_{t-1} + N_t w_t, \tag{B.4}$$

$$C_t = \mathcal{C}_t\left(\left\{r_s, Y^{hh}_s\right\}^{\infty}_{s=0}\right), \tag{B.5}$$

$$Y^{hh}_t = \frac{W_t N_t}{P_t}, \tag{B.6}$$

$$Y_t = Z_t N_t, \tag{B.7}$$

$$W_t = P_{H,t} Z_t, \tag{B.8}$$

$$w_t = \frac{W_t}{P_t}, \tag{B.9}$$

$$\pi_{w,t} = \kappa_w\left(\frac{\xi N_t^{\frac{1}{\varphi}}}{\frac{1}{\mu_w} w_t} - 1\right) + \beta\pi_{w,t+1}, \tag{B.10}$$

$$Q_t = E_t \frac{P^*_t}{P_t}, \tag{B.11}$$

$$P_t = \left[\alpha P_{F,t}^{1-\eta} + (1-\alpha) P_{H,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{B.12}$$

$$P_{F,t} = E_t P^*_t, \tag{B.13}$$

$$P^*_{H,t} = \frac{P_{H,t}}{E_t}, \tag{B.14}$$

$$i_t = i_{ss} + \phi^{\pi} \pi_{H,t+1}, \tag{B.15}$$

$$Y_t = C^*_{H,t} + C_{H,t}, \tag{B.16}$$

$$1 + r_t = (1 + r^*_t) \frac{Q_{t+1}}{Q_t}. \tag{B.17}$$

- Equations (B.1) through (B.3) are domestic and foreign household CES-demand functions, respectively.
- Equations (B.4) and (B.5) are budget constraint and consumption function of domestic households and together make up the household block of the model.
- Equation (B.6) defines real labor income.
- Equations (B.7) and (B.8) are the production function and associated first-order condition for labor demand of domestic firms.
- Equation (B.9) defines the real wage.
- Equation (B.10) is the New-Keynesian wage Philips-curve (NKWPC).
- Equation (B.11) is the definition of the real exchange rate.
- Equation (B.12) is the domestic CPI which follows from the CES specification of consumer preferences over consumption bundles.
- Equations (B.13) and (B.14) reflect the law of one price of domestic and foreign goods, respectively.
- Equation (B.15) is the Taylor rule for the domestic central bank.
- Equation (B.16) is domestic goods market clearing.
- Equation (B.17) is the UIP condition in real terms.

Linearization

We linearize the model around a non-stochastic steady state. We focus on a steady state where prices and output are normalized to 1 and the NFA position is zero.

B.1.1 Domestic price level

We start by deriving $P_{H,t}$ as a function of P_t and Q_t since this will be useful in terms of rewriting the budget constraint of the households. First, linearize (B.12) around the steady state:

$$dP_t = (1-\alpha)\, dP_{H,t} + \alpha dP_{F,t}$$
$$\Leftrightarrow dP_{H,t} = \frac{1}{1-\alpha} dP_t - \frac{1}{1-\alpha} \alpha dP_{F,t}.$$

Use the sequence space version of the law of one price in (B.13), $dP_{F,t} = dE_t + dP_t^*$, and the real exchange rate in (B.11), $dQ_t = dE_t + dP_t^* - dP_t$, to rewrite the last term and arrive at:

$$dP_{H,t} = dP_t - \frac{\alpha}{1-\alpha} dQ_t. \tag{B.18}$$

Note that this can also be written in terms of inflation:

$$d\pi_{H,t} = d\pi_t - \frac{\alpha}{1-\alpha} \left(dQ_t - dQ_{t-1}\right). \tag{B.19}$$

B.1.2 Household income

Now we express real household labor income $Y_t^{hh} \equiv W_t N_t / P_t$ as a function of domestic production and the real exchange rate. First, use (B.7) and (B.8) to substitute out W_t and Z_t:

$$Y_t^{hh} = \frac{W_t N_t}{P_t} = \frac{P_{H,t}}{P_t} Y_t.$$

Next, linearize and use (B.18):

$$dY_t^{hh} = dY_t + \left(dP_{H,t} - dP_t\right)$$
$$dY_t^{hh} = dY_t - \frac{\alpha}{1-\alpha} dQ_t. \tag{B.20}$$

B.1.3 UIP and Taylor rule

Start with (B.19) forwarded one period:

$$d\pi_{H,t+1} = d\pi_{t+1} - \frac{\alpha}{1-\alpha} \left(dQ_{t+1} - dQ_t\right). \tag{B.21}$$

The Taylor rule in (B.15) in real terms can be written as $dr_t + d\pi_{t+1} = \phi^{\pi} d\pi_{H,t+1}$. Use this to substitute π_{t+1} out of (B.21) and rearrange:

$$d\pi_{H,t+1} = -dr_t + \phi^{\pi}\pi_{H,t+1} - \frac{\alpha}{1-\alpha}\left(dQ_{t+1} - dQ_t\right). \tag{B.22}$$

Use the UIP condition in (B.17) to substitute dr_t out of (B.22):

$$(1-\phi^{\pi})d\pi_{H,t+1} + dr^* = -\frac{1}{1-\alpha}\left(dQ_{t+1} - dQ_t\right).$$

From here on we set $d\boldsymbol{r}^* = 0$ for analytical clarity. In sequence space, the above can then be written as

$$\left(1-\phi^{\pi}\right) d\boldsymbol{\pi_H} = \frac{1}{1-\alpha}\boldsymbol{G}^{r,Q} d\boldsymbol{Q}, \tag{B.23}$$

where

$$\boldsymbol{G}^{r,Q} \equiv \begin{bmatrix} 1 & -1 & 0 & \cdots & 0 \\ 0 & 1 & -1 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix}.$$

The UIP condition in sequence space and with this notation can be written as

$$d\boldsymbol{r} = -\boldsymbol{G}^{r,Q} d\boldsymbol{Q}. \tag{B.24}$$

B.1.4 NKWPC

Linearizing the NKWPC in (B.10) around the zero-inflation steady state with $\frac{1}{\mu_w} w_{ss} = \xi$ and $w_{ss} = 1$, we get:

$$\begin{aligned} d\pi_{w,t} &= \kappa_w \left(\frac{1}{\varphi} dY_t - dw_t\right) + \beta d\pi_{w,t+1} \\ \Leftrightarrow d\pi_{H,t} &= \kappa_w \left(\frac{1}{\varphi} dY_t - dw_t\right) + \beta d\pi_{H,t+1} \\ \Leftrightarrow d\pi_{H,t} &= \kappa_w \left(\frac{1}{\varphi} dY_t - \left(dP_{H,t} - dP_t\right)\right) + \beta d\pi_{H,t+1} \\ \Leftrightarrow d\pi_{H,t} &= \kappa_w \left(\frac{1}{\varphi} dY_t + \frac{\alpha}{1-\alpha} dQ_t\right) + \beta d\pi_{H,t+1}, \end{aligned}$$

where the first line uses labor market clearing $dN_t = dY_t$ and the second line uses $\pi_{w,t} = \pi_{H,t}$ from the firm FOC in (B.8). We now write the NKPC in sequence space:

$$\mathbf{\Gamma} d\boldsymbol{\pi}_{\boldsymbol{H}} = \frac{\kappa_w}{\varphi} d\boldsymbol{Y} + \kappa_w \frac{\alpha}{1-\alpha} d\boldsymbol{Q},$$

where

$$\mathbf{\Gamma} \equiv \begin{bmatrix} 1 & -\beta & 0 & \cdots & 0 \\ 0 & 1 & -\beta & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix}.$$

Finally, we can substitute out $d\boldsymbol{\pi}_{\boldsymbol{H}}$ using (B.23) to establish a link between the real exchange rate and output:

$$0 = (\phi^{\pi} - 1)\, \kappa_w \frac{1}{\varphi} d\boldsymbol{Y} + \frac{1}{1-\alpha} \left((\phi^{\pi} - 1)\, \kappa_w \alpha \boldsymbol{I} + \mathbf{\Gamma} \boldsymbol{G}^{r,Q} \right) d\boldsymbol{Q},$$

or equivalently, solving for $d\boldsymbol{Q}$,

$$d\boldsymbol{Q} = -\boldsymbol{G}^{Q,Y} d\boldsymbol{Y}, \tag{B.25}$$

where

$$\boldsymbol{G}^{Q,Y} \equiv \Xi\, (\phi^{\pi} - 1)\, \kappa_w \frac{1}{\varphi}, \tag{B.26}$$

$$\Xi \equiv \left(\frac{1}{1-\alpha} \left((\phi^{\pi} - 1)\, \alpha \kappa_w \boldsymbol{I} + \mathbf{\Gamma} \boldsymbol{G}^{r,Q} \right) \right)^{-1}. \tag{B.27}$$

B.1.5 Households

Linearizing the budget constraint in (B.4) we have

$$d\boldsymbol{C} = \boldsymbol{M}^r d\boldsymbol{r} + \boldsymbol{M} d\boldsymbol{Y}^{hh},$$

where $\boldsymbol{M}^r$ and $\boldsymbol{M}$ are the Jacobians of $\boldsymbol{C}$ w.r.t the real interest rate and household labor income $Y^{hh} = W_t N_t / P_t$, respectively. Using the expression for household income

$d\boldsymbol{Y}^{hh}$ from (B.20) yields

$$d\boldsymbol{C} = \boldsymbol{M}^r d\boldsymbol{r} + \boldsymbol{M} d\boldsymbol{Y} - \frac{\alpha}{1-\alpha} \boldsymbol{M} d\boldsymbol{Q}. \tag{B.28}$$

We can now derive the response of consumption as a function of output. Starting from (B.28) and substituting out interest rates and the real exchange rate using (B.24) and (B.25) gives

$$\begin{aligned} d\boldsymbol{C} &= \boldsymbol{M}^r d\boldsymbol{r} + \boldsymbol{M} d\boldsymbol{Y} - \frac{\alpha}{1-\alpha} \boldsymbol{M} d\boldsymbol{Q} \\ &= \boldsymbol{M}^r d\boldsymbol{r} + \boldsymbol{M} d\boldsymbol{Y} + \frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y} d\boldsymbol{Y} \\ &= -\boldsymbol{M}^r \boldsymbol{G}^{r,Q} d\boldsymbol{Q} + \boldsymbol{M} d\boldsymbol{Y} + \frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y} d\boldsymbol{Y} \\ &= \left(\boldsymbol{M} + \boldsymbol{M}^r \boldsymbol{G}^{r,Q} \boldsymbol{G}^{Q,Y} + \frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y} \right) d\boldsymbol{Y} \\ &= \boldsymbol{G}^{C,Y} d\boldsymbol{Y}, \end{aligned} \tag{B.29}$$

where

$$\boldsymbol{G}^{C,Y} \equiv \boldsymbol{M} + \boldsymbol{M}^r \boldsymbol{G}^{r,Q} \boldsymbol{G}^{Q,Y} + \frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y}. \tag{B.30}$$

Note that (B.29) describes the partial equilibrium response of consumption as a function of the response of domestic production to the foreign demand shock. Conditional on the response of production, the matrix $\boldsymbol{G}^{C,Y}$ determines the response of consumption, including its sign.

B.1.6 Goods market clearing

Substitute the CES demand functions in equations (B.1)–(B.3) into the goods market clearing condition (B.4) to get

$$\begin{aligned} dY_t &= dC_{H,t} + dC^*_{H,t} \\ &= (1-\alpha) \, dC_t + \alpha dC^*_t + \frac{\alpha}{1-\alpha} \chi dQ_t, \end{aligned}$$

where $\chi = \eta (1-\alpha) + \eta^*$ is the composite trade elasticity.

Writing this in sequence space and substituting in for $d\boldsymbol{Q}$ from (B.25) yields

$$\begin{aligned} d\boldsymbol{Y} &= (1-\alpha)\, d\boldsymbol{C} + \alpha d\boldsymbol{C}^{*} + \frac{\alpha}{1-\alpha}\chi d\boldsymbol{Q} \\ &= (1-\alpha)\, d\boldsymbol{C} - \frac{\alpha}{1-\alpha}\chi \boldsymbol{G}^{Q,Y} d\boldsymbol{Y} + \alpha d\boldsymbol{C}^{*}. \end{aligned}$$

Use (B.29) to derive the general equilibrium solution for output in response to a foreign demand shock as

$$\begin{aligned} d\boldsymbol{Y} &= (1-\alpha)\, \boldsymbol{G}^{C,Y} d\boldsymbol{Y} - \frac{\alpha}{1-\alpha}\chi \boldsymbol{G}^{Q,Y} d\boldsymbol{Y} + \alpha d\boldsymbol{C}^{*} \\ &= \left\{ \boldsymbol{I} - (1-\alpha)\boldsymbol{G}^{C,Y} + \frac{\alpha}{1-\alpha}\chi \boldsymbol{G}^{Q,Y} \right\}^{-1} \alpha d\boldsymbol{C}^{*} \\ &= \boldsymbol{G}^{Y,C^{*}} d\boldsymbol{C}^{*}, \end{aligned} \tag{B.31}$$

where

$$\boldsymbol{G}^{Y,C^{*}} = \left\{ \boldsymbol{I} - (1-\alpha)\boldsymbol{G}^{C,Y} + \frac{\alpha}{1-\alpha}\chi \boldsymbol{G}^{Q,Y} \right\}^{-1} \alpha. \tag{B.32}$$

Finally, insert this into (B.29) to get that

$$d\boldsymbol{C} = \left(\boldsymbol{M} + \boldsymbol{M}^{r} \boldsymbol{G}^{r,Q} \boldsymbol{G}^{Q,Y} + \frac{\alpha}{1-\alpha} \boldsymbol{M} \boldsymbol{G}^{Q,Y} \right) \boldsymbol{G}^{Y,C^{*}} d\boldsymbol{C}^{*}.$$

B.1.7 Floating vs. fixed exchange rate regimes

We now consider the case of a fixed exchange rate, in which case the Taylor rule (B.15) is replaced by $dE_t = 0$. From the definition of the real exchange rate $Q_t = E_t \frac{P_t^*}{P_t}$ under the assumption of a constant foreign price level, we get $dQ_t = -dP_t$. Combining with the linearized version of (B.12) and using $dP_{F,t} = 0$ we find that:

$$dP_{H,t} = \frac{1}{1-\alpha} dP_t = -\frac{1}{1-\alpha} dQ_t.$$

We get the following expression for household income:

$$
\begin{aligned}
dY_t^{hh} &= dY_t + (dP_{H,t} - dP_t) \\
&= dY_t + \left(-\frac{1}{1-\alpha} dQ_t - (-dQ_t)\right) \\
&= dY_t - \frac{\alpha}{1-\alpha} dQ_t,
\end{aligned}
$$

which is unchanged compared to the floating exchange rate case.

Next, we consider the implications for the matrix $\boldsymbol{G}^{Q,Y}$, whose entries depend on the Taylor rule under a floating exchange rate. Note that the matrix $\boldsymbol{G}^{r,Q}$ depends only on the real UIP condition, which still holds under a peg.

To proceed, start from the real UIP condition $dr_t = dr_t^* + dQ_{t+1} - dQ_t$ and rewrite it in terms of cross-country inflation levels using the Fisher equation:

$$
\begin{aligned}
di_t - d\pi_{t+1} &= dr_t^* + dQ_{t+1} - dQ_t \\
\Leftrightarrow -d\pi_{t+1} &= dr_t^* - di_t^* + dQ_{t+1} - dQ_t \\
\Leftrightarrow -d\pi_{t+1} &= -d\pi_{t+1}^* + dQ_{t+1} - dQ_t,
\end{aligned}
$$

where the second line uses $di_t = di_t^*$, which follows from the fixed exchange rate assumption. Using $d\pi_{H,t} = \frac{1}{1-\alpha} d\pi_t$ from (B.1.7) and writing in sequence-space yields:

$$
d\boldsymbol{\pi_H} = \frac{1}{1-\alpha}\left(\boldsymbol{G}^{r,Q} d\boldsymbol{Q} + d\boldsymbol{\pi}^*\right).
$$

Inserting in the NKPC and solving for $d\boldsymbol{Q}$ gives:

$$
\begin{aligned}
\boldsymbol{\Gamma}\frac{1}{1-\alpha}\left(\boldsymbol{G}^{r,Q} d\boldsymbol{Q} + d\boldsymbol{\pi}^*\right) &= \kappa_w \frac{1}{\varphi} d\boldsymbol{Y} + \kappa_w \frac{\alpha}{1-\alpha} d\boldsymbol{Q} \\
\Leftrightarrow \boldsymbol{\Gamma}\frac{1}{1-\alpha} d\boldsymbol{\pi}^* &= \kappa_w \frac{1}{\varphi} d\boldsymbol{Y} + \frac{1}{1-\alpha}\left[\kappa_w \alpha - \boldsymbol{\Gamma}\boldsymbol{G}^{r,Q}\right] d\boldsymbol{Q} \\
\Leftrightarrow d\boldsymbol{Q} &= \left(\frac{1}{1-\alpha}\left[\kappa_w \alpha - \boldsymbol{\Gamma}\boldsymbol{G}^{r,Q}\right]\right)^{-1}\left\{\boldsymbol{\Gamma}\frac{1}{1-\alpha} d\boldsymbol{\pi}^* - \kappa_w \frac{1}{\varphi} d\boldsymbol{Y}\right\}.
\end{aligned}
$$

Defining $\Xi_{\text{Peg}} \equiv \left(\frac{1}{1-\alpha}\left[\kappa_w \alpha - \boldsymbol{\Gamma}\boldsymbol{G}^{r,Q}\right]\right)^{-1}$ we obtain a relation similar to that from the floating exchange rate model:

$$
d\boldsymbol{Q} = \Xi_{\text{Peg}}\left\{\boldsymbol{\Gamma}\frac{1}{1-\alpha} d\boldsymbol{\pi}^* - \kappa_w \frac{1}{\varphi} d\boldsymbol{Y}\right\}.
$$

The notable difference is that under a floating exchange rate, we have found that Ξ tends to have positive entries (for the parameter combinations we consider), whereas Ξ_{Peg} tends to have negative entries. Hence shifting exchange rate regime flips the sign of the $\boldsymbol{Q}, \boldsymbol{Y}$ relation. In the absence of a domestic monetary policy response to increasing inflation, the sign of the movement in the domestic real interest rate flips over. If we set $d\boldsymbol{\pi}^* = 0$ we obtain the following expression for $\boldsymbol{G}^{Q,Y}$ under a peg:

$$\boldsymbol{G}^{Q,Y} = \Xi_{\text{Peg}} \kappa_w \frac{1}{\varphi},$$

such that $d\boldsymbol{Q} = -\boldsymbol{G}^{Q,Y} d\boldsymbol{Y}$. From here on, the rest of the algebra carries through to the main results using the new definition of $\boldsymbol{G}^{Q,Y}$.

C Model Appendix: Quantitative model

This appendix contains additional details on the model in Section 4.

C.1 Producers

We begin by stating the problem of the producers in the economy, and the associated first-order conditions. We choose to present the problem in the most general way possible, which means that we are including a VAT, τ_t^v, and a payroll subsidy, ζ_t^p (used for the study of fiscal devaluations in Section 7), as well as capital formation (as considered in Section 8). The version relevant for our baseline model presented in Section 4 is obtained by setting $\tau_t^v = \zeta_t^p = 0$ and $\alpha_s^K = 0$. Note that the production function for the model with capital is given by:

$$Z_{s,t} = \mathcal{Z}_s X_{s,t}^{\alpha_s^X} H_{s,t}^{1-\alpha_s^X} - F_s, \tag{C.1}$$

where $H_{s,t}$ is a CES aggregate of labor and capital:

$$H_{s,t} = \left[\left(1 - \alpha_s^K\right)^{\frac{1}{\eta_{KL}}} L_{s,t}^{\frac{\eta_{KL}-1}{\eta_{KL}}} + \left(\alpha_s^K\right)^{\frac{1}{\eta_{KL}}} K_{s,t}^{\frac{\eta_{KL}-1}{\eta_{KL}}} \right]^{\frac{\eta_{KL}}{\eta_{KL}-1}}.$$

Here, $0 \leq \alpha_s^K \leq 1$ is the share parameter for capital, and $\eta_{KL} > 0$ is the elasticity of substitution between labor and capital. As noted above, when α_s^K equals zero, this collapses to the expression presented in Section 4 (see 4.14).

The problem of the firm can be stated as:

$$V_{s,t}^F \equiv \max_{P_{s,t}, Z_{s,t}, X_{s,t}, L_{s,t}, K_{s,t}} \left\{ D_{s,t} + \frac{1}{1+r_t} V_{s,t+1}^F \right\}$$

s.t.

$$Z_{s,t}^j = \left(\frac{P_{s,t}^j}{P_{s,t}} \right)^{-\epsilon^P} Z_{s,t},$$

and subject to the production function. Flow dividends are given by:

$$D_{s,t} = (1 - \tau_t^v) \frac{P_{s,t} Z_{s,t} - P_{s,t}^X X_{s,t}}{P_t} - \left(1 - \zeta_t^p\right) \frac{W_{s,t}}{P_t} L_{s,t} - r_{s,t}^K K_{s,t} - (1 - \tau_t^v) \frac{\theta_s^P}{2} \pi_{s,t}^2 Z_{s,t}.$$

Denote by $\lambda_{s,t}$ the Lagrange multiplier associated with the demand function (4.13).

The first-order conditions for factor demands are:

$$(1-\tau_t^v)\,\frac{P_{s,t}}{P_t}\frac{\partial Z_{s,t}}{\partial X_{s,t}} - (1-\tau_t^v)\,\frac{P_{s,t}^X}{P_t} - \lambda_{s,t}\frac{\partial Z_{s,t}}{\partial X_{s,t}} = 0,$$
$$(1-\tau_t^v)\,\frac{P_{s,t}}{P_t}\frac{\partial Z_{s,t}}{\partial L_{s,t}} - \left(1-\zeta_t^p\right)\frac{W_{s,t}}{P_t} - \lambda_{s,t}\frac{\partial Z_{s,t}}{\partial L_{s,t}} = 0,$$
$$(1-\tau_t^v)\,\frac{P_{s,t}}{P_t}\frac{\partial Z_{s,t}}{\partial K_{s,t}} - r_{s,t}^K - \lambda_{s,t}\frac{\partial Z_{s,t}}{\partial K_{s,t}} = 0.$$

Defining real marginal costs as $mc_{s,t} = (1-\tau_t^v)\,\frac{P_{s,t}}{P_t} - \lambda_{s,t}$ we get the first-order conditions for optimal inputs of intermediate goods, labor, and capital:

$$mc_{s,t}\frac{\partial Z_{s,t}}{\partial X_{s,t}} = (1-\tau_t^v)\,\frac{P_{s,t}^X}{P_t}, \tag{C.2}$$
$$mc_{s,t}\frac{\partial Z_{s,t}}{\partial L_{s,t}} = \left(1-\zeta_t^p\right)\frac{W_{s,t}}{P_t}, \tag{C.3}$$
$$mc_{s,t}\frac{\partial Z_{s,t}}{\partial K_{s,t}} = r_{s,t}^K. \tag{C.4}$$

The marginal products of labor and capital are given by:

$$\frac{\partial Z_{s,t}}{\partial X_{s,t}} = \alpha_s^X\frac{Z_{s,t}}{X_{s,t}},$$
$$\frac{\partial Z_{s,t}}{\partial L_{s,t}} = \left(1-\alpha_s^X\right)\left(1-\alpha_s^K\right)^{\frac{1}{\eta_{KL}}}\mathcal{Z}_s X_{s,t}^{\alpha_s^X} H_{s,t}^{\frac{1}{\eta_{KL}}-\alpha_s^X} L_{s,t}^{-\frac{1}{\eta_{KL}}},$$
$$\frac{\partial Z_{s,t}}{\partial K_{s,t}} = \left(1-\alpha_s^X\right)\left(\alpha_s^K\right)^{\frac{1}{\eta_{KL}}}\mathcal{Z}_s X_{s,t}^{\alpha_s^X} H_{s,t}^{\frac{1}{\eta_{KL}}-\alpha_s^X} K_{s,t}^{-\frac{1}{\eta_{KL}}}.$$

The first-order condition for price-setting ($P_{s,t}$) is:

$$(1-\tau_t^v)\,\frac{1}{P_t}Z_{s,t} - (1-\tau_t^v)\,\theta_s^P\left(\frac{P_{s,t}}{P_{s,t-1}}-1\right)Z_{s,t}\frac{1}{P_{s,t-1}} - \epsilon^P\lambda_{s,t}\left(\frac{P_{s,t}^j}{P_{s,t}}\right)^{-\epsilon^P-1}Z_{s,t}\frac{1}{P_{s,t}}$$
$$+\frac{\left(1-\tau_{t+1}^v\right)}{1+r_t}\theta_s^P\left(\frac{P_{s,t+1}}{P_{s,t}}-1\right)Z_{s,t+1}\frac{P_{s,t+1}}{P_{s,t}^2} = 0.$$

Imposing a symmetric equilibrium, we may rewrite this as:

$$\pi_{s,t}\left(1+\pi_{s,t}\right) = \frac{\epsilon^P}{\theta_s^P}\left(\frac{mc_{s,t}}{(1-\tau_t^v)} - \frac{P_{s,t}}{P_t}\frac{1}{\mu_s}\right) + \frac{1}{1+r_t}\frac{\left(1-\tau_{t+1}^v\right)}{\left(1-\tau_t^v\right)}\pi_{s,t+1}\left(1+\pi_{s,t+1}\right)\frac{Z_{s,t+1}}{Z_{s,t}},$$

where $\frac{1}{\mu} = \frac{\epsilon^P - 1}{\epsilon^P}$.

In the model with capital, producers rent capital services from capital firms, which own and accumulate capital, subject to the following standard law of motion for capital:

$$K_{s,t+1} = (1 - \delta_K) K_{s,t} + I_{s,t}. \tag{C.5}$$

Capital firms maximize profits, which are given by $r^K_{s,t} K_{s,t} - I_{s,t} - g\left(\frac{I_{s,t}}{I_{s,t-1}}\right) I_{s,t}$, where $r^K_{s,t}$ is the real rental rate of capital, and $g\left(\frac{I_{s,t}}{I_{s,t-1}}\right) = \frac{\phi^I}{2}\left(\frac{I_{s,t}}{I_{s,t-1}} - 1\right)^2$ is a quadratic adjustment cost.

C.2 Intermediate-good retailers

Demand for intermediate goods in sector s is:

$$X_{s\to s,t} = \Theta_{s\to s}\left(\frac{P_{s,t}}{P^X_{s,t}}\right)^{-\eta_X} X_{s,t}, \tag{C.6}$$

$$X_{s'\to s,t} = \Theta_{s'\to s}\left(\frac{P_{s',t}}{P^X_{s,t}}\right)^{-\eta_X} X_{s,t}, \tag{C.7}$$

$$X_{F\to s,t} = \Theta_{F\to s}\left(\frac{P_{F,t}}{P^X_{s,t}}\right)^{-\eta_X} X_{s,t}. \tag{C.8}$$

Correspondingly, the price index of the intermediate-good bundle is then given by:

$$P^X_{s,t} = \left[\Theta_{s\to s}\left(P_{s,t}\right)^{1-\eta_X} + \Theta_{s'\to s}\left(P_{s',t}\right)^{1-\eta_X} + \Theta_{F\to s}\left(P_{F,t}\right)^{1-\eta_X}\right]^{\frac{1}{1-\eta_X}}.$$

C.3 Labor unions

Within each sector, aggregate labor supply is assembled from all union-specific tasks using a CES technology:

$$L_{s,t} = \left(\int_j \left(L^j_{s,t}\right)^{\frac{\epsilon^W - 1}{\epsilon^W}}\right)^{\frac{\epsilon^W}{\epsilon^W - 1}},$$

where $\epsilon^W > 0$ is the elasticity of substitution between labor types. The problem of union j in sector s is to maximize the discounted stream of future utility of its members, net of a virtual Rotemberg adjustment cost on nominal wages:

$$\sum_{t=0}^{\infty} \beta_t^U \left(\int \{u(c_{i,s,t}) - \nu(l_{i,s,t})\} \, d\mathcal{D}_t - \frac{\theta_s^W}{2} \left(\frac{W_{s,t}^j}{W_{s,t-1}^j} - 1 \right)^2 \right),$$

where β_t^U denotes the discount factor of the union, which we set to $\beta_t^U = \frac{1}{1+r_t}$, as in Hagedorn et al. (2019). The solution to this problem yields the sector-specific New Keynesian wage Phillips Curve reported in the main text.

C.4 Specification of the tax rate

We apply the following functional form for the tax rate τ_t:

$$\tau_t = \begin{cases} \tau_{ss} & \text{if } t < t_B \\ (1-\omega(\tilde{t}))\tau_{ss} + \omega(\tilde{t})\tilde{\tau}_t & \text{if } t \in [t_B, t_B + \Delta_B], \tilde{t} = (t - t_B)/\Delta_B, \\ \tilde{T}_t & \text{if } t > t_B + \Delta_B \end{cases}$$

where

$$\tilde{\tau}_t = \tau_{ss} (B_{t-1}/B_{ss})^{\varepsilon_B},$$
$$\omega(x) = 3x^2 - 2x^3 \in [0,1], \text{ and } \omega'(x) > 0 \text{ for } x \in [0,1].$$

We set $\Delta_B = 20$ such that the full effect of stabilizing taxes is phased in over another 20 quarters (after the initial $t_B = 50$ quarters of constant taxes). Finally, we set $\epsilon_B = 1$ such that taxes increase when government debt is higher than in steady state, and convergence back to the steady-state level of debt is thus ensured. Our results are fully robust to alternative assumptions regarding the phase-in. We explore the implications of allowing an immediate gradual adjustment on the tax rate below.

C.5 Debt-dependent interest rate

To close the HANK and RANK models in the same way, we assume that there is a debt-dependent interest rate premium, ι_t, in the UIP condition. It is given by

$$\iota_t = \begin{cases} 0 & \text{if } t < t_{NFA} \\ \omega(\tilde{t})\tilde{\iota}_t - 1 & \text{if } t \in [t_{NFA}, t_{NFA} + \Delta_B], \tilde{t} = (t - t_{NFA}) / \Delta_{NFA}, \\ \tilde{\iota}_t - 1 & \text{if } t > t_{NFA} + \Delta_{NFA} \end{cases}$$

where

$$\tilde{\iota}_t = (NFA_{t-1}/NFA_{ss})^{\varepsilon_{NFA}},$$
$$\omega(x) = 3x^2 - 2x^3 \in [0,1], \text{ and } \omega'(x) > 0 \text{ for } x \in [0,1].$$

We choose $t_{NFA} = 250$, $\Delta_{NFA} = 30$ and $\epsilon_{NFA} = 0.5$. Our results are again not sensitive to the exact phase-in chosen, as long as it initiates far out in the future.

D Summary of parameter values

Table D.1 and D.2 summarize the parameter values employed in the baseline calibration of the model.

	Description	Value	Target/source
	Foreign economy		
i^*	Foreign interest rate (annual)	2%	Standard value
α^*	Size of export market	0.42	$\frac{\text{(Exports+Imports)/2}}{\text{GDP}} = 42\%$
η^*	Armington elasticity	2.00	Boehm et al. (2023)
ρ^*	Export rigidity	0.90	Boehm et al. (2023)
	Households		
$1/\sigma$	Intertemporal sub. elasticity	0.4	Standard value
φ	Frisch elasticity	0.5	Chetty et al. (2011)
$\bar{\beta}$, HA	Mean discount factor	0.944	Foreign interest rate
$\bar{\beta}$, RA	Mean discount factor	0.995	Foreign interest rate
$\Delta\beta$	Discount factor dispersion	0.047	MPC $=$ 0.51 (annual)
ρ_e	Persistence of idiosyncratic income	0.966	Floden and Lindé (2001)
σ_e	Std. of idiosyncratic income	0.13	Floden and Lindé (2001)
s_T	Share of households working in T	0.30	Data
α_T	Share of T in home basket	0.41	Data
α_F	Share of foreign T in home basket	0.64	$\frac{C_F}{\text{Imports}} = 29\%$
$\eta_{T,NT}$	Sub. elasticity for C_T and C_{NT}	0.5	Akinci (2011)
$\eta_{H,F}$	Sub. elasticity for C_F and C_H	2.0	Boehm et al. (2023)
	Government and monetary policy		
$\frac{G}{GDP}$	Public consumption to GDP	0.20	Data
$\frac{B}{GDP}$	Government debt to GDP	0.58	Data
s_T^G	Share of G going to T	0.20	Cardi and Restout (2023)
ϕ^π	Taylor rule coefficient	1.5	Standard value
ρ^r	Degree of interest rate smoothing	0.90	Standard value

Table D.1: Calibration of foreign economy, households and government

	Description	Value	Target/source
	Production and input-output structure		
α_T^X	Intermediate goods share, T	0.81	$\frac{P_T^X X_T}{P_T^X X_T + W_T N_T} = 0.81$
α_{NT}^X	Intermediate goods share, NT	0.57	$\frac{P_{NT}^X X_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT}} = 0.57$
η_X	Sub. elasticity for intermediates	0.5	See text
ϵ_T^P	Sub. elasticity for final goods, T	6	Markup of 20%
ϵ_{NT}^P	Sub. elasticity. for final goods, NT	6	Markup of 20%
ϵ_T^w	Sub. elasticity for labor, T	6	Markup of 20%
ϵ_{NT}^w	Sub. elasticity for labor, NT	6	Markup of 20%
F_T	Fixed cost, T	0.22	$\frac{\text{Wealth}}{\text{Income}} = 2.5$ (annual)
F_{NT}	Fixed cost, NT	0.33	$\frac{D_T}{D} = \frac{Y_T}{Y}$
	Nominal rigidities		
θ_T^P	Rotemberg price parameter, T	30	Slope of NKPC = 0.2
θ_{NT}^P	Rotemberg price parameter, NT	60	Slope of NKPC = 0.1
θ_T^w	Rotemberg wage parameter, T	120	Slope of NKWPC = 0.05
θ_{NT}^w	Rotemberg wage parameter, NT	120	Slope of NKWPC = 0.05
	Model with capital formation		
η_{KL}	Sub. elasticity for capital-labor	0.5	Gechert et al. (2022)
δ_K	Depreciation rate of capital	0.025	Smets and Wouters (2003)
ϕ^I	Investment adjustment cost	10	Auclert et al. (2020)
α_T^K	Capital share, T	0.35	$\frac{r_T^K K_T}{P_T^X X_T + W_T N_T + r_T^K K_T} = 0.09$
α_{NT}^K	Capital share, NT	0.39	$\frac{r_{NT}^K K_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}} = 0.21$
α_T^X	Intermediate goods share, T	0.74	$\frac{P_T^X X_T}{P_T^X X_T + W_T N_T + r_T^K K_T} = 0.74$
α_{NT}^X	Intermediate goods share, NT	0.46	$\frac{P_{NT}^X X_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}} = 0.46$

Table D.2: Calibration of firms and sectors

D.1 Calibration details

We now describe some details of the calibration strategy outlined in the main text.

D.1.1 Sectoral data

We calibrate the supply side of the economy using the OECD STAN database using the longest time span available. In the following, we assume that the tradable sector ("T") in the model corresponds to the manufacturing sector in the data (STAN code C, ISIC 4 code: D10T33), and the non-tradable sector ("NT") corresponds to the service sector, which in the OECD classification is the sum of Market Services and non-Market Services (STAN codes: G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U).

To calibrate the Cobb-Douglas share parameter in the production function (α_s^X), we need sectoral data on the cost of each input; $P_s^X X_s$ and $W_s N_s$. For costs associated with labor we use "total labor costs" (variable name : LABR), while for $P_s^X X_s$ we use total purchases of intermediate goods (variable name : INTI). We then calibrate α_s^X to match the following target:

$$\text{Spending on intermediate inputs} = \frac{P_s^X X_s}{P_s^X X_s + W_s N_s}.$$

In the model with capital, we also need data on the costs associated with capital, $r_s^K K_s$, in order to also pin down α_s^K. Data on total costs associated with capital is not readily available. Instead, we use the capital accumulation equation in steady state:

$$K_s = \frac{I_s}{\delta_K},$$

which relates the capital stock to investment and the deprecation rate. We obtain data on investment from the STAN database using gross fixed capital formation (variable name : GFCF). Then, multiplying through by the steady state cost of capital $r^K = \delta_K + r$, we obtain a measure of the cost of capital:

$$r_s^K K_s = \frac{\delta^K + r}{\delta^K} I_s,$$

where we use values of r and δ^K as described in the main text. We proceed to calibrate the parameters α_s^X and α_s^K to match the following two targets:

$$\text{Spending on intermediate inputs} = \frac{P_s^X X_s}{P_s^X X_s + W_s N_s + r_s^K K_s},$$
$$\text{Spending on capital} = \frac{r_s^K K_s}{P_s^X X_s + W_s N_s + r_s^K K_S}.$$

Input-output matrix For the input-output matrix of the model, we use the input-output matrix from the STAN database for the year 2010. Given that the model features only two broader sectors, we need to recalculate the IO matrix. We first define total spending on intermediate goods in each sector as:

$$X_T = X_{NT\to T} + X_{T\to T} + X_{F\to T},$$
$$X_{NT} = X_{NT\to NT} + X_{T\to NT} + X_{F\to NT}.$$

We then specify the IO matrix as:

$$\mathbf{\Theta} = \begin{array}{c} \\ T \\ NT \\ F \end{array} \begin{array}{c} \begin{array}{cc} T & NT \end{array} \\ \begin{bmatrix} \frac{X_{T\to T}}{X_T} & - \\ - & \frac{X_{NT\to NT}}{X_{NT}} \\ - & - \end{bmatrix} \end{array},$$

where we have left four elements empty, namely the amount of intermediate goods purchased from the other domestic sector sector and from abroad. We calibrate the model to match i) the aggregate import-to-GDP ratio, and ii) the ratio of imports in the tradable sector to imports in the non-tradable sector $\frac{X_{F\to T}}{X_{F\to NT}}$. This allows us to pin two additional parameters in $\mathbf{\Theta}$. The remaining parameters are obtained from the restriction that the columns must sum to 1.[32]

Import of final goods. To calibrate the share of foreign tradables in the domestic consumption basket, α_F, we use data on imports by end-use contained in the OECD dataset *BTDIXE_I4*. We then calculate total imports, M, as the sum of im-

32. In principle we could calibrate the remaining entries in $\mathbf{\Theta}$ using data on import of intermediate goods by the tradable sector. However, given our calibration of domestic consumption of tradables C_T, using that strategy implies that the ratio of imported intermediates to value-added in the tradables sector becomes too high. The consequence of this is that households' imports of final goods are almost zero, since at the aggregate level we match an import-to-GDP ratio of 42%.

ports used as intermediate inputs in production, M^X, and imports going to household consumption, M^C. We calibrate α_F to match the ratio of household imports over aggregate imports, $\frac{M^C}{M^X+M^C}$, which for our sample equals 29%.

D.1.2 Jacobians

We now present some properties of the calibrated household structure.

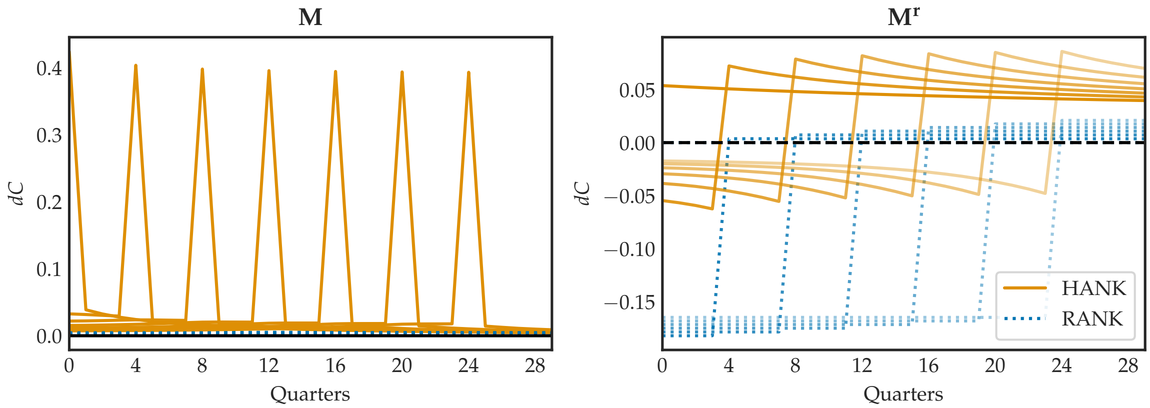
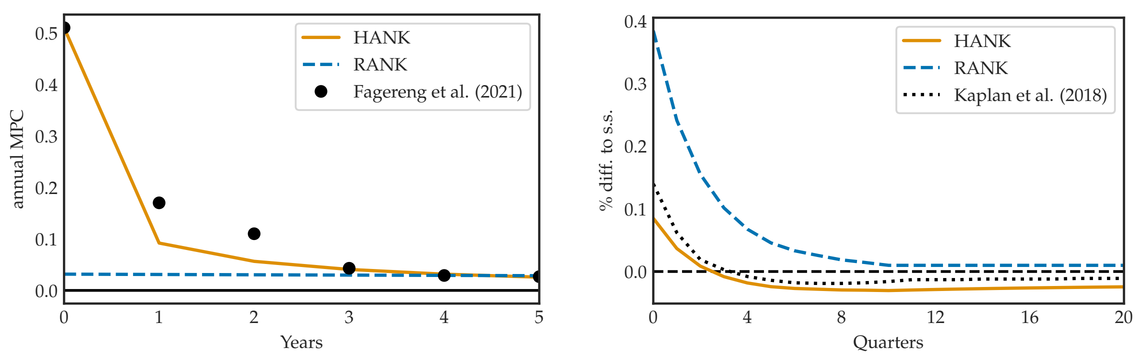


Figure D.1: Columns of Jacobians in HANK and RANK

Note: The left panel shows the columns of the intertemporal marginal propensities to consume (**M**). The right panel shows the effect of real interest rate changes on consumption ($\mathbf{M}^r$). In both panels, the matrix entries are plotted for the quantitative HANK and RANK models presented in Section 4.



(a) Calibration of MPCs.

(b) Interest rate sensitivity.

Figure D.2: Household calibration moments

Note: Panel (a): Annual MPCs from the HANK and RANK models vis-a-vis estimates from Fagereng et al. (2021). Panel (b): Consumption response to a persistent interest rate decrease vis-a-vis the corresponding response from Kaplan et al. (2018).

D.1.3 Foreign economy

In Figure D.3 we plot the estimated IRFs for the foreign economy from the LP obtained in Section 2 along with the smoothed versions we feed into the model as our main shock. We smooth the IRFs using a Gaussian filter and assume that they converge to zero after 6 quarters for M^*, 10 quarters for π^*, and 14 quarters for i^*. We do this using a smoothing parameter of 1 for M^* and π^*, and 2 for i^*, which is estimated with more noise in the LP.

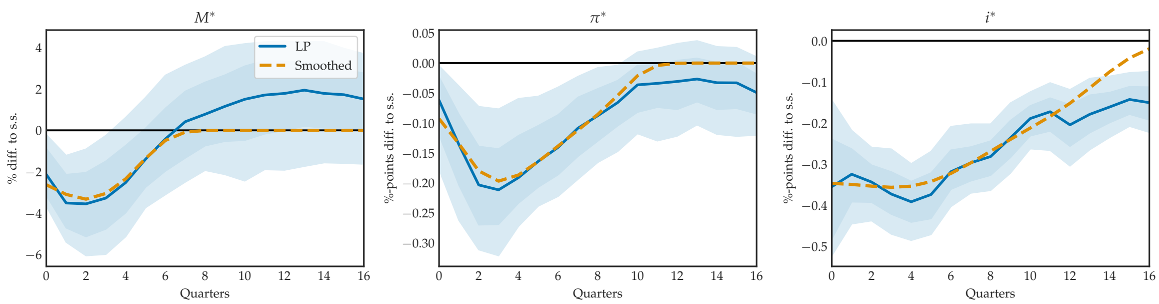


Figure D.3: Foreign demand shock

Note: The figure reports the foreign demand shock as estimated in the data alongside the smoothed versions used in the quantitative model exercise.

E Additional model results

We now present a set of additional results from the quantitative model.

E.1 Model analysis with a fixed exchange rate

We now present a set of results for the model with a fixed exchange rate.

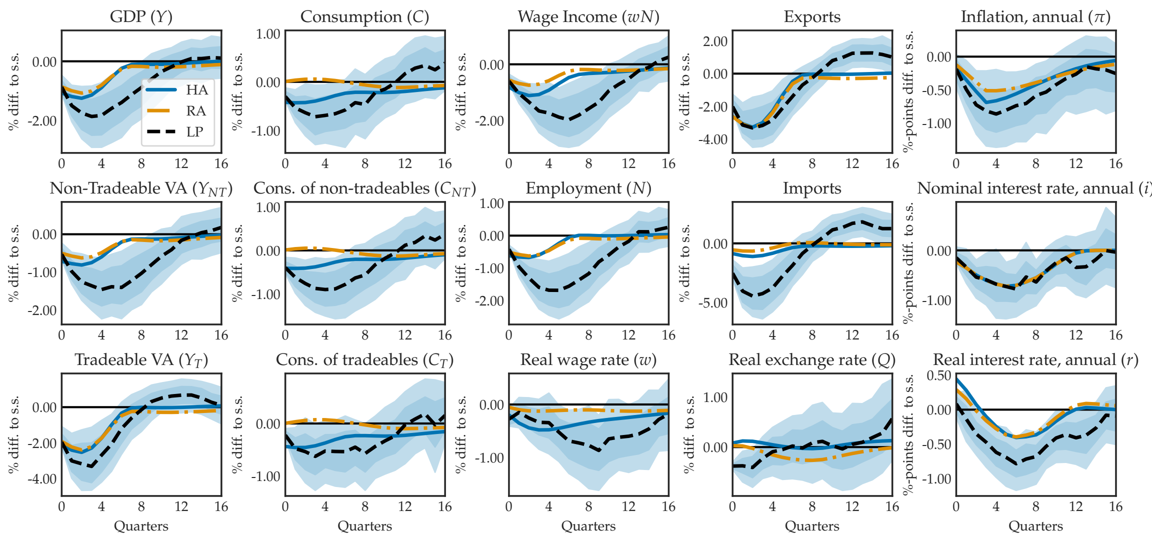


Figure E.1: Fixed exchange rate: Response of the domestic economy to a foreign demand shock

Note: The figure shows the response of domestic variables to a foreign demand shock under a fixed exchange rate in the HANK and the RANK model, alongside our empirical LP-based results from Section 2.

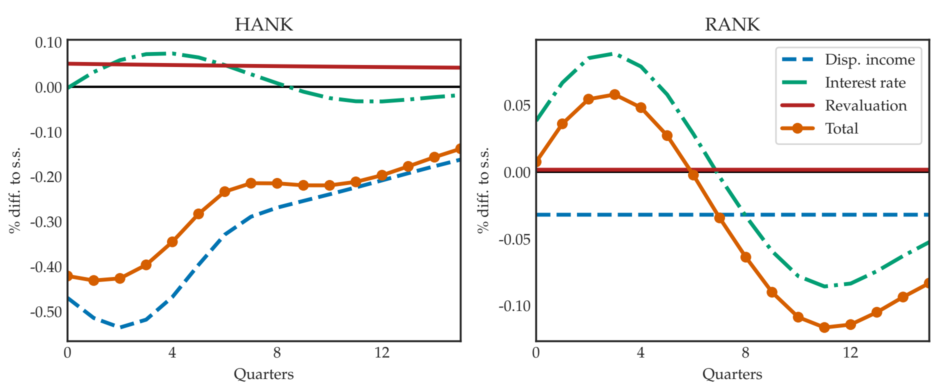


Figure E.2: Fixed exchange rate: Decomposed consumption response to a foreign demand shock

Note: See Figure 5.

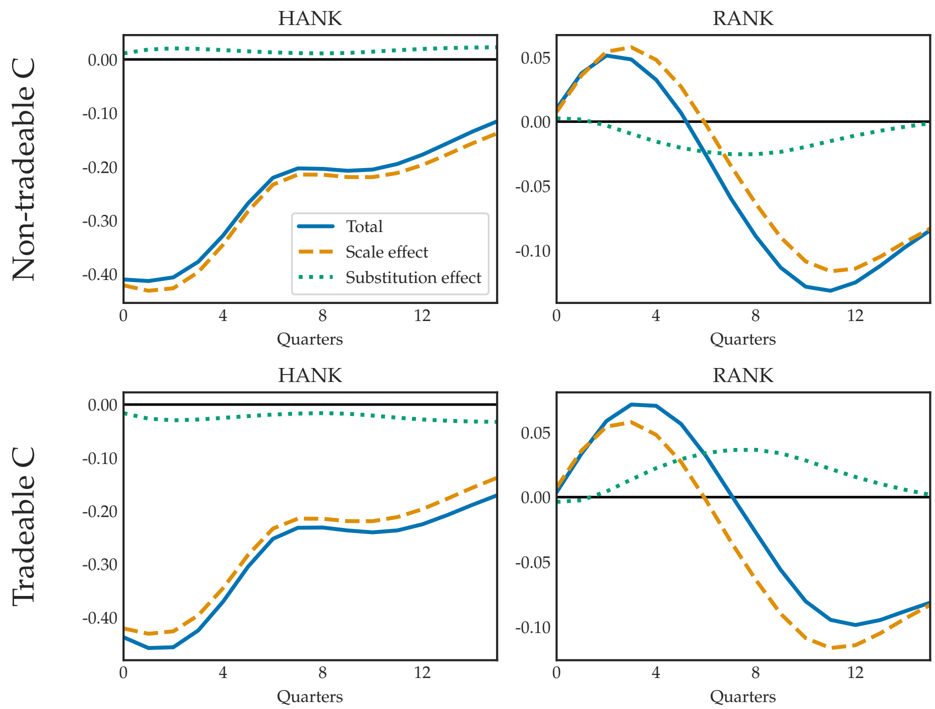


Figure E.3: Fixed exchange rate: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock

Note: See Figure 6.

Table E.1 reports the same set of covariances shown in Table 1, but from the model with a fixed exchange rate instead of a floating rate.

	$\text{Cov}(C, Y)$	$\text{Cov}(C_{NT}, Y)$	$\text{Cov}(C_T, Y)$
		Data	
Unconditional	9.71	8.89	9.07
Conditional	7.96	9.75	7.30
		Model	
HANK	2.60	2.48	2.77
RANK	-0.06	0.00	-0.15

Table E.1: Covariances

Note: The table reports the covariances of domestic output with domestic consumption or either of its sectoral components in the model with a fixed exchange rate.

E.2 Robustness analysis

We now consider a variety of alternative model specifications and parameter values to assess the robustness of our quantitative findings.

E.2.1 Alternative households specifications

We first consider the sensitivity of our results in the context of two alternative models that are both consistent with relatively high MPCs out of short-run income gains. The first is a two-agent New Keynesian (TANK) model à la Galí et al. (2007). A fraction λ^c of domestic households are constrained at all times and simply consume their labor income plus transfers. Unconstrained agents are on their Euler equation at all times. The household block is thus given by:

$$\begin{aligned} c_t^c &= (1-\tau_t)\, w_{s,t} L_{s,t} e_t + T_t, \\ u'\left(c_t^u\right) &= \beta\left(1+r_{t+1}^a\right) u'\left(c_{t+1}^u\right), \\ C_t &= \lambda^c c_t^c + (1-\lambda^c)\, c_t^u. \end{aligned}$$

We calibrate the share of constrained agents λ^c to match the same annual MPC as in the baseline HANK model.

The second model is a two-asset extension of our baseline HANK model, as in Auclert et al. (2020). Households receive after-tax income $(1-\tau_t)\, w_{s,t} L_{s,t} e_t + T_t$. They can invest in liquid assets ℓ_t and illiquid assets a_t through a financial intermediary subject to a zero borrowing constraint. The function $d\left(a_{t-1}\right)$ governs the transfer of resources from the illiquid asset to the liquid asset:

$$d_t\left(a_{t-1}\right) = \frac{r_{ss}^a}{1+r_{ss}^a}\left(1+r_t^a\right) a_{t-1} + \chi\left(\left(1+r_t^a\right) a_{t-1} - \left(1+r_{ss}^a\right) \overline{a}\right),$$

where $\overline{a}$ is the long run target of illiquid assets, and χ determines the speed of transition to this level. The full problem faced by households is then given by:

$$V_t^{s,k}(e_t, a_{t-1}, \ell_{t-1}) = \max_{c_t, \ell_t} u(c_t) - v(L_{s,t}) + \beta_t \mathbb{E}_t \left[V_{t+1}^{s,k}(e_{t+1}, a_t, \ell_t) \right] \tag{E.1}$$

s.t.

$$c_t + \ell_t = \left(1 + r_t^{\ell}\right) \ell_{t-1} + d_t(a_{t-1}) + (1 - \tau_t) w_{s,t} L_{s,t} e_t + T_t, \tag{E.2}$$

$$a_t = (1 + r_t^a) a_{t-1} - d_t(a_{t-1}), \tag{E.3}$$

$$\ell_t \geq 0, \tag{E.4}$$

$$\ln e_t = \rho_e \ln e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim \mathcal{N}\left(0, \sigma_e^2\right). \tag{E.5}$$

We set $\chi = 0.01$ in order to match the second-year MPC estimate from Fagereng et al. (2021). We then subject each of these two alternative models to the same foreign demand shock as considered in our baseline analysis. In Figure E.4, we report the responses of GDP and aggregate consumption in each of the two models, alongside our baseline model and the empirical results from our LP analysis. As seen from the figure, each of the two alternative models have largely similar quantitative implications as our baseline model.

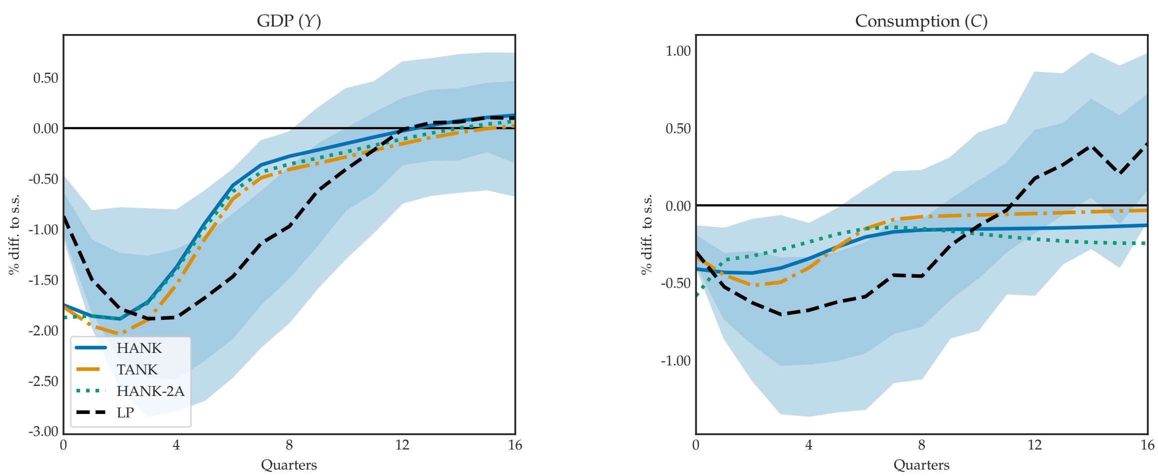


Figure E.4: Varying the household specification

Note: The figure shows the response of selected domestic variables to a foreign demand shock when varying the specification of the household block.

E.2.2 Different government budget rule

We now consider an alternative specification of the government budget rule in the model. Instead of the baseline specification presented above, we now assume that the government sets the tax rate according to the following rule in all periods: $\tau_t -$

$\tau = \epsilon^B \frac{B_{t-1} - B_{ss}}{Y_{ss}}$. This rule is similar to the one considered in Auclert et al. (2020). Figure E.5 reports the responses of output and consumption, alongside the implied paths for the tax rate and government debt, when the government follows this rule with $\epsilon^B = 0.10$. As seen from the figure, we observe a somewhat larger drop in consumption when the government raises taxes at an earlier point in time, as compared to our baseline model. This suggests that our baseline specification is a rather conservative approach.

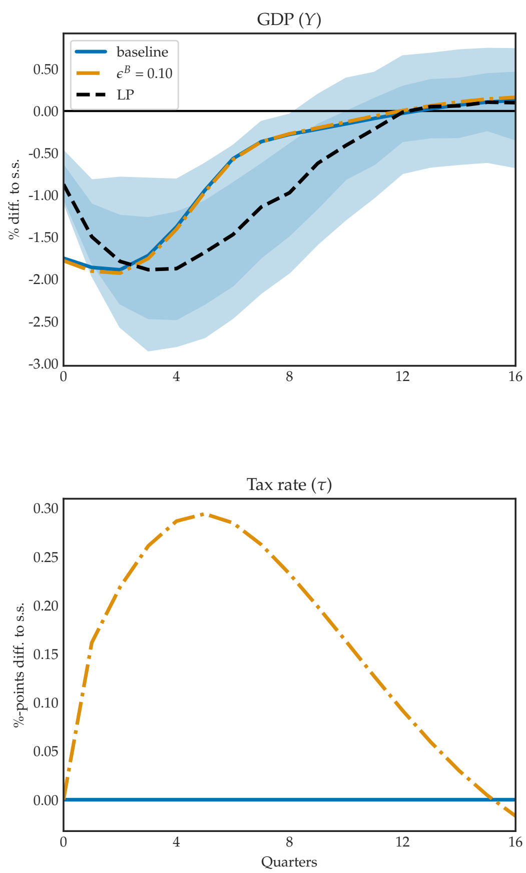


Figure E.5: Varying the budget rule

Note: The figure shows the response of selected domestic variables to a foreign demand shock when varying the specification of the budget rule.

E.2.3 Alternative parameter values

We finally consider a range of alternative parameter values. The results are reported in Figures E.6, E.7, and E.8.

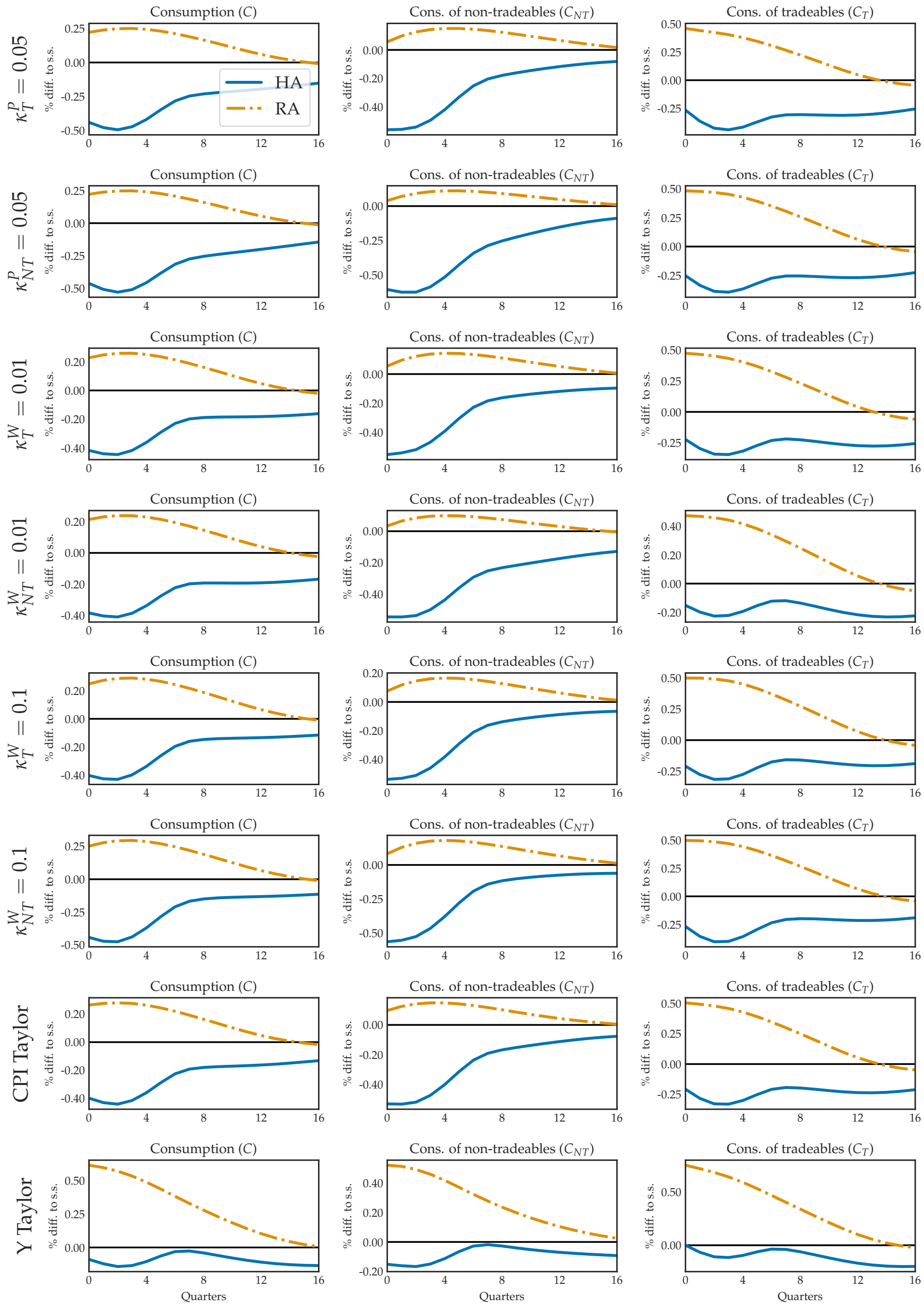


Figure E.6: Foreign demand shock responses under various NK calibrations

Note: The figure shows the response to a foreign demand shock under various different parametric assumptions. In row 1 and 2 we change the slope of the NKPC in each sector. In row 3 to 6 we change the slope of the NKWPC in each sector. Row 7 replaces the PPI Taylor rule with a CPI-based rule. Row 8 considers a Taylor rule featuring output as well as inflation, with $\phi^Y = 0.25$.

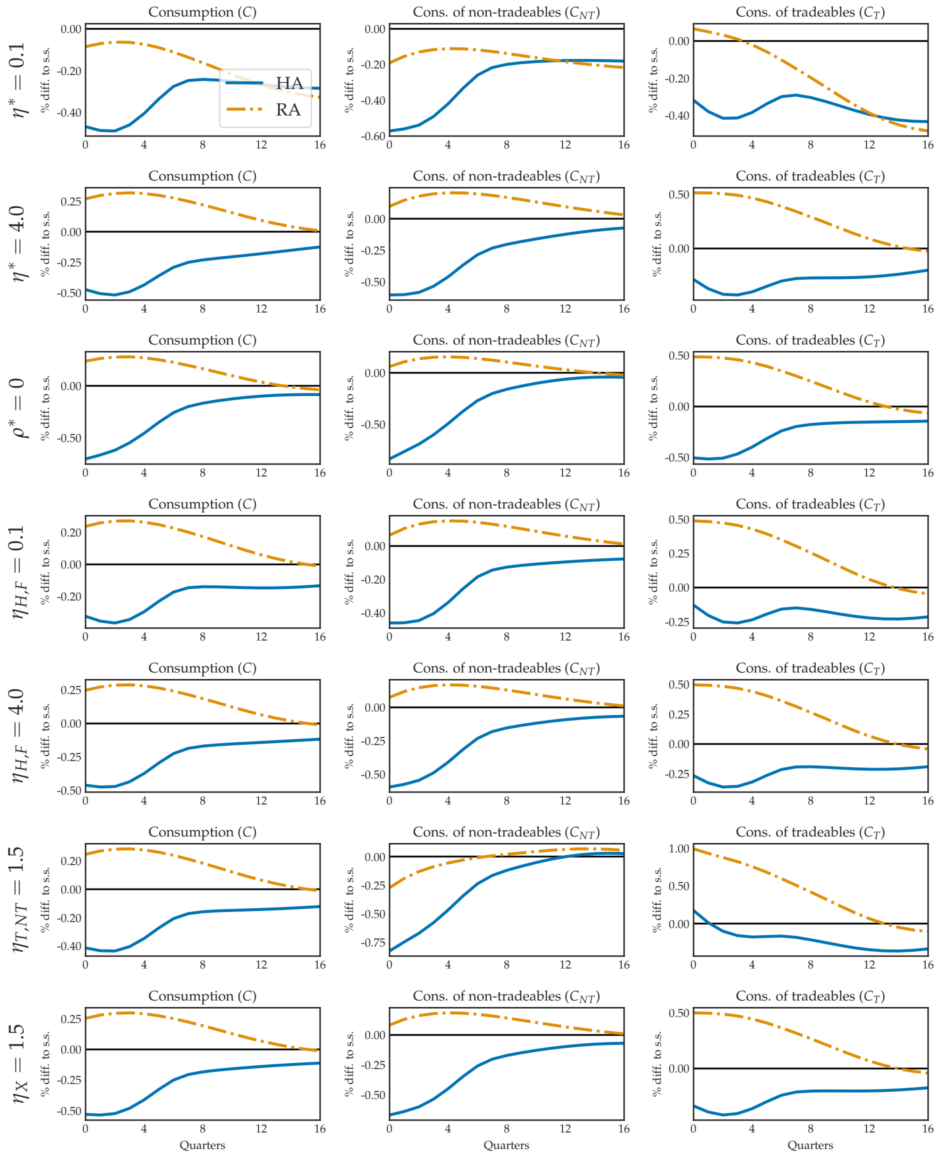


Figure E.7: Foreign demand shock responses with different trade elasticities

Note: The figure shows the response to a foreign demand shock under various different parametric assumptions. In row 1 and 2 we reduce/increase the long run elasticity of exports. In row 3 we change the persistence of the export rigidity. In row 4 and 5 we reduce/increase the elasticity of substitution between domestic and foreign tradables for domestic households. In row 6 we change the elasticity of substitution between tradables and non-tradables for domestic households. In row 7 we consider a higher elasticity of substitution between intermediate goods.

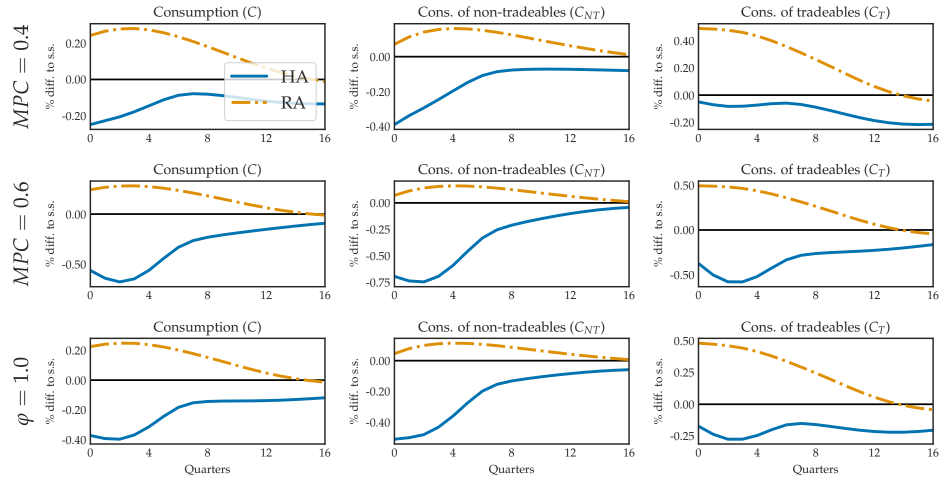


Figure E.8: Foreign demand shock responses with different calibration of households

Note: The figure shows the response to a foreign demand shock under various different parametric assumptions. In row 1 and 2 we reduce/increase the average MPC in the model compared to the baseline. In row 3 we consider a higher Frisch elasticity of labor supply.

E.3 Model analysis with capital

We now present some results for the model augmented with capital formation. We first report the fit of the model with capital but without the investment wedge.

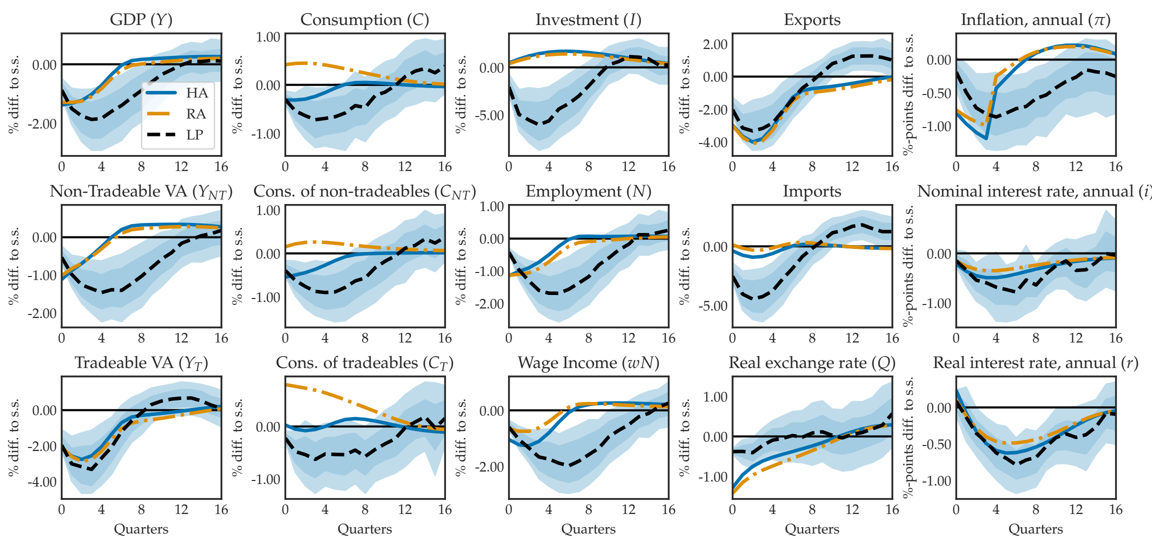


Figure E.9: Response of the domestic economy to a foreign demand shock with capital and no investment wedge

Note: The figure shows the response of domestic variables to a foreign demand shock in the model with capital and no investment wedge.

We then turn to the model with an active investment wedge, and report some additional results from that model.

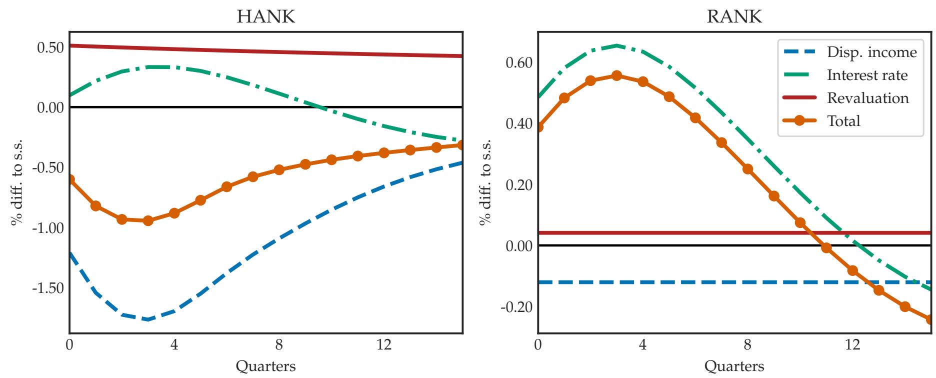


Figure E.10: Decomposed consumption response to a foreign demand shock with capital and investment wedge

Note: See Figure 5.

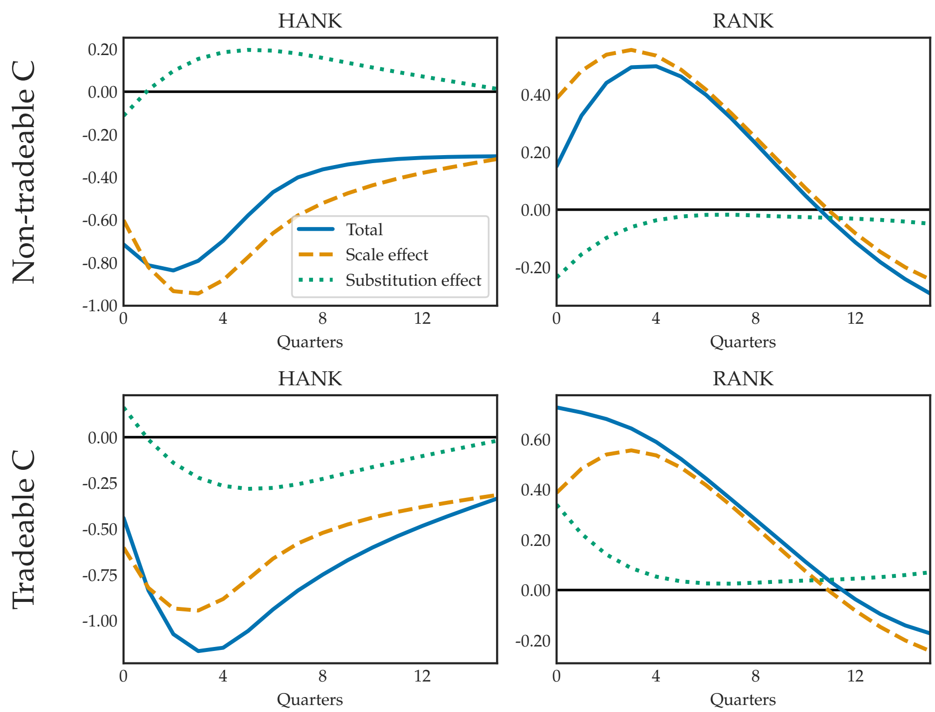


Figure E.11: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock with capital and investment wedge

Note: See Figure 6.

E.4 Stabilization Policy: Details

Table E.2 presents the responses of labor income to foreign and domestic demand shocks and the policy instruments considered in Section 7.

	Floating				Fixed			
	C	Y_T^{hh}	Y_{NT}^{hh}	$\frac{Y_T^{hh}}{Y_{NT}^{hh}}$	C	Y_T^{hh}	Y_{NT}^{hh}	$\frac{Y_T^{hh}}{Y_{NT}^{hh}}$
Foreign demand	-1.00	-3.54	-2.80	1.26	-1.00	-2.10	-1.94	1.08
Domestic demand, β	-1.00	-0.31	-0.71	0.43	-1.00	-0.29	-0.68	0.42
Public transfers, T	1.00	-0.02	1.14	-0.02	1.00	0.15	1.20	0.13
Public spending, G	1.00	0.60	2.66	0.22	1.00	0.74	2.57	0.29
Monetary policy, i	1.00	1.98	1.94	1.02	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	2.75	2.20	1.25
Fiscal devaluation	-	-	-	-	1.00	3.09	2.68	1.15

Table E.2: Cumulative labor income effects of demand shocks and policy instruments.

Note: See notes to Table 2. Y_T^{hh} and Y_{NT}^{hh} denote labor income of households employed in the tradable and non-tradable sectors, respectively.

Figure E.12 reports the impulse responses of the real exchange rate and the terms of trade to a foreign demand shock in our baseline model, alongside the responses to the policy instruments we consider in Section 7. Figure E.13 reports the corresponding responses from the model with a fixed exchange rate.

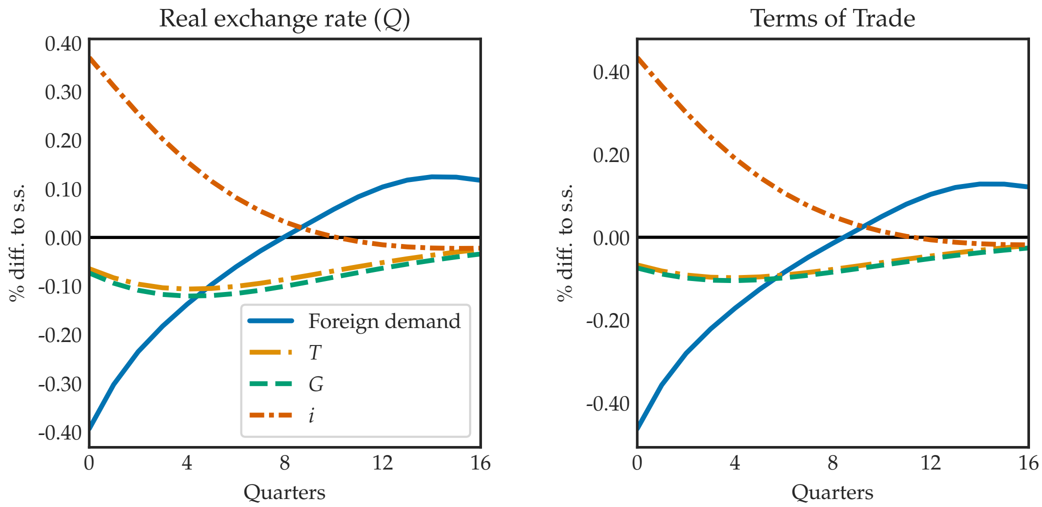


Figure E.12: International relative price dynamics under a floating exchange rate

Note: All policy instruments follow AR(1) processes with a persistence of 0.75. The foreign demand shock is scaled to generate a cumulative 1% decrease in aggregate consumption over the first 16 quarters, and the policy instruments are scaled to exactly offset this. The *real exchange rate* is $Q_t = E_t P_t^* / P_t$. The *terms of trade* is $S_t = \frac{P_{F,t}}{P_{H,t}}$.

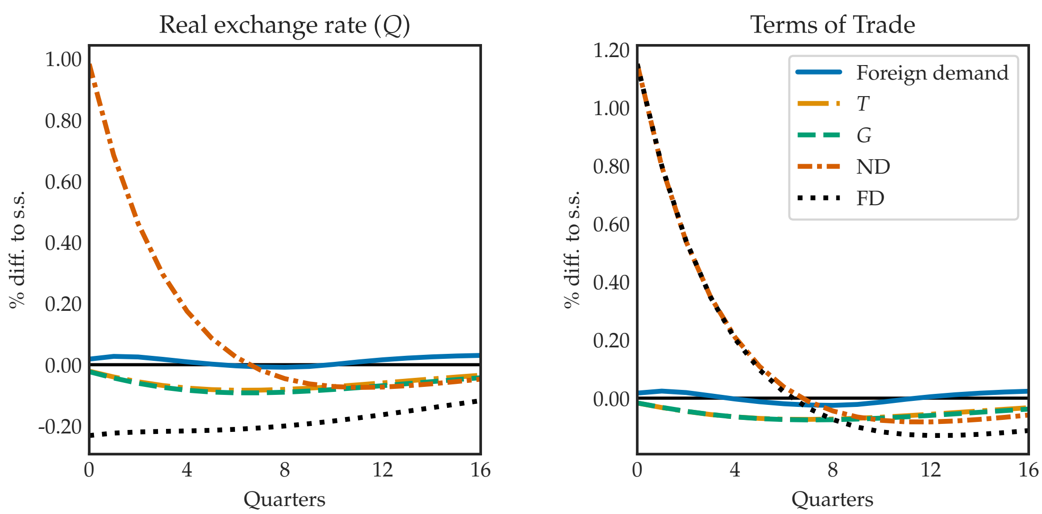


Figure E.13: International relative price dynamics under a fixed exchange rate

Note: All policy instruments follow AR(1) processes with a persistence of 0.75. The foreign demand shock is scaled to generate a cumulative 1% decrease in aggregate consumption over the first 16 quarters, and the policy instruments are scaled to exactly offset this. *FD* is fiscal devaluation and *ND* is nominal devaluation. The implementation details are in Appendix E.4. The *real exchange rate* is $Q_t = E_t P_t^* / P_t$. The *terms of trade* is $S_t = \frac{(1-\tau_t^v)P_{F,t}}{P_{H,t}^* E_t} = \frac{P_{F,t}}{P_{H,t}}$.

E.4.1 Details of a fiscal devaluation

We implement a fiscal devaluation using a value-added tax τ_t^v and a payroll subsidy ζ_t^p. We now report the equations from the main text that change with the introduction of the tax and the subsidy.

Since the VAT is reimbursed for exports, but enforced on imports, the law of one price implies:

$$P^*_{H,t} = (1 - \tau^v_t)\,\frac{P_{H,t}}{E_t},$$
$$P^*_{F,t} = (1 - \tau^v_t)\,\frac{P_{F,t}}{E_t}.$$

Since firms maximize the discounted value of dividends, the tax and the subsidy affect the first-order condition of the firms, as already described in Appendix C. Finally, the government budget is now:

$$B_t + \tau_t + \tau^v_t Y_t = \zeta^p \frac{W_{T,t}N_{T,t} + W_{NT,t}N_{NT,t}}{P_t} + T_t + \frac{P^G_t}{P_t}G_t + \frac{1 + i_{t-1}}{1 + \pi_t}B_{t-1}.$$

We construct a fiscal devaluation following Farhi et al. (2014). We choose a sequence $\{\delta_t\}$ and impose the following paths for the tax and subsidy:

$$\tau^v_t = \omega^v \frac{\delta_t}{1 + \delta_t}$$
$$\zeta^p_t = (1 - \omega^v)\frac{\delta_t}{1 + \delta_t}$$

In the numerical model, we assume that δ_t follows an AR(1) process with persistence 0.75 to be consistent with the other shocks considered in the model. As shown in Farhi et al. (2014) one can perfectly mimic a permanent, one-time unexpected nominal devaluation using the VAT and labor subsidy. Since we consider a temporary shock, it is generally not the case that the fiscal and nominal devaluation coincide perfectly. In practice, we choose the mix of the VAT and the subsidy (determined by ω^v) to resemble the terms-of-trade movement under a nominal devaluation as closely as possible. This obtains when $\omega^v = 0.47$, which is close to the value of Farhi et al. (2014) of $\omega^v = 0.5$.