

The Transmission of Foreign Demand Shocks*

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Abstract

We show that incorporating household heterogeneity enables a New Keynesian model of a small open economy to match key stylized facts about the transmission of foreign demand shocks. In representative-agent versions of the model, a shortfall in foreign demand leads to a counterfactual increase in domestic consumption, as the central bank lowers interest rates in response to the shock. By contrast, with empirically plausible marginal propensities to consume, household heterogeneity generates a strong labor-income channel, leading to a decline in domestic consumption, including of both tradable and non-tradable goods, consistent with the data. As a result, foreign demand shocks play a substantially larger role in domestic business cycles than implied by existing models that abstract from such heterogeneity. While monetary policy is well suited to counteract such shocks, traditional fiscal policies are less effective, as they provide insufficient stimulus to the tradable sector. This shortcoming is particularly relevant for economies with a fixed exchange rate or in a monetary union.

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1 Introduction

In small open economies, external shocks are widely believed to be important drivers of domestic business cycles. Shocks to foreign demand for domestic goods represent a prominent example. Yet, the existing open-economy business-cycle literature has struggled to provide 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. Using data from 31 small open OECD economies, we first characterize and quantify their empirical effects. We establish three key findings regarding the response of the domestic economy to a *negative* foreign demand shock: *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 (around 20%) of domestic business cycles.

Our second 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 for explaining 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 evidence. 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 resulting decline in the real interest rate triggers the powerful intertemporal substitution effect characteristic of RANK models, leading to a counterfactual *increase* in domestic consumption, including both tradable and non-tradable goods. 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 driving domestic business fluctuations, as found, e.g., by Justiniano and Preston (2010), but in contrast to our empirical findings.

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.

To account for our results, we instead propose a small open economy heterogeneous-agent New-Keynesian (SOE-HANK) model featuring idiosyncratic income risk and borrowing constraints, tradable and non-tradable goods, and cross-country input-output linkages. Our model implies a sizeable but realistic MPC. Consistent with the closed-economy HANK literature (e.g., Kaplan et al., 2018, or Auclert, 2019), a strong direct income effect 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, reducing wages and hours worked, and thereby households' labor income. With a high average MPC, this gives rise to a *drop* in consumption that more than offsets the intertemporal substitution effect described above. This mechanism allows the model to account for the observed decline in aggregate consumption. We first establish this result analytically in a stylized version of the 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. 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 match the response of domestic consumption in the data. The required correlation is close to zero in our calibrated HANK model (-0.13), but much larger in the corresponding RANK model (0.94). In other words, the HANK model is able to generate the required propagation of foreign shocks to domestic variables endogenously, while the RANK model is not.

We then turn to the implications for macroeconomic policy. A negative foreign demand shock reduces income and consumption of households working in both domestic sectors, with particularly strong effects in the tradable sector. 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, thereby supporting 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 short-

fall in foreign demand for domestic tradables. In other words, expansionary fiscal policy provides inadequate stimulus to the tradable sector, under both fixed and floating exchange rates.

These results pose 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. This is especially relevant when foreign demand shocks are quantitatively important for domestic fluctuations, as we find. We show that a fiscal devaluation (as studied by Farhi et al., 2014, among others) can mitigate this problem. 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 mainly related to four branches of the existing literature. First, we contribute to the empirical literature quantifying the effects of foreign demand shocks on small open economies. Most existing studies utilize structural vector autoregression (VAR) models identified using small open-economy assumptions and, in some cases, sign restrictions. We adopt a complementary pooled local projections approach. 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 broadly consistent with this literature, but we extend it by documenting positive sectoral comovement and quantifying the contribution of foreign demand shocks. Moreover, while most studies focus on one or a few countries, we use data from 31 OECD economies.

Second, we connect to the literature aimed at proposing structural models to explain these results. Early contributions to this literature typically constructed international Real Business Cycle models (e.g., Backus et al., 1992). 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, while the model of Bergholt (2015) features positive responses of both output and consumption to this type of shock. Lubik and Schorfheide (2007) find that 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.

Third, 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 emphasizes the role of high MPCs in shaping 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 branch of this literature extends HANK models to open-economy settings. 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 cycles of emerging economies through the lens of a HANK model. Others focus on the cross-country transmission of monetary policy shocks and their distributional effects (e.g., Zhou, 2022; Oskolkov, 2023), or the optimal design of monetary policy (Acharya and Challe, 2025). Bellifemine et al. (2023) emphasize how a large non-tradable sector coupled with high MPCs amplifies the effects of monetary policy on employment in a HANK model of a monetary union. In recent work, we compare fiscal multipliers in open-economy HANK and RANK models (Drue Dahl et al., 2025).

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 operates in our model, it is quantitatively less important for foreign demand shocks; instead, 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: we focus less on inequality and more on the transmission channels of foreign demand shocks, including their empirical validation and implications for business-cycle comovement across sectors and countries.

The papers discussed above share a small open-economy framework. In contrast, Chen et al. (2023), Acharya and Pesenti (2024), and Bayer et al. (2024) employ two-country HANK models 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.

Finally, our paper is also related to the literature on deleveraging and sudden stops, in which a strong link between domestic income and consumption emerges from financial accelerator mechanisms. Fornaro (2018) studies international debt deleveraging in a framework with heterogeneity across countries, rather than the household-level heterogeneity emphasized in HANK models. He shows that deleveraging episodes depress global demand and interest rates and that, in a monetary union, the inability to adjust through exchange-rate depreciation amplifies these effects, potentially leading to a liquidity trap and a severe aggregate recession. Other contributions based on representative-agent small open economy models include Mendoza (2010), Benigno and Romei (2014), Fornaro (2015), and Ottonello (2021). Our HANK framework instead generates a powerful response of domestic consumption that operates primarily through changes in labor income rather than through financial accelerator effects.

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; Corsetti et al., 2021) to estimate impulse response functions (IRFs).

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.1 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 LP equation by OLS for $h = 1, \dots, H$:

$$Z_{j,t+h} = \beta_h X_{j,t} + \sum_{k=1}^p \delta_{h,k} X_{j,t-k} + \gamma_h V_{t+h} + \varepsilon_{j,t,h}, \quad (2.1)$$

where $X_{j,t} = (Z_{j,t}, Y_{j,t}^*, \pi_{j,t}^*, i_{j,t}^*)'$, and p is the number of lags. We include a control variable V_t capturing time-varying global factors, following the approach of Cloyne et al. (2023). As a baseline, we use the index of industrial production in the OECD plus six major economies developed by Baumeister and Hamilton (2019). In Section

2.4, we discuss the distinction between foreign and global shocks, and we consider a range of alternative ways to control for global factors.

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:

$$Y_{j,t+h}^* = \beta_h^Y X_{j,t} + \sum_{k=1}^p \delta_{h,k}^Y X_{j,t-k} + \gamma_h V_{t+h} + \varepsilon_{j,t,h}^Y, \quad (2.2)$$

$$\pi_{j,t+h}^* = \beta_h^\pi X_{j,t} + \sum_{k=1}^p \delta_{h,k}^\pi X_{j,t-k} + \gamma_h V_{t+h} + \varepsilon_{j,t,h}^\pi, \quad (2.3)$$

$$i_{j,t+h}^* = \beta_h^i X_{j,t} + \sum_{k=1}^p \delta_{h,k}^i X_{j,t-k} + \gamma_h V_{t+h} + \varepsilon_{j,t,h}^i. \quad (2.4)$$

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.2. 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.3.

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).² 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. 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 Appendix A.3 we report and analyze the implied shocks from our estimation procedure. For each of the identified shocks, we find evidence that they are correlated with some of the relevant identified shock series from the existing literature, though the magnitude of these correlations is modest.

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, $Y_{j,t}^*$, $\pi_{j,t}^*$, $i_{j,t}^*$. This leaves us with a panel of 31 small open economies for the construction of domestic economic outcomes, $Z_{j,t}$ (Appendix A.1 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 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 end the sample in 2019:Q4 to avoid the volatility of the pandemic and post-pandemic period. We take logs of all variables where applicable, and detrend the data using a country-specific regression on $(1, t, t^2)$. As a baseline, we include $p = 2$ lags. A detailed description of the variables and the transformations we apply is provided in Appendix A.1.

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

2.3 Results

We first consider the effects of a foreign demand shock on the foreign economy itself. The estimation results are reported in Figure 1 alongside 68 and 95 percent confidence bands (see Appendix A.2 for details on the computation of these). The results highlight the nature of the shock faced by the small open economy: A prolonged contraction in output of its trading partners, alongside a persistent decline in foreign inflation and the foreign nominal interest rate.

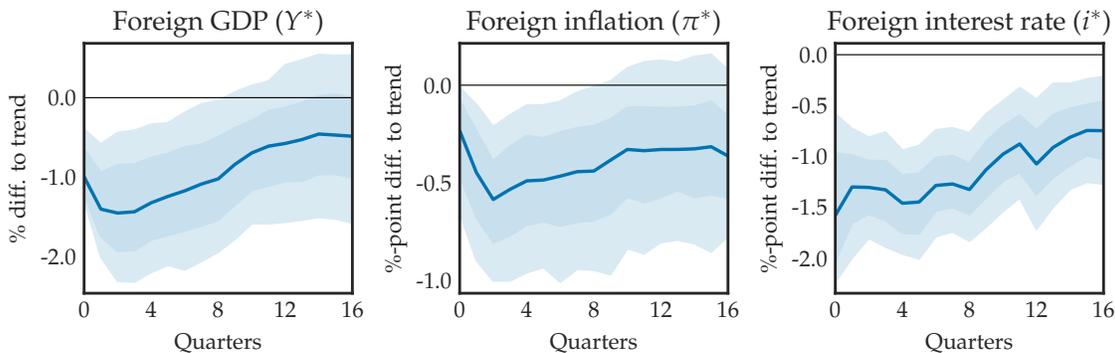


Figure 1: Effects of a foreign demand shock in the foreign economy

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).

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 foreign trade, employment, the real wage, and the nominal and real interest rates. The real exchange rate displays a modest appreciation on impact, but is otherwise not significant. In general, the persistence of the responses of domestic variables is somewhat smaller than what we observe in the foreign economy. Finally, we observe a clear decline in investment, see Appendix A.4. We return to this finding in Section 8, where we consider a model with capital formation.

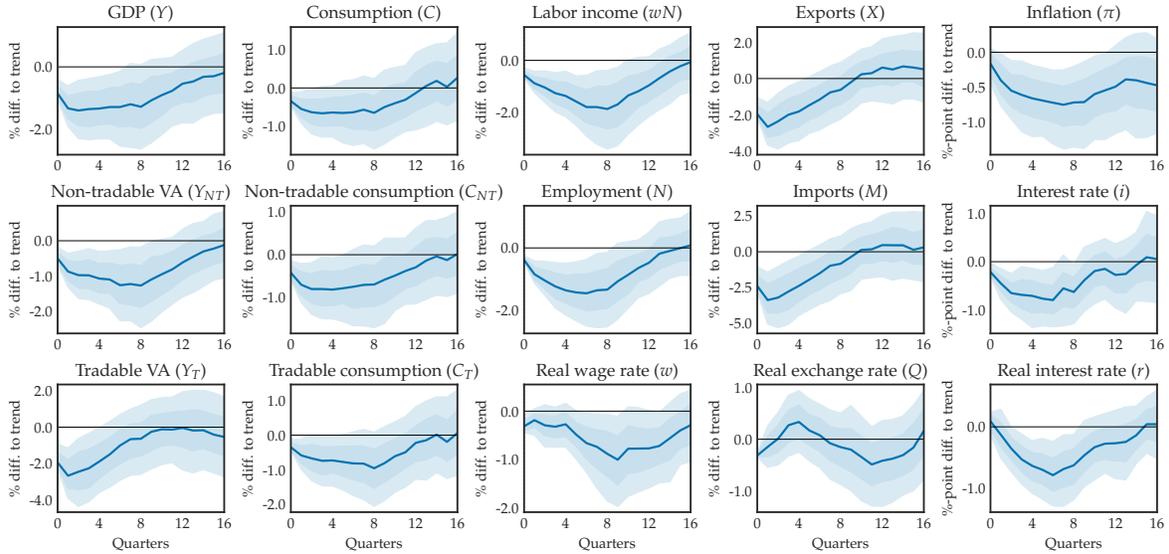


Figure 2: Effects of a foreign demand shock in the small open economy

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).

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.5 for details). The variance decomposition is reported in Figure 3. The main takeaway is that foreign demand shocks account for around 20% of the variation in domestic macroeconomic variables at business-cycle frequencies.³ 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).

3. Recall that we are controlling for the global component V_t in our regressions, so we are effectively decomposing the variation that remains after doing so. Appendix Table A.7 reports the exact numbers and corresponding confidence intervals at selected horizons.

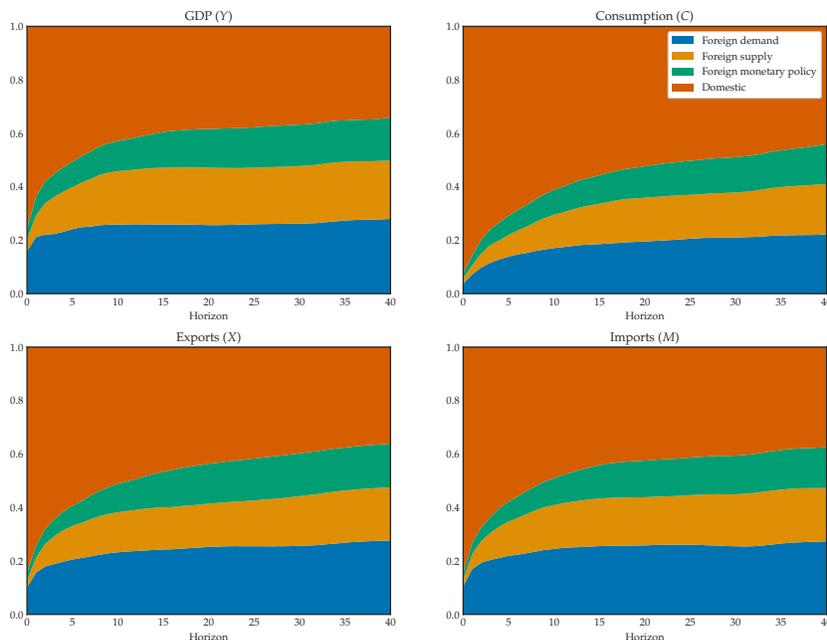


Figure 3: Forecast error variance decomposition

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.

2.4 Controlling for global factors

A potential threat to our identification strategy arises from the presence of “global” shocks that hit a large number of countries simultaneously, such as financial crises, shifts in global sentiments, or pandemics. If the small open economy was hit directly by a negative shock, rather than indirectly by a negative shock to its trading partners, this would have important implications for the appropriate way of modelling the shock. To address this concern, our baseline specification includes a control variable V_t capturing global factors in the form of the “global” industrial production index of Baumeister and Hamilton (2019). According to these authors, the countries included in their index account for 75 percent of estimated global GDP. One can think of this approach as using an instrument for global shocks in order to control for these.⁴

We have employed a broad set of alternative indicators of global economic factors as controls (results are reported in Appendix A.6). We consider activity-based measures in the form of the the index of global real economic activity developed in Kil-

4. An alternative would be to use an instrument for country-specific foreign output, $Y_{j,t}^*$. This is the approach we take in our analysis of foreign fiscal consolidations; see Section 2.7.

ian (2009), the CPB World Industrial Production index developed for the European Commission, and OECD-wide GDP. The results are reported in Appendix Figures A.5 through A.7. In the first two cases, our results display only minor changes. When we include OECD-wide GDP, the results become weaker and in some cases insignificant. Most likely, this reflects that by construction this variable is strongly correlated with *foreign*, trade-weighted GDP ($Y_{j,t}^*$), making it very hard to distinguish between foreign and global shocks in this case.

We have also employed measures of global oil prices, commodity prices, and a dummy variable for the Global Financial Crisis (equal to 1 from 2008:Q4 to 2009:Q2), arguably the most salient example of a global shock in our sample period. Furthermore, we study a case where the weight of the US in the construction of foreign variables is set to zero to address any concern that the US could be driving our results. As seen from Figures A.8 through A.11, these changes do not materially affect our results.⁵ Altogether, this supports our interpretation that the results are not mainly driven by global factors. To further support this conclusion, Section 2.7 reports corroborative evidence from narratively identified foreign fiscal shocks, which are unlikely to be driven by global factors.

2.5 Robustness

We conduct a variety of additional sensitivity checks to confirm the robustness of our empirical findings. First, we estimate responses separately for countries with fixed and floating exchange rate regimes. In both cases, the results are broadly consistent with those reported above (see Appendix Figures A.12 and A.13). For some variables, however, we find evidence of a shorter contraction followed by an expansion in floating-rate countries, consistent with the idea that exchange-rate flexibility can act as a shock absorber in response to foreign disturbances. Overall, these findings indicate that our results are not specific to any particular exchange rate regime.

We then 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 LP; changing the number of lags; 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.,

5. An alternative approach would be to include time fixed effects in (2.1)-(2.4). However, this would be problematic, as it would eliminate much of the variation we wish to retain.

$Y_{j,t}^* = Y_t^*, \forall j$, 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. Finally, we supplement our baseline identification with the additional restriction that foreign demand shocks cannot exert a permanent effect on foreign output, following Blanchard and Quah (1989). The main takeaway from these exercises—which are reported in Appendix Figures A.14 through A.20—is that our main results are quite robust with respect to all the alterations we have considered, though with somewhat weaker results when adding more lags.

2.6 Effects of other shocks

While foreign demand shocks are the primary focus of this paper, we also examine the additional shocks identified in our procedure. As outlined in Section 2.1, these include a foreign supply shock and a foreign monetary policy shock.⁶ By assumption, a negative foreign supply shock is characterized by a fall in foreign output accompanied by an increase in foreign inflation and the foreign interest rate. As shown in Figure 4, foreign output responds strongly and persistently to this shock, whereas the responses of inflation and the interest rate are brief (extending the sign restrictions beyond one quarter does not materially alter this result).

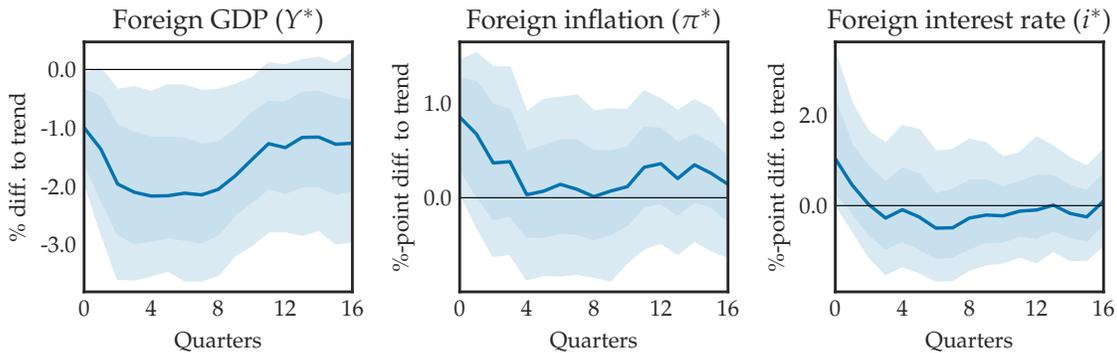


Figure 4: Effects of a foreign supply shock in the foreign economy

Note: The figure reports impulse responses of $Y_{j,t}^*$, $\pi_{j,t}^*$, and $i_{j,t}^*$ to a negative foreign supply 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).

6. Formally, we also identify a domestic “business cycle” shock. However, the only assumptions used to identify this shock are that it is orthogonal to all foreign variables and that it induces a positive response in the relevant domestic variable in the LP regression (e.g., output). Since these restrictions provide little basis for a structural interpretation, we do not analyze this shock further.

The corresponding responses of the domestic economy are presented in Figure 5. Mirroring the foreign recession, the small open economy experiences sizable and persistent declines in real activity, including output, employment, and consumption and its components. Somewhat surprisingly, domestic inflation and interest rates react only weakly and are mostly insignificant, while the real exchange rate appears to depreciate. We return to the effects of foreign supply shocks in Section 6.6, where we confront the empirical results with the predictions of our HANK and RANK models.

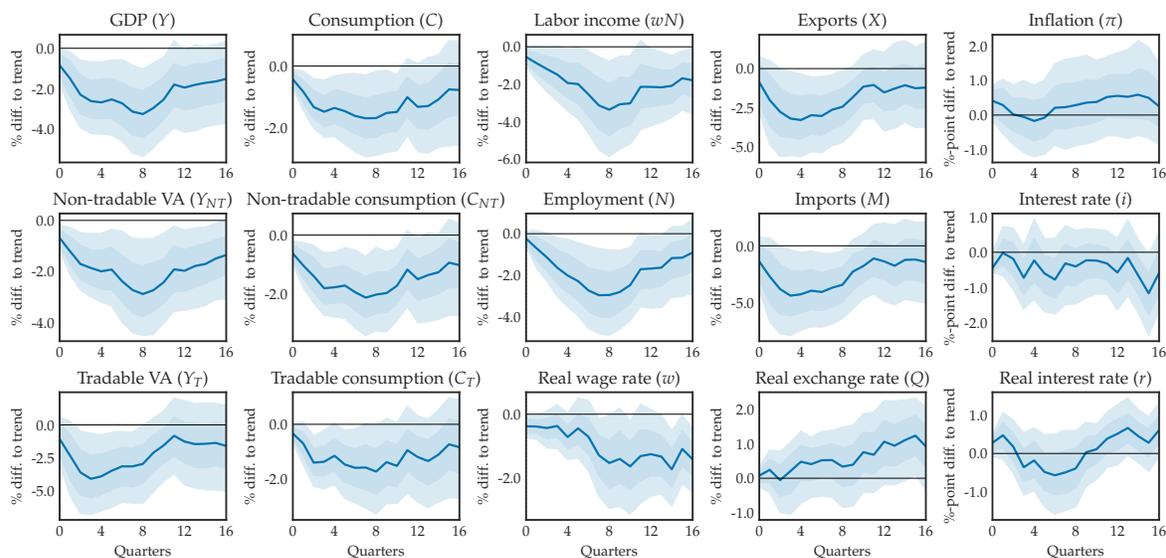


Figure 5: Effects of a foreign supply shock in the small open economy

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

We have also considered the effects of foreign monetary policy shocks, with results presented in Appendix Figures A.21 and A.22. This type of shock is identified as an increase in the foreign interest rate accompanied by declines in foreign output and inflation. We find that the drop in foreign output is modest and short-lived, while movements in the interest rate and especially inflation are more persistent. However, the responses of the domestic economy are generally insignificant, with wide confidence bands that make the results difficult to interpret. We can think of several potential explanations. First, the international transmission of monetary policy remains imperfectly understood, both empirically and theoretically (e.g. Iacoviello and Navarro, 2019; Miranda-Agrippino et al., 2020; Ilzetzki and Jin, 2021; Camara, 2025; and Boeck and Mori, 2025). This may be particularly relevant for our results, which reflect average spillovers across both large and small countries, and

over time.⁷ Second, it is well known that monetary policy shocks identified through sign restrictions often yield wide confidence bands (e.g., Ramey, 2016). Partly in response to this, recent research has increasingly turned towards high-frequency identification strategies (e.g., Jarociński and Karadi, 2020), which tend to produce more tightly estimated and interpretable results. Taken together, these issues suggest that our results offer limited insight into the effects of foreign monetary policy shocks. A more comprehensive study of cross-country spillovers of monetary policy would require a high-frequency and/or narrative identification strategy, which would extend beyond the scope of this paper.

2.7 Evidence from identified fiscal consolidations

As a final step in our empirical analysis, we seek to corroborate our findings from Section 2.3 through an alternative identification strategy. In particular, we study a specific type of negative foreign demand shock in the form of fiscal consolidations in a given country's trading partners. To this end, we rely on the series of shocks developed by Guajardo et al. (2014). These authors take a narrative approach by studying contemporaneous policy documents to identify episodes of fiscal consolidation that are exogenous to current economic developments in the country in question, but instead are motivated by a desire to reduce prospective budget deficits. Based on evidence from 17 OECD countries, they find that such episodes lead to a large domestic contraction in output and consumption. This makes these shocks a relevant example of identified negative demand shocks that are unlikely to reflect global factors. We study the potential international spillovers of such episodes.

The annual shock series developed by Guajardo et al. (2014) has been widely used in subsequent work, e.g., by Broner et al. (2022), Gabriel et al. (2023), or Jordà and Taylor (2025). We use the updated shock series from Adler et al. (2024), who updated and expanded the sample to cover 21 OECD countries for the period 1978-2019 using the same methodology. The updated dataset contains 269 identified fiscal consolidations. The average magnitude of a consolidation episode in our sample is roughly 1 percent of GDP, though several episodes are considerably larger. We include both spending- and tax-based consolidations. Appendix A.1.4 reports the list of countries.

7. For example, the international transmission of U.S. monetary policy is known to be different from that of other countries (e.g., Miranda-Agrippino and Rey, 2020). There is also evidence that the international transmission of monetary policy has changed over time (e.g., Ilzetzi and Jin, 2021).

In line with our previous approach, we construct a trade-weighted measure of foreign fiscal consolidations, $FC_{j,t}^*$, for each country j in the group of 31 small open OECD economies. We then use this measure directly in our regressions, projecting foreign and domestic outcome variables on $FC_{j,t}^*$ (including lags and controls). In other words, this approach does not make use of sign restrictions. When constructing the foreign variables (e.g., $Y_{j,t}^*$), we now assign a weight of zero to countries not included in the fiscal consolidations data (since these countries by construction have a weight of zero in $FC_{j,t}^*$). We then run the following pooled LP regressions:

$$Z_{j,t+h} = \beta_h FC_{j,t}^* + \sum_{k=1}^p \delta_{h,k} Z_{j,t-k} + \sum_{k=1}^p \gamma_{h,k} FC_{j,t-k}^* + \xi_h D_{t+h} + \varepsilon_{j,t,h}, \quad (2.5)$$

where $Z_{j,t+h}$ now denotes any domestic *or* foreign outcome variable. We opt for $p = 1$ lag and otherwise perform the same data transformations as described above. Since a notable share of the fiscal consolidations in our sample occur during the European Debt Crisis, we include a dummy variable D_t equal to 1 for the years 2011-2013.

We first report the results for the foreign economy. In addition to $Y_{j,t}^*$, $\pi_{j,t}^*$, and $i_{j,t}^*$, we also report the responses of foreign government spending $G_{j,t}^*$ and foreign private consumption $C_{j,t}^*$ in order to validate the shock measure. As seen from Figure 6, a fiscal consolidation abroad leads to a significant decline in foreign public spending.⁸ Next, we observe that such episodes are associated with a drop in foreign consumption and output, consistent with the results of Guajardo et al. (2014). Finally, we find that foreign inflation tends to decline, whereas foreign interest rates display an insignificant response. With the exception of the latter, these results confirm that fiscal consolidations “look like” negative demand shocks in the foreign economy, although with some noise, which is not very surprising, since in a given year most countries do not conduct a fiscal consolidation.

We turn next to our results for the domestic economy, which are reported in Figure 7. In line with our findings from Section 2.3, we observe that a negative demand shock abroad leads to a broad-based domestic recession in the small open economy, with significant declines in output, consumption, and employment, while imports and exports also tend to decline. We also observe a drop in both tradeable and non-

8. Since this part of the analysis is based on notably fewer observations due to the use of annual data for a shorter sample and the fact that we only have data on fiscal consolidations in 21 out of 38 OECD member countries, we report 68 and 90 percent confidence bands in Figures 6 and 7.

tradeable consumption. In other words, two of our three main empirical findings are confirmed in this case (with only one shock, we cannot perform a variance decomposition to verify the third of these). However, the responses of domestic inflation and interest rates now display small and insignificant movements. The muted response of domestic interest rates appears to mirror that of foreign interest rates. The real exchange rate again displays a modest response, except for a delayed appreciation after five years. Altogether, these results largely corroborate those presented above.

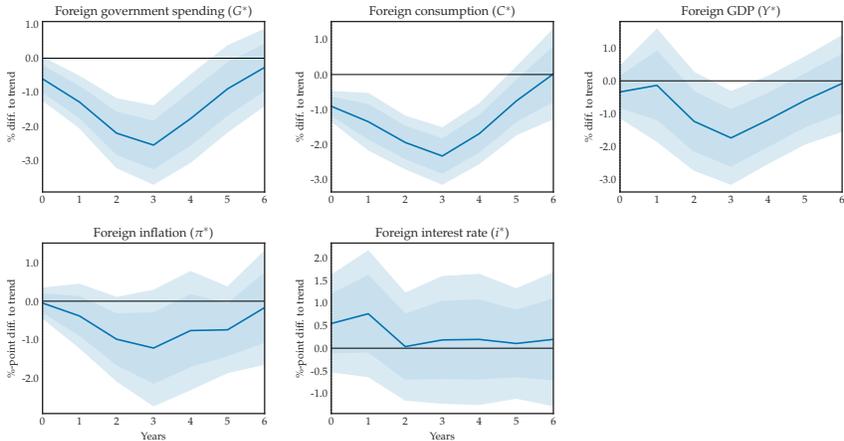


Figure 6: Effects of a fiscal consolidation in the foreign economy

Note: The figure reports impulse responses of $G_{j,t}^*$, $C_{j,t}^*$, $Y_{j,t}^*$, $\pi_{j,t}^*$ and $i_{j,t}^*$ to a fiscal consolidation. The shaded areas indicate 90 and 68 pct. confidence bands. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

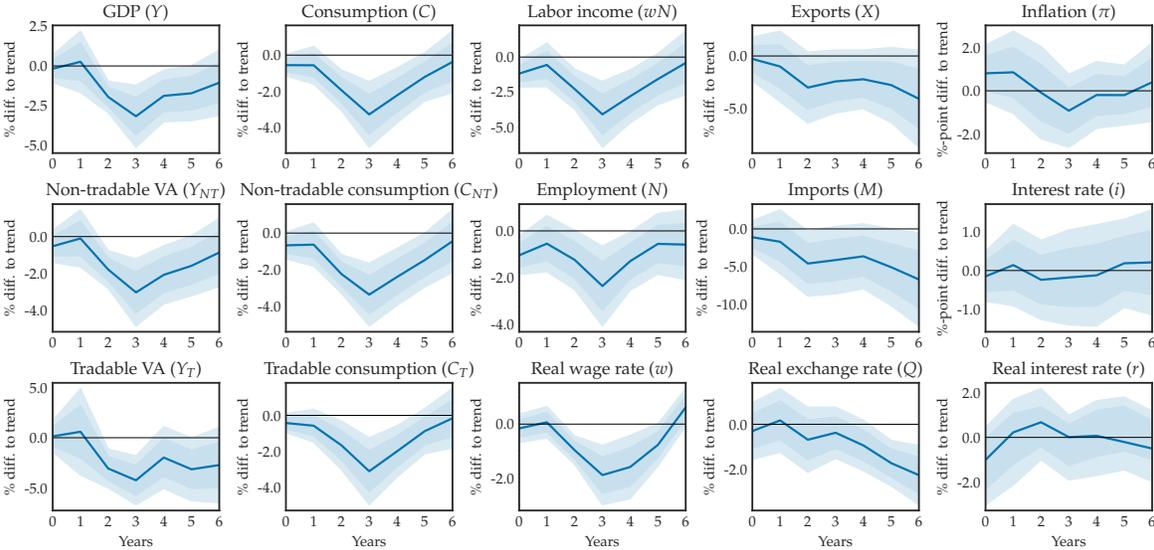


Figure 7: Effects of a fiscal consolidation in the small open economy

Note: The figure reports impulse responses to a fiscal consolidation. The shaded areas indicate 90 and 68 pct. confidence bands. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

We conduct two important robustness checks. In the first, motivated by the discussion in Section 2.4, we control for global economic activity by including the industrial production index of Baumeister and Hamilton (2019) employed above, although this is arguably less of a concern when using narratively identified shocks. As seen from Appendix Figure A.23, this does not lead to any notable changes in our results. Second, we account for the criticism of Alesina et al. (2019), who argue that some of the austerity episodes identified by Guajardo et al. (2014) should be treated as a single multi-year consolidation episode instead of several independent shocks. Thus, we replace $FC_{j,t}^*$ with the narrative series of Alesina et al. (2019).⁹ The results show that this has only a small impact on our findings (see Appendix Figure A.24).

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.¹⁰

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

9. This also corresponds to the baseline shock series used by Gabriel et al. (2023), with the exception that these authors focus only on spending-based consolidations. Note that the dataset of Alesina et al. (2019) ends in 2014 and covers only 16 countries.

10. 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).

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. $\mathbf{X} = \{X_0, X_1, \dots\}$. We are interested in the response of domestic consumption, C , to a drop in foreign consumption demand, C^* . We focus here on the overall intuition, while a detailed exposition is provided in Appendix B.

Denote the real exchange rate by 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, Y , can be written in terms of linearized deviations from steady state, $dY_t = Y_t - Y_{ss}$, as follows:

$$dY = (1 - \alpha)dC + \alpha dC^* + \frac{\alpha}{1 - \alpha} \chi dQ, \quad (3.1)$$

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, Y^{hh} , can be written, also in deviations from steady state, as

$$dY^{hh} = dY - \frac{\alpha}{1 - \alpha} dQ. \quad (3.2)$$

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

$$dC = M dY^{hh} + M^r dr, \quad (3.3)$$

where M is the matrix of intertemporal marginal propensities to consume, and 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:

$$dr = -G^{r,Q} dQ. \quad (3.4)$$

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:

$$dQ = -G^{Q,Y} dY. \quad (3.5)$$

The matrices $G^{Q,Y}$ and $G^{r,Q}$ 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 (dC) to a change in foreign consumption (dC^*) is given by:*

$$dC = \left[\underbrace{M}_{\text{Labor income}} + \underbrace{\frac{\alpha}{1-\alpha} MG^{Q,Y}}_{\text{Real income}} + \underbrace{M^r G^{r,Q} G^{Q,Y}}_{\text{Intertemporal sub.}} \right] G^{Y,C^*} dC^*, \quad (3.6)$$

with 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 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.¹¹

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 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, $M \approx \mathbf{0}$, as in representative-agent models operating under the permanent income hypothesis, it holds that

$$dC \approx M^r G^{r,Q} G^{Q,Y} G^{Y,C^*} dC^*. \quad (3.7)$$

Since the dominant entries in each of the G -matrices are positive, and those in 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 effectively switches off the two other channels.

In contrast, the presence of high-MPC households in our HANK model implies that $M \approx \mathbf{0}$ 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 $G^{Q,Y}$ flips sign; see Appendix B). This implies that the

11. 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.

RANK version of the model (with $M \approx 0$) 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.¹²

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

12. A similar case arises when the domestic economy is constrained by the zero lower bound on nominal interest rates. Also in that setting, the combination of a fixed nominal interest rate and a decline in inflation would lead to an increase in the real interest rate, and thus a drop in consumption in the RANK model. However, our empirical findings do not support this interpretation: First, we observe a clear decline in both nominal and real interest rates in the data, and second, we have verified that our main findings are robust to excluding the period in which such episodes were prevalent.

permanent subjective discount factor β^k is denoted by $\beta_t^k = \beta^k \exp \{ \epsilon_t^\beta \}$.

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

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

s.t.

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

$$a_t \geq 0, \quad (4.3)$$

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

where σ is the inverse intertemporal elasticity of substitution, and φ is the Frisch elasticity of labor supply. \mathbb{E}_t^e and \mathbb{E}_t denote expectations over idiosyncratic and aggregate states, respectively. 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:

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

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

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:

$$A_t = B_t + \int p_{j,t}^D v_{j,t} dj + B_t^*, \quad (4.7)$$

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 $p_{j,t}^D$, 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 $r_t \equiv \frac{1+i_t}{1+\mathbb{E}_t \pi_{t+1}} - 1$, 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 $(1 + r_t^*) \frac{\mathbb{E}_t Q_{t+1}}{Q_t}$. 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 $r_t = \mathbb{E}_t r_{t+1}^a$ denote the ex-ante real return, we obtain the no-arbitrage conditions:¹³

$$1 + r_t = \frac{\mathbb{E}_t \left(D_{j,t+1} + p_{j,t+1}^D \right)}{p_{j,t}^D}, \quad (4.8)$$

$$1 + r_t = (1 + r_t^*) \frac{\mathbb{E}_t Q_{t+1}}{Q_t}. \quad (4.9)$$

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.

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

$$r_t^a = \frac{p_{j,t}^D + D_{j,t} + \frac{1+i_{t-1}}{1+\pi_t} B_{t-1}}{A_{t-1}} - 1,$$

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

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:

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

As is well known, this type of small open economy model is not stationary. Following Schmitt-Grohé and Uribe (2003) and much of the subsequent literature, we therefore introduce a debt-elastic interest-rate premium $\iota_t = \iota(B_t^*)$, which enters only the household's Euler equation. Effectively, this generates an endogenous discount factor and is sufficient to ensure stationarity of the net foreign asset position.¹⁴

4.1.3 Consumption goods

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

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

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:

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

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

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 substi-

14. Although this is not required 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.

tution $\eta_{H,F} > 0$, 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):

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

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:

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

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:

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

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:

$$X_{s,t} = \left[\Theta_{s \rightarrow s}^{\frac{1}{\eta_X}} X_{s \rightarrow s,t}^{\frac{\eta_X-1}{\eta_X}} + \Theta_{s' \rightarrow s}^{\frac{1}{\eta_X}} X_{s' \rightarrow s,t}^{\frac{\eta_X-1}{\eta_X}} + \Theta_{F \rightarrow s}^{\frac{1}{\eta_X}} X_{F \rightarrow s,t}^{\frac{\eta_X-1}{\eta_X}} \right]^{\frac{\eta_X}{\eta_X-1}}, \quad (4.16)$$

where $X_{s \rightarrow s,t}$ and $X_{s' \rightarrow s,t}$ denote input materials produced in sector s and s' , respectively, and used as input for the intermediate-good bundle in sector s . The parameters $\Theta_{s \rightarrow s}$ and $\Theta_{s' \rightarrow s}$ are the diagonal elements of a domestic input-output matrix. Likewise, $X_{F \rightarrow s,t}$ denotes intermediate inputs imported from the foreign economy (with weights $\Theta_{F \rightarrow s}$). $\eta_X > 0$ 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 :¹⁵

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

and aggregate VA (Y_t) as:

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

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 $l_{i,s,t}^j$ hours of work to union j in sector s . Total labor supply of household i is then $l_{i,s,t} = \int l_{i,s,t}^j dj$. Each union assembles individual labor supply to a union-specific task, $L_{s,t}^j = \int e_{i,t} l_{i,s,t}^j di$, and aggregate

15. 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.

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:

$$\pi_{s,t}^w (1 + \pi_{s,t}^w) = \frac{\epsilon^w}{\theta_s^w} L_{s,t} \left\{ \nu L_{s,t}^{\frac{1}{\phi}} - \frac{\epsilon^w - 1}{\epsilon^w} \frac{(1 - \tau_t) W_{s,t}}{P_t} U'(C_{s,t}) \right\} + \beta_t^U \mathbb{E}_t \pi_{s,t+1}^w (1 + \mathbb{E}_t \pi_{s,t+1}^w), \quad (4.19)$$

where $U'(C_{s,t}) = \int e_i u'(c_{i,s,t}) d\mathcal{D}_t$ denotes the aggregate, productivity-weighted marginal utility of consumption, and β_t^U is the discount factor of the union, which we set to $\beta_t^U = \frac{1}{1+r_t}$, 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:

$$i_t = \left(i_{ss} + \phi^\pi \mathbb{E}_t \pi_{t+1}^{PP} \right) (1 - \rho^r) + \rho^r i_{t-1} + \epsilon_t^r, \quad (4.20)$$

where π_t^{PP} is the inflation rate of the the domestic producer price index (PPI), defined as the Laspeyres index over $C_{H,t}$ and $C_{NT,t}$.¹⁶ 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 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:

$$E_t = E_{ss}. \quad (4.21)$$

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

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:

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

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 $t_B - 1$ quarters after a shock. From period t_B onwards, the government smoothly adjusts the tax rate τ_t to ensure that the level of public debt returns 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 import demand, foreign inflation, and the foreign nominal interest rate, $\{M_t^*, \pi_{F,t}^*, i_t^*\}$, which enter the set of domestic equilibrium conditions. This approach allows us to feed the estimated foreign demand shock, as studied in Section 2, directly into the model.¹⁷

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

$$C_{H,t}^* = \alpha^* (\hat{p}_t^*)^{-\eta^*} M_t^*, \quad (4.23)$$

17. A 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.

where $a^* \in [0, 1]$ 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^* :

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

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:

$$Z_{NT,t} = C_{NT,t} + G_{NT,t} + X_{NT \rightarrow T,t} + X_{NT \rightarrow NT,t} + \Xi_{NT,t}, \quad (4.25)$$

$$Z_{T,t} = C_{H,t} + G_{H,t} + C_{H,t}^* + X_{T \rightarrow T,t} + X_{T \rightarrow NT,t} + \Xi_{T,t}, \quad (4.26)$$

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

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

$$NFA_t \equiv B_t^* = A_t - p_t^D - B_t. \quad (4.28)$$

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.¹⁸ As discussed above, we are interested in foreign demand (and later, supply) shocks consisting of the sequences $\{M_t^*, \pi_{F,t}^*, i_t^*\}$ 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 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:

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

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 deterministic steady state. We then proceed to solve for the full non-linear transition paths to each shock using Broyden's method.¹⁹

18. 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).

19. The code is written in Python and based on the [GEModelTools](#) package.

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 $[\bar{\beta} - \Delta\beta, \bar{\beta} + \Delta\beta]$, 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.

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 and semi-durables to be tradables, and consumption of services to be non-tradables. We find that tradables make up 47% of the consumption basket; $\alpha_T = 0.47$. 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 1.25 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).²⁰

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:

$$\Theta = \begin{array}{c} \\ T \\ NT \\ F \end{array} \begin{array}{cc} T & NT \\ \left[\begin{array}{cc} 0.29 & 0.29 \\ 0.49 & 0.51 \\ 0.22 & 0.20 \end{array} \right] \end{array},$$

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 Θ . We calibrate the share of imports in each sector ($\Theta_{F,T}$, $\Theta_{F,NT}$) 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 ($\frac{X_{F \rightarrow T}}{X_{F \rightarrow NT}} = 1.26$). The remaining two parameters in Θ are then obtained residually. Finally, we fix the elasticity of substitution 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 elasticities 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

20. 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.

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, as in most of the existing HANK literature (see 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).²¹ Figure 8 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.²²

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. 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

21. Using foreign imports as the measure of foreign import demand, M_i^* in (4.23), has two potential shortcomings. Firstly, it neglects that changes in the real exchange could be driving some of the observed import response. Due to the flat response of the real exchange rate, this is not a problem in practice. Secondly, our measure of the foreign economy does not include all trading partners, and even with spillovers to these countries, total demand for domestic exports likely moves less than our measure of foreign imports. In practice, this is not a big concern as the RANK and HANK models are treated equally, and our fit of the domestic export response is good.

22. 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.

shed further light on this result in the next section.

Finally, neither model can account for the behavior of the real exchange rate: Both generate a sizeable appreciation, whereas in the data the real exchange rate remains roughly flat. This discrepancy reflects the fact that, in both models, the domestic real interest rate declines by less than its foreign counterpart.²³ All else equal, this pushes up the response of imports, helping to explain why both models fail to deliver the sharp fall in imports observed in the data. We return to this issue in Section 8, where we allow for UIP deviations by introducing a cognitive discounting term in the UIP condition, following Gabaix (2020) and Galí (2020). We find that this modification aligns the exchange-rate and import responses more closely with the data, without altering our main results.

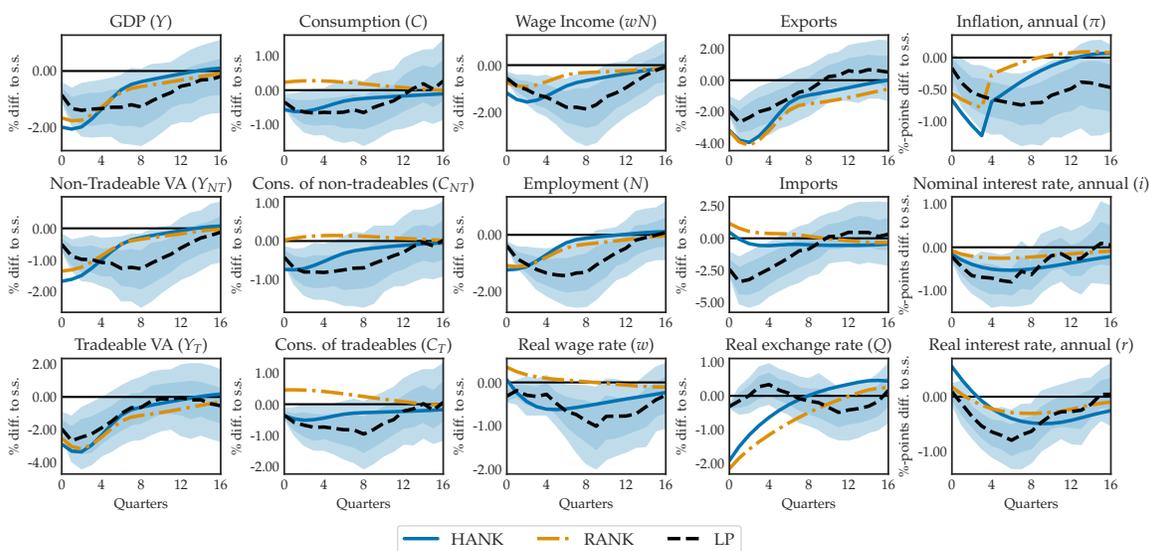


Figure 8: Response of the domestic economy to a foreign demand shock

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.

5.2.1 Fixed nominal exchange rate

Our empirical investigation yielded little 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

23. The linearized UIP condition (4.9) solved forward yields $dQ_t = \sum_{k=0}^{\infty} \mathbb{E}_t (dr_{t+k}^* - dr_{t+k})$.

the one conducted above, i.e., where we feed the estimated paths of foreign variables into a version of our model with a currency peg.²⁴ 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.

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:

$$dC = \underbrace{M dY^{hh}}_{\text{Disp. income}} + \overbrace{M^r dr}^{\text{Interest rate}} + \underbrace{M^v (dr^a - dr)}_{\text{Revaluation}}. \quad (6.1)$$

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).²⁵ M^v denotes the matrix of intertemporal effects on consump-

24. 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 $i_{j,t}^*$.

25. 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 9, 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.

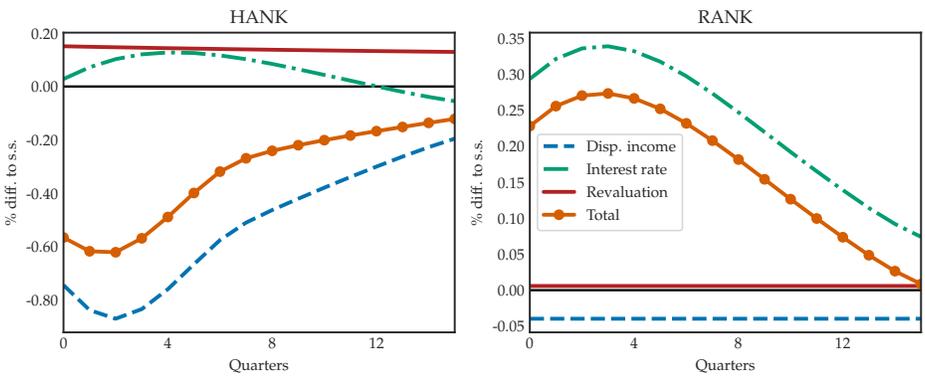


Figure 9: Decomposed consumption response to a foreign demand shock

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

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.²⁶

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:

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

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

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 10.

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.

26. Since 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.

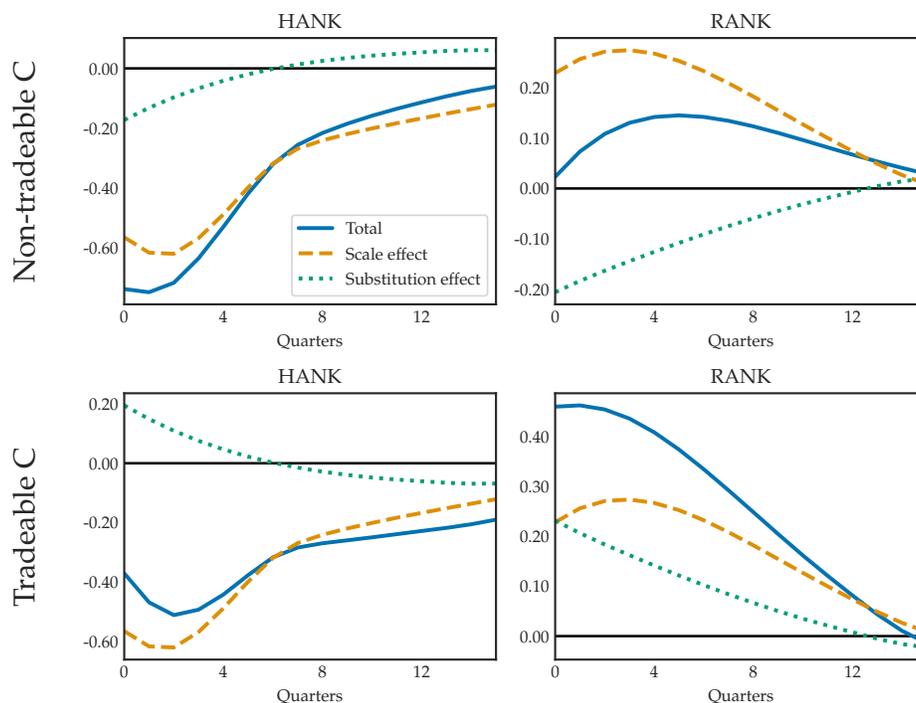


Figure 10: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock

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).

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 0.69.²⁷ 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

27. 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).

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.²⁸ 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 wrong, the HANK model can match the sign of the covariance between output and aggregate consumption, and account for more than 50% of its magnitude. By aligning the conditional covariance of output and consumption 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	11.20	10.07	12.77
Conditional	7.88	9.93	10.23
Model			
HANK	6.22	7.18	5.14
RANK	-2.93	-1.31	-4.76

Table 1: Covariances

Note: The table reports the covariances of domestic output with domestic consumption or either of its sectoral components. The unconditional data moments refers to covariances of the filtered data series, whereas the conditional data moments are based on our estimated foreign demand shocks. The (conditional) model moments are computed from the model based impulse responses displayed in Figure 8.

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

28. 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.

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 rather close to zero (-0.13), whereas the RANK model requires a correlation of 0.94. In other words, the HANK model is able to generate all 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, the puzzling lack of comovement between domestic and foreign business cycles found by Justiniano and Preston (2010) is confirmed in the RANK model, while 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 not have 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.²⁹

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-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

29. 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.

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.

6.6 Foreign supply shocks

We now shift our attention to foreign supply shocks and evaluate the extent to which our model can reproduce their effects. Following the same approach as in Section 5.2, we now feed the model with smoothed versions of the estimated responses of the foreign economy to a foreign supply shock (see Appendix Figure D.4). We then report the implied responses of the domestic variables in the HANK and RANK models against their empirical counterparts in Figure 11. Consistent with the data, both models generate a notable contraction in domestic GDP, foreign trade, and (to a lesser extent) employment. However, as with foreign demand shocks, they differ markedly in their ability to match the behavior of consumption and its sectoral components. The HANK model delivers a sizeable decline in consumption, consistent with the empirical response. In contrast, the RANK model produces a virtually flat response of both aggregate and sector-specific consumption. This divergence reflects the same mechanism discussed above: Although both models feature a substantial drop in wage income, only the HANK model maps this into a drop in consumption due to the differences in MPCs across the two models. In the RANK model, instead, consumption dynamics depend primarily on the path of the real interest rate, which remains close to zero and therefore induces a weak intertemporal substitution effect. Finally, although the HANK model generates somewhat more front-loaded movements in some cases (e.g., the real wage and the real exchange rate), its predictions for most other variables remain broadly aligned with the empirical evidence. Taken together, the results in Figure 11 provide further validation of our HANK model, demonstrating that it can replicate both the qualitative patterns and the quantitative magnitudes associated with multiple types of foreign shocks. Moreover, applying the same logic as in Section 6.3, our findings suggest that foreign supply shocks are also likely to account for a sizeable share of business-cycle fluctuations in small open economies, consistent with our empirical findings (see Figure 3). This would reinforce the overall importance of foreign shocks, in line with the empirical evidence discussed in the introduction.

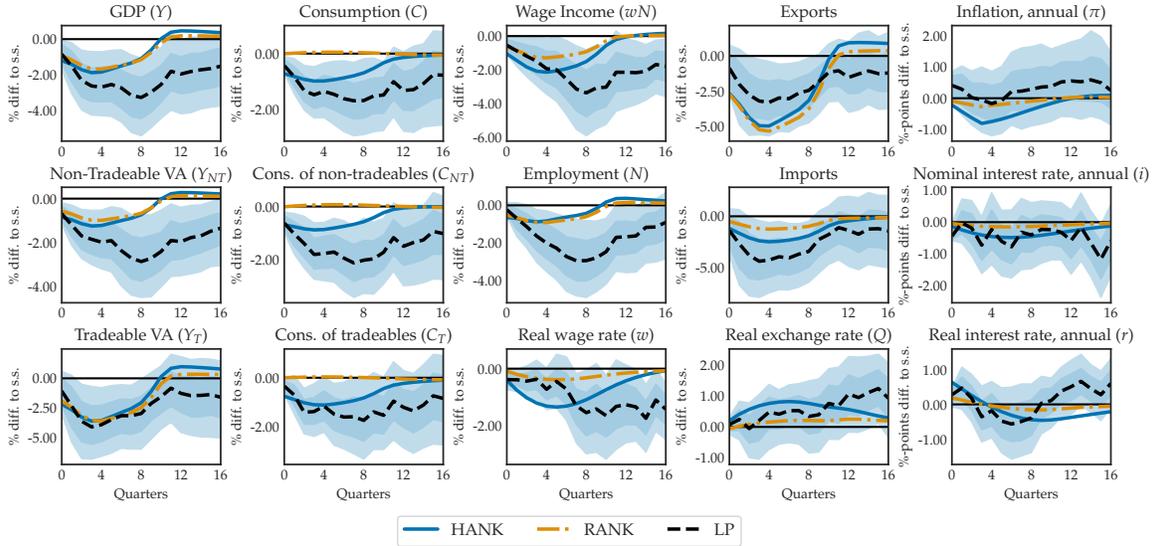


Figure 11: Response of the domestic economy to a foreign supply shock

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

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.³⁰

30. 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 (2025) 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.

	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, β^*	-1.00	-1.12	-0.96	1.17	-1.00	-0.98	-1.01	0.97
Domestic demand, β	-1.00	-0.82	-1.06	0.78	-1.00	-0.83	-1.06	0.79
Public transfers, T	1.00	0.65	1.13	0.58	1.00	0.68	1.12	0.61
Public spending, G	1.00	0.25	1.27	0.19	1.00	0.26	1.27	0.20
Monetary policy, i	1.00	0.94	1.02	0.92	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.16	0.94	1.23
Fiscal devaluation	-	-	-	-	1.00	1.07	0.98	1.09

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).³¹ 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.³²

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 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.

31. In Appendix E.4 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.

32. 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.

7.1 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.

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 now affect households in the two sectors almost symmetrically, 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 also under a peg. 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.

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, stimulating economic activity also in the former sector. Thus, the bottom line is that a fiscal devaluation may be an effective way to offset a shortfall of foreign demand in countries without an independent monetary policy.

Effects on inflation Finally, we assess the extent to which each policy stabilizes inflation. We report the responses of aggregate and sector-specific producer price inflation rates in Appendix Table E.3 and Appendix Figure E.14. The findings can be summarized as follows. Under a floating exchange rate, monetary policy is more effective than fiscal policy in stabilizing inflation, partly reflecting the different exchange-rate responses discussed above. Under a fixed exchange rate, domestic policies can stabilize inflation in the first two years after the shock but become less effective thereafter, as inflation must reverse to realign domestic prices with foreign prices. Across both regimes, the two sectors display highly synchronized inflation dynamics.

8 Capital Formation

As a final step in our analysis, we extend the model to allow for capital formation, in an effort to assess whether the model can account for our empirical findings along this dimension. As discussed briefly in Section 2, we observe a notable decline in investment following a negative foreign demand shock in the data. In a frictionless environment, however, the observed drop in the real interest rate would lead to an *increase* in investment, all else equal. To counteract this force, we incorporate a financial friction in the form of an earnings-based borrowing constraint, as in Lian and Ma (2021) and Drechsel (2023). Since earnings tend to decline after a negative demand shock, this generates a contraction in credit issuance. The latter finds empirical support in the data: As seen in Appendix Figure A.4, we observe a clear decline in real credit to the private non-financial sector after a negative foreign demand shock.

Formally, we now assume that production requires inputs of a CES aggregate of capital and labor, in addition to intermediate goods. Capital services are rented from capital firms, which own and accumulate the capital stock. These firms maximize profits subject to an earnings-based borrowing constraint and a standard law of motion for capital. In addition to standard investment adjustment costs, they incur a cost of adjusting dividend payouts, following Jermann and Quadrini (2012), which introduces a borrowing motive. We describe the details of the problem and the asso-

ciated first-order conditions in Appendix C. We set the depreciation rate of capital to 2.5% per quarter, as is standard in the literature, while 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).³³ The import share of investment goods and the debt-to-earnings ratio are calibrated to match sample averages across the OECD countries. We pin down the dividend adjustment cost parameter using the calibrated value of Jermann and Quadrini (2012). Finally, since we do not incorporate variable capital utilization, we choose a moderate value of the investment adjustment cost parameter, which is set to 1, well within the range of available estimates in the literature (e.g., Christiano et al., 2005 or Liu et al., 2013). All parameter values are summarized in Table D.2.

Finally, as anticipated in Section 5, we introduce a UIP deviation to allow the HANK and RANK models to better match the behavior of the real exchange rate. Following Gabaix (2020) and Galí (2020), we replace the rational expectations operator $\mathbb{E}_t[Q_{t+1}]$ in the UIP condition (4.9) with a subjective expectations operator $\tilde{\mathbb{E}}_t[Q_{t+1}]$ featuring “cognitive discounting” of future real-exchange-rate movements. Specifically, we let $\tilde{\mathbb{E}}_t[Q_{t+1}] = Q_{ss} + m\mathbb{E}_t[dQ_{t+1}]$, with $m \leq 1$, and where Q_{ss} is the “default” value of the real exchange rate that agents have in mind. Under this assumption, the linearized UIP condition solved forward yields $dQ_t = \sum_{k=0}^{\infty} m^k \mathbb{E}_t(dr_{t+k}^* - dr_{t+k})$, implying that future interest-rate differentials exert a smaller influence on the current exchange rate than under full rationality ($m = 1$). This attenuation is consistent with the empirical evidence in Galí (2020). We set $m = 0.7$, in line with the empirical estimates of Pfäuti and Seyrich (2022), which are in a range between 0.6 and 0.85.

We then turn to the quantitative results, which are reported in Figure 12. We observe a clear drop in investment on impact and throughout the first year or so. On impact, both the HANK and RANK models match the magnitude of the investment response well, but they struggle to replicate the persistence observed in the data. The responses of most other variables remain qualitatively similar to our previous findings. The initial decline in investment now contributes to a drop in imports, in line with the data, reflecting the import content of investment goods. Conversely, the fact that investment subsequently “overshoots” implies that the contractions in output and consumption (and their components) are less persistent than in our baseline

33. 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.

model results (see Section 6.)³⁴

We next examine the implications of cognitive discounting for the exchange-rate response. This mechanism dampens movements in the real exchange rate in both models, bringing the model-implied dynamics closer to the data and within the LP confidence bands for most horizons. The resulting milder appreciation further contributes to the decline in imports via expenditure switching. Beyond these effects, cognitive discounting has a modest impact on our findings, as seen from Appendix Figure E.11, which reports impulse responses for the fully rational case ($m = 1$).

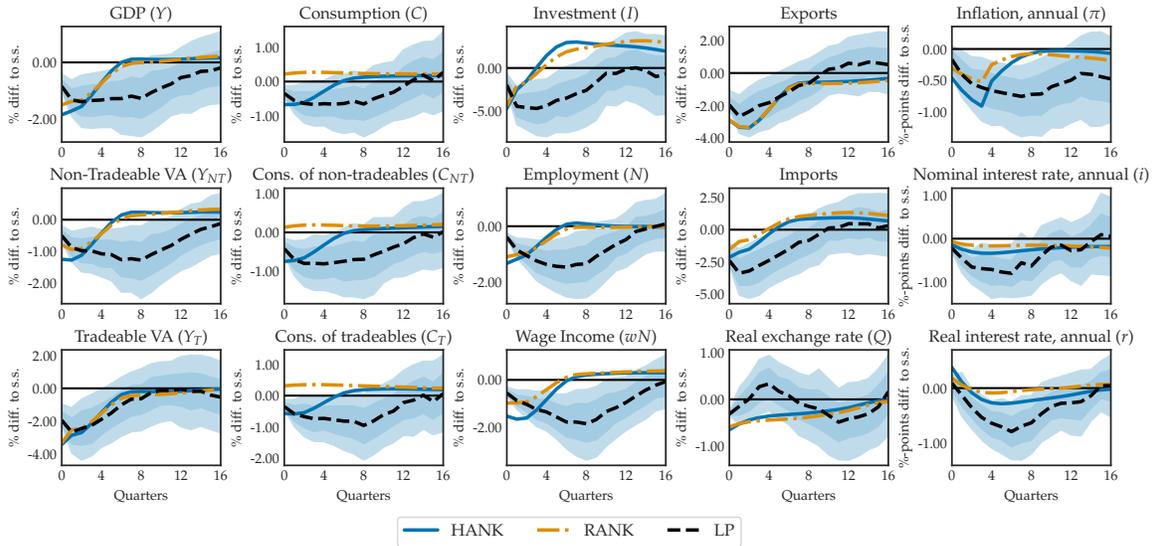


Figure 12: Response of the domestic economy to a foreign demand shock with capital formation

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.

Obtaining a positive comovement between consumption and investment in response to demand shocks is a well-known challenge 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). Our HANK model extended with a financial friction attains this for a number of quarters after the shock, whereas the RANK model entails a negative comovement between the two variables. However, additional frictions are

34. The drop in investment is associated with a credit contraction of a realistic magnitude. In the HANK model, credit drops by around -1.2 percent on average in the first three years after the shock. The corresponding number in the data is -1.1 percent, see Appendix Figure A.4. The model response is more front-loaded and less persistent than in the data, reflecting in part that all debt in the model is short-term (one-period), whereas the empirical counterpart has a longer average maturity.

required in order to induce a more persistent investment response in the HANK model and improve the quantitative fit. These may include sticky expectations (as in Auclert et al., 2020), sticky discount rates (Fukui et al., 2024), or time to build (Kydland and Prescott, 1982). Overall, we conclude that the introduction of capital does not alter the main takeaways from our analysis, and that our model can account for the initial decline in investment, but not its persistence.

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 study labor market dynamics in more detail. 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.

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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 Data description

We begin by providing details about the data used for the empirical analysis.

A.1.1 List of countries

Table A.1 contains a complete list of the countries we consider in our baseline analysis, and the classification we apply. We consider the G7 countries as large economies, and the remaining 31 OECD members as small open economies.³⁵

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.1: List of countries

35. 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.1.2 Variable description

Symbol	Variable	Description	Measurement	Log
Y_{NT}	Non-tradable value added	Gross value added in services	Chained, SA	Yes
Y_T	Tradable value added	Gross value added in manufacturing	Chained, SA	Yes
C_{NT}	Consumption of non-tradables	Consumption of services	Chained, SA	Yes
C_T	Consumption of tradables	Cons. of non-durables + semidurables	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
w_N	Real labor compensation	See text		Yes
w	Real wage rate	See text		Yes
π	Annual CPI inflation	See text		No
i	Nominal annual interest rate	See text		No
r	Real annual interest rate	See text		No
b^{cap}	Real credit (non-fin. sector)	See text		Yes

Table A.2: Variable description

Note: All data is quarterly and obtained from the OECD database, except credit, which we obtain from the BIS. 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 sums, we make sure to not simply add the underlying components, since these are chained, but to aggregate them appropriately.

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.

Real wage rate

The real wage rate, w_t , is computed as

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

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.

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.

Real annual interest rate

The real annual interest rate, r_t , is computed as

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

Real credit

As our measure of credit, we use credit to the private non-financial sector from the BIS database. This series is available for most of the OECD countries. We convert the series to real terms in the same way as described above for labor compensation.

Measures of global economic activity

We employ the following measures of global economic activity:

- Index of Industrial Production in the OECD + Six Major Economies (Brazil, China, India, Indonesia, Russia, South Africa): The index was developed by Baumeister and Hamilton (2019), and an updated version is available from Christiane Baumeister's personal website.
- Index of Global Real Economic Activity: The index was developed by Kilian (2009). A corrected and updated version is available from Lutz Kilian's personal website, with the corrections described in Kilian (2019).
- CPB World Industrial Production Index: The index is developed and maintained by the CPB Netherlands Bureau for Economic Policy Analysis for the European Commission. The data is available from the CPB's World Trade Monitor webpage.
- OECD-wide GDP is obtained directly from the OECD database as described above.

- Oil Price: We use the West Texas Intermediate Spot Crude Oil Price. The series is available from the FRED database (series name: WTISPLC).
- Commodity Price Index: We use the U.S. Producer Price Index for all commodities. The series is available from the FRED database (series: PPIACO).

Trade linkages

We calculate trade linkages based on data for “Gross exports” from the OECD Trade in Value-Added (TiVA) database. Data is available from 1995 and we use data until and including 2019.

A.1.3 Construction of 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:

$$w_{j,p}^{\text{raw}} = \frac{X_{j,p}}{\sum_{p=1}^{38} X_{j,p}} \quad \text{for } j, p = 1, \dots, 38,$$

where $X_{j,p}$ denotes country j 's exports to country p . We use a simple time-average over 1995-2019.

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:

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

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.17 and A.18—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:

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

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 $t = 1, \dots, T$ 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.16, our empirical findings are largely unaltered when we use a balanced panel of countries (starting in 1996).

A.1.4 Data for analysis of fiscal consolidations

For the study of fiscal consolidations in Section 2.7, we rely on annual instead of quarterly data, since the shock series itself is available at the annual frequency. For most variables, we simply rely on the annual versions of the quarterly data series described in Appendix A.1.2. For interest rates, we use data from the Macroeconomic History database of Jordà et al. (2017).³⁶

The fiscal consolidations shock series developed by Guajardo et al. (2014) and updated by Adler et al. (2024) covers the following 21 OECD countries for the sample period 1978-2019: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Mexico, Netherlands, Portugal, Spain, Sweden, United Kingdom, United States.

A.2 Sign restrictions

We continue with additional details about our identification strategy.

36. The response of the real interest rate is computed by subtracting the response of the inflation rate (leaded by one period) from that of the nominal interest rate.

A.2.1 Method

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

$$C_h \equiv \begin{pmatrix} \beta_{1,h} & \beta_{1,h}^Y & \beta_{1,h}^\pi & \beta_{1,h}^i \\ \beta_{2,h} & \beta_{2,h}^Y & \beta_{2,h}^\pi & \beta_{2,h}^i \\ \beta_{3,h} & \beta_{3,h}^Y & \beta_{3,h}^\pi & \beta_{3,h}^i \\ \beta_{4,h} & \beta_{4,h}^Y & \beta_{4,h}^\pi & \beta_{4,h}^i \end{pmatrix},$$

for $h = 1, \dots, H$ 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 $\varepsilon_{t,h} = (\varepsilon_{t,1}, \varepsilon_{t,1}^Y, \varepsilon_{t,1}^\pi, \varepsilon_{t,1}^i)'$, 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 $n = 1, 2, \dots, N$:

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 $\Theta^{(n)} \equiv (\Theta_0^{(n)'}, \Theta_1^{(n)'}, \dots, \Theta_H^{(n)'})'$, 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 1000), 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.3 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.3: 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.3 requires setting the matrices S_m as follows:

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

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

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.3 Implied shock series from LP regressions

In this appendix, we report the implied shocks obtained from our baseline empirical approach based on sign restrictions, as outlined in Section 2.1. We also compute correlations with identified shock series from the existing literature, so as to validate that our shocks are capturing demand, supply, and monetary policy disturbances, respectively. Since our baseline approach is to construct country-specific

foreign variables $(Y_{j,t}^*, \pi_{j,t}^*, i_{j,t}^*)$ for each country j , our estimation procedure produces country-specific shock series for each of the foreign shocks, rather than one common shock series for, e.g., foreign demand shocks. We then report the implied shocks for each of the small open economies (obtained as the average across the draws in the sign-restriction procedure).³⁷

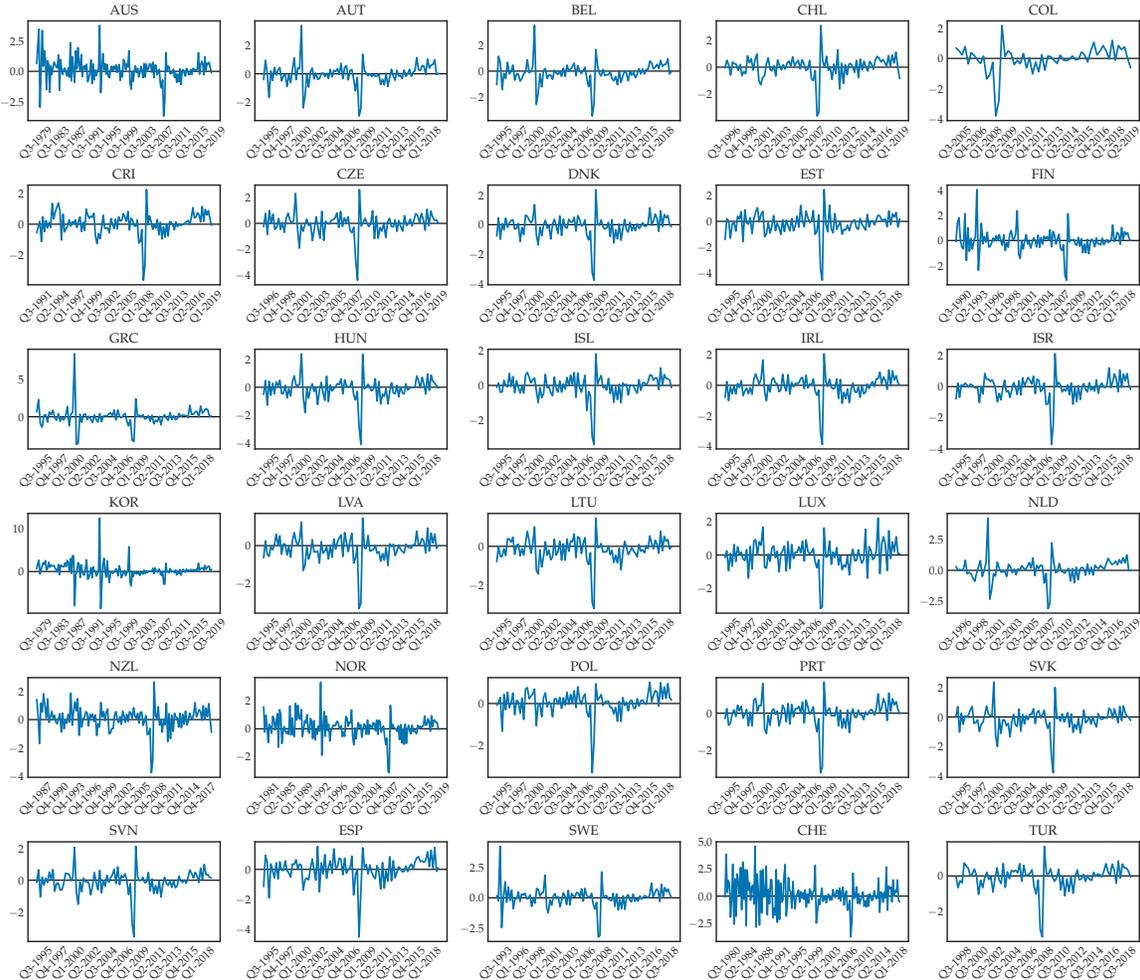


Figure A.1: Foreign demand shocks

Note: Estimated foreign demand shocks. The reported shocks are the average across draws, and obtained from regressions with exports on the left-hand side.

The implied shocks to foreign demand, supply, and monetary policy are reported

37. Our empirical approach implies that we estimate the entire system of equations, (2.1)-(2.4), for each domestic variable. As a result, we obtain “variable-specific” series for each of the foreign shocks. In practice, the implied foreign shock series from the different regressions display a very high correlation (typically > 0.95). Thus, while Figures A.1-A.3 report implied shocks from regressions with domestic exports on the left-hand side, this choice makes virtually no difference.

in Figures A.1-A.3.³⁸ For each type of shock, the series display a high degree of cross-country correlation, with the median country-pair correlation (excluding self-correlations) equal to 0.83 for both demand and supply shocks, and slightly higher for monetary policy shocks. This is consistent with our finding that using equal trade weights for all countries (that is, $Y_{j,t}^* = Y_t^*, \forall j$, and similar for $\pi_{j,t}^*$ and $i_{j,t}^*$) yields results very similar to our baseline (see Appendix Figure A.18).

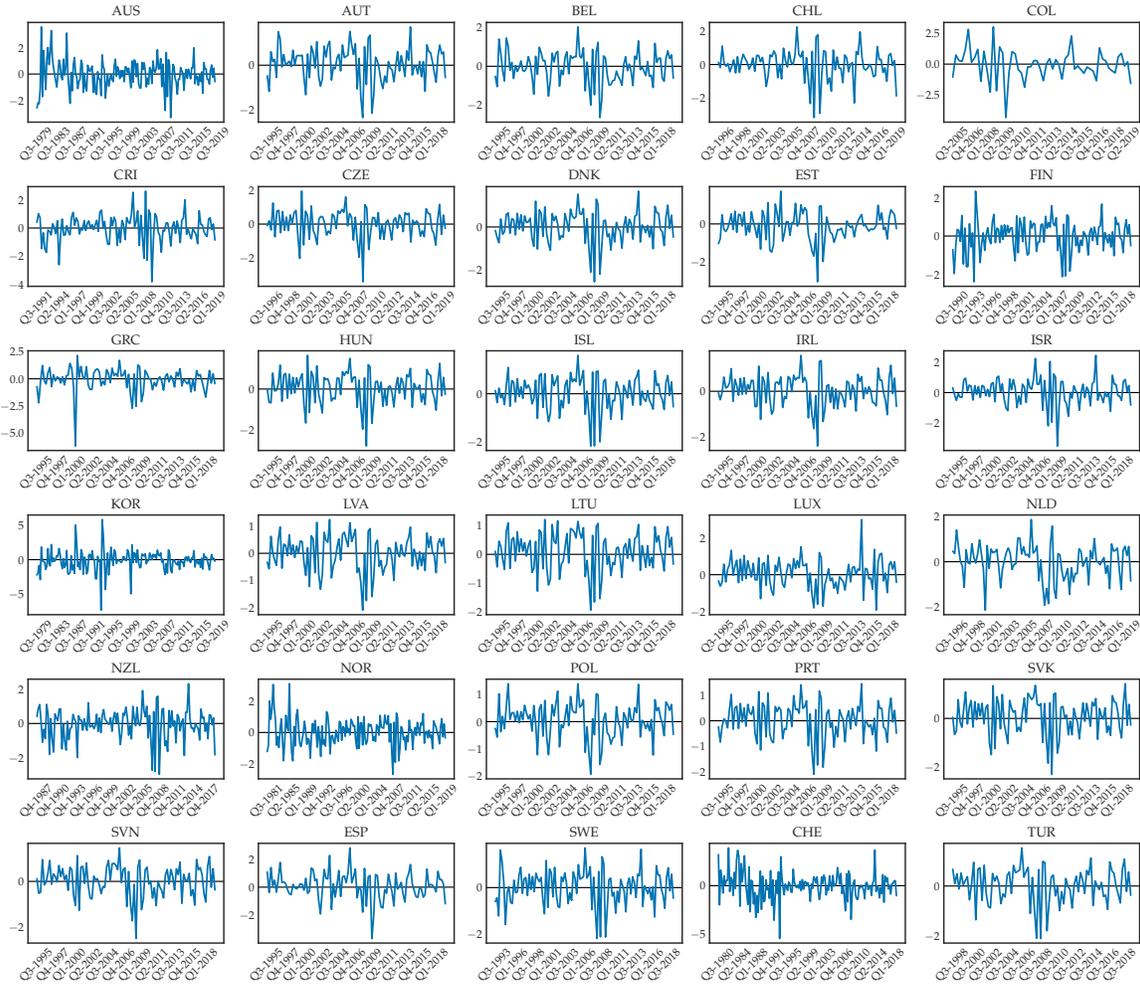


Figure A.2: Foreign supply shocks

Note: Estimated foreign supply shocks. The reported shocks are the average across draws, and obtained from regressions with exports on the left-hand side.

Next, we consider the correlation between the implied foreign shocks and other identified shock series from the existing literature. For a range of relevant identi-

38. While there are 31 countries in our sample, the OECD database does not have data on exports for Mexico, which is therefore not included in these figures.

fied shock series, we compute their correlation (and the associated p-values) with each of the 30 country-specific foreign shocks reported in Figures A.1-A.3. We summarize these results by reporting the median correlation across countries and the number of country-level correlations that are statistically significant at the 5 percent level. For foreign demand shocks, Table A.4 shows that our shocks display some correlation (0.16) with the U.S. military spending shocks of Ramey (2011), though this relationship is significant only in two of the 30 countries. We observe no correlation with other fiscal shocks. We also find some (negative) correlation with the uncertainty measure of Bloom (2009), but not with other uncertainty shocks. Finally, we find evidence of a negative correlation with the financial shocks of Gilchrist and Zakrajšek (2012). In sum, our shocks are correlated with some existing series with the expected sign, but the magnitude of the correlations is modest.

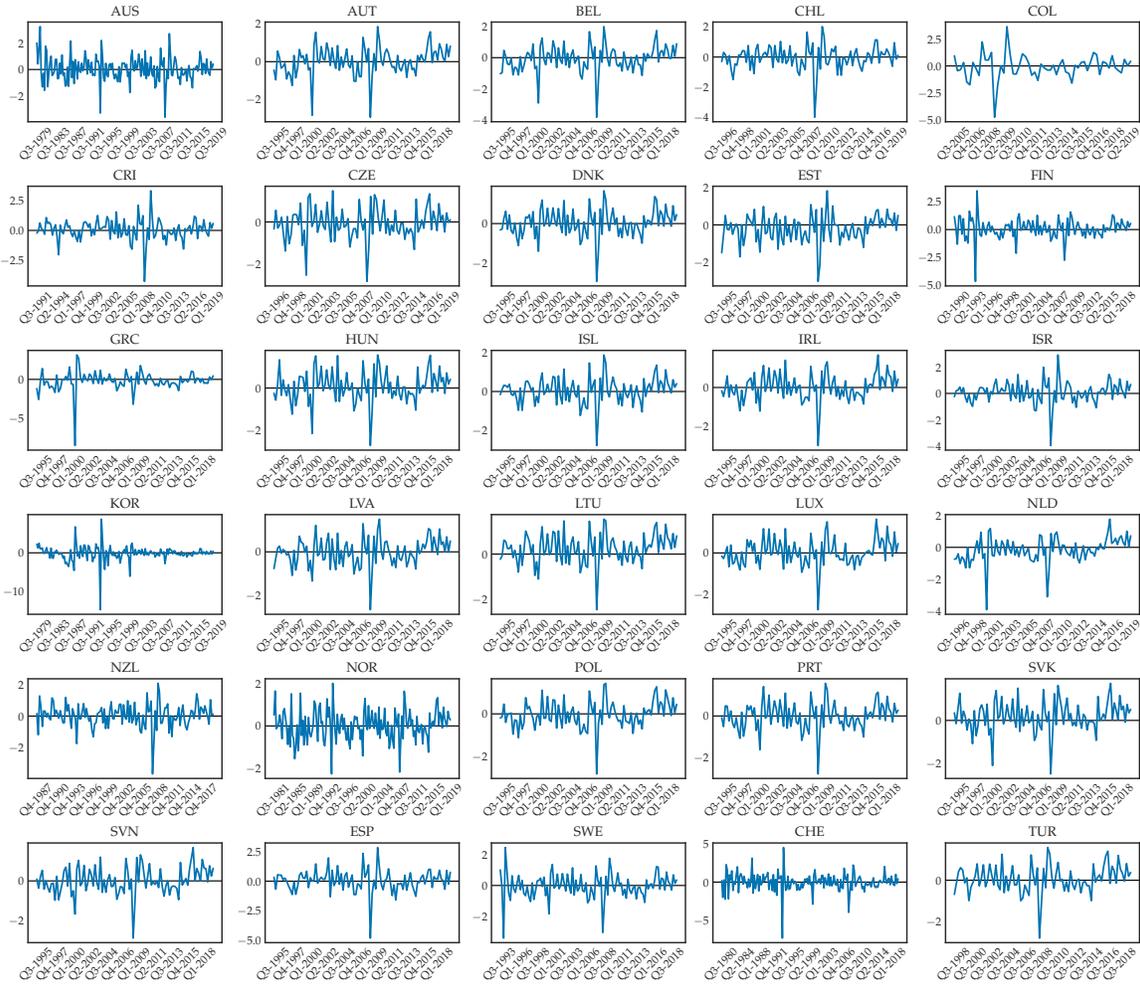


Figure A.3: Foreign monetary policy shocks

Note: Estimated foreign monetary policy shocks. The reported shocks are the average across draws, and obtained from regressions with exports on the left-hand side.

Turning to foreign supply shocks, Table A.5 shows that our shocks correlate with some other supply-side shocks in the form of the oil supply news shocks of Känzig (2021) as well as the oil supply shocks of Caldara et al. (2019), with weaker evidence of a correlation with some of the other oil supply shocks. The correlations have the expected signs, as a positive realization of our shocks implies a positive supply shock, in line with Caldara et al. (2019), while the opposite is true for the measure of Känzig (2021). This suggests that our shocks are indeed capturing supply disturbances.

Finally, as seen from Table A.6, our monetary policy shocks display some correlation with existing monetary policy shocks. In particular, they are correlated with the Euro area shocks of Jarociński and Karadi (2020) as well as the U.S. monetary policy shocks from Romer and Romer (2004) and from the estimated model of Smets and Wouters (2007). The negative correlation reflects that a positive value of the shocks in Figure 8 correspond to an expansionary shock, while the opposite is true for the remaining shock series. Thus, our measure is consistent with these.

	Median correlation	# countries with $p < 0.05$	Sample
<i>Fiscal shocks</i>			
Ramey (2011)	0.16	2	1979:Q3 - 2015:Q4
Auerbach and Gorodnichenko (2012)	0.07	0	1979:Q3 - 2019:Q4
Romer and Romer (2010)	-0.06	0	1979:Q3 - 2007:Q4
Fisher and Peters (2010)	0.03	0	1979:Q3 - 2008:Q4
<i>Uncertainty shocks</i>			
Ahir et al. (2022)	-0.02	0	1990:Q1 - 2019:Q4
Piffer and Podstawski (2018)	0.02	1	1979:Q3 - 2019:Q4
Bloom (2009)	-0.17	9	1979:Q3 - 2017:Q4
Baker et al. (2016)	-0.08	0	1985:Q3 - 2017:Q4
<i>Financial shocks</i>			
Bassett et al. (2014)	0.04	0	1992:Q1 - 2010:Q4
Gilchrist and Zakrajšek (2012)	-0.22	19	1979:Q3 - 2015:Q4

Table A.4: Correlation of demand shocks with other identified demand shocks

Note: The first column reports the median across countries of the correlation between the relevant identified shock series and our implied foreign demand shocks. The second column reports the number of countries (out of 30) for which the correlation is statistically significant, as measured by a p-value below 0.05. The third column reports the sample period for which we have employed each of the shocks.

	Median correlation	# countries with $p < 0.05$	Sample
<i>Productivity shocks</i>			
Smets and Wouters (2007)	-0.05	0	1979:Q3 - 2004:Q4
Basu et al. (2006)	-0.09	0	1979:Q3 - 2011:Q4
<i>Oil supply shocks</i>			
Känzig (2021) (news)	-0.28	27	1979:Q3 - 2019:Q4
Baumeister and Hamilton (2019)	0.08	4	1979:Q3 - 2017:Q4
Kilian (2009)	0.02	0	1979:Q3 - 2019:Q4
Caldara et al. (2019)	0.19	7	1985:Q1 - 2015:Q4
Kilian (2008)	0.13	1	1979:Q3 - 2004:Q3
<i>Other oil shocks</i>			
Hamilton (2003) (oil price)	-0.13	5	1979:Q3 - 2017:Q4
Kilian (2009) (oil-spec. demand)	0.04	0	1979:Q3 - 2017:Q4

Table A.5: Correlation of supply shocks with other identified supply shocks

Note: The first column reports the median across countries of the correlation between the relevant identified shock series and our implied foreign demand shocks. The second column reports the number of countries (out of 30) for which the correlation is statistically significant, as measured by a p-value below 0.05. The third column reports the sample period for which we have employed each of the shocks.

	Median correlation	# countries with $p < 0.05$	Sample
<i>US monetary policy shocks</i>			
Jarociński and Karadi (2020)	0.09	2	1990:Q1 - 2019:Q4
Romer and Romer (2004)	-0.21	3	1979:Q3 - 2007:Q4
Smets and Wouters (2007)	-0.27	8	1979:Q3 - 2004:Q4
Gertler and Karadi (2015)	0.05	1	1990:Q1 - 2016:Q4
<i>Euro area monetary policy shocks</i>			
Jarociński and Karadi (2020)	-0.25	23	1999:Q1 - 2019:Q4

Table A.6: Correlation of monetary policy shocks with other identified MP shocks

Note: The first column reports the median across countries of the correlation between the relevant identified shock series and our implied foreign demand shocks. The second column reports the number of countries (out of 30) for which the correlation is statistically significant, as measured by a p-value below 0.05. The third column reports the sample period for which we have employed each of the shocks.

A.4 Investment and credit

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

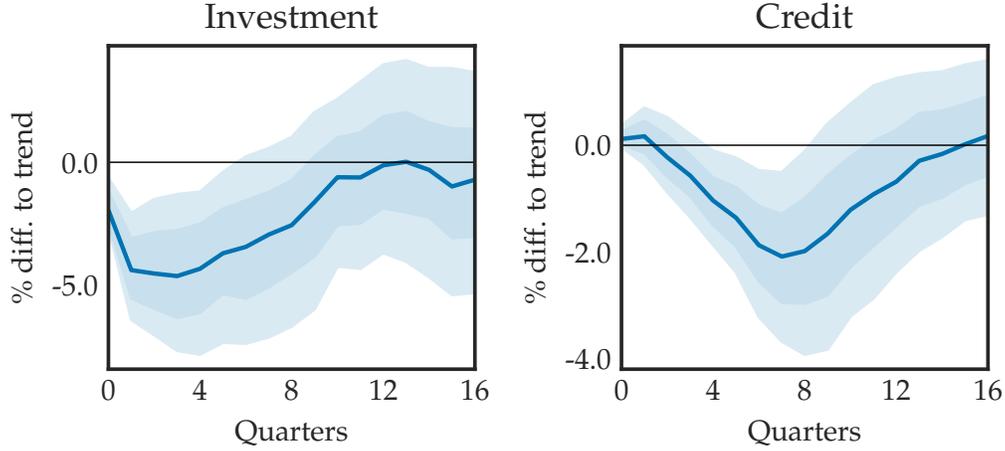


Figure A.4: LP results for investment and credit

Note: See Figure 2.

A.5 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.

We compute the FEVD as follows. For each accepted draw, we calculate the contribution of shock j to the variance of variable i at horizon h by accumulating the squared structural impulse responses as follows. The h -step mean-squared forecast error of variable i is $\sum_{k=1}^K \sum_{l=0}^h \Theta_{i,k,l}^2$, and the portion attributable to shock j is $\sum_{l=0}^h \Theta_{i,j,l}^2$. Thus, the FEVD is

$$\text{FEVD}_{i,j,h} = \frac{\sum_{l=0}^h \Theta_{i,j,l}^2}{\sum_{k=1}^K \sum_{l=0}^h \Theta_{i,k,l}^2}.$$

Here, $\Theta_{i,j,l}$ is the structural impulse response of variable i to shock j at horizon l . This is calculated for every accepted draw in the simulation.

In Table A.7 we report the FEVD of each variable at selected horizons alongside quantiles across the distribution of countries.

h	Y	C	X	M
4	22.2 (2.3,47.3)	5.6 (0.9,19.8)	13.5 (2.1,40.4)	15.6 (1.8,50.1)
16	24.1 (9.9,45.6)	16.7 (8.3,31.2)	22.5 (8.7,44.4)	25.5 (10.2,45.0)
∞	26.7 (13.8,41.1)	21.9 (11.3,32.2)	28.4 (13.3,41.1)	26.3 (14.1,41.3)

Table A.7: Forecast error variance decomposition (FEVD) of foreign demand shocks

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

A.6 Empirical robustness checks

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

A.6.1 Controlling for Kilian index

We consider using the Kilian index as a control variable in the main regressions. The IRFs are shown in Figure A.5.

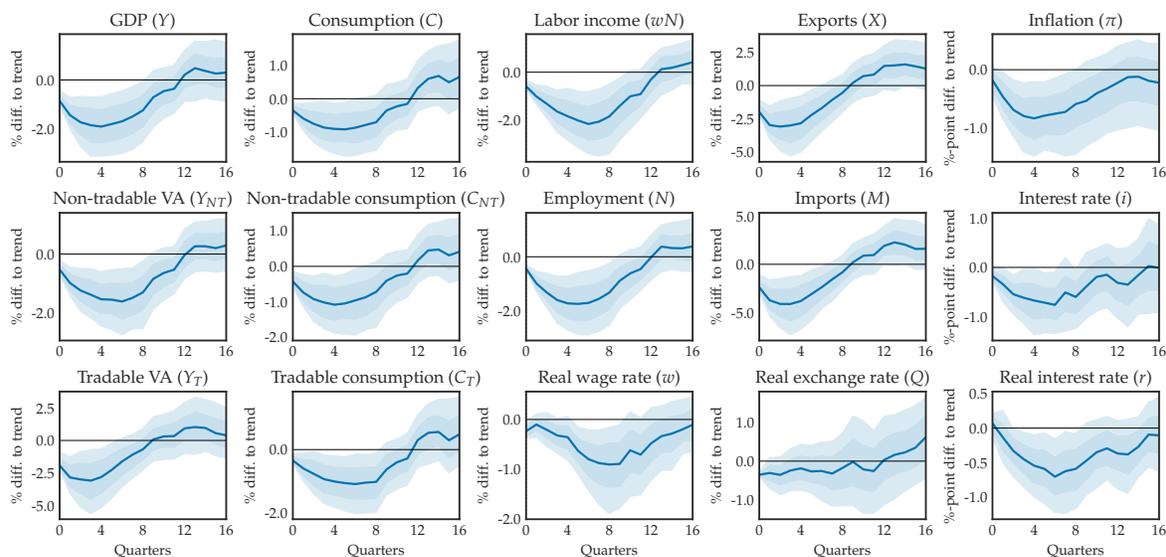


Figure A.5: LP results controlling for the Kilian index.

Note: See Figure 2.

A.6.2 Controlling for CPB index

We consider using the CPB index as a control variable in the main regressions. The IRFs are shown in Figure A.6.

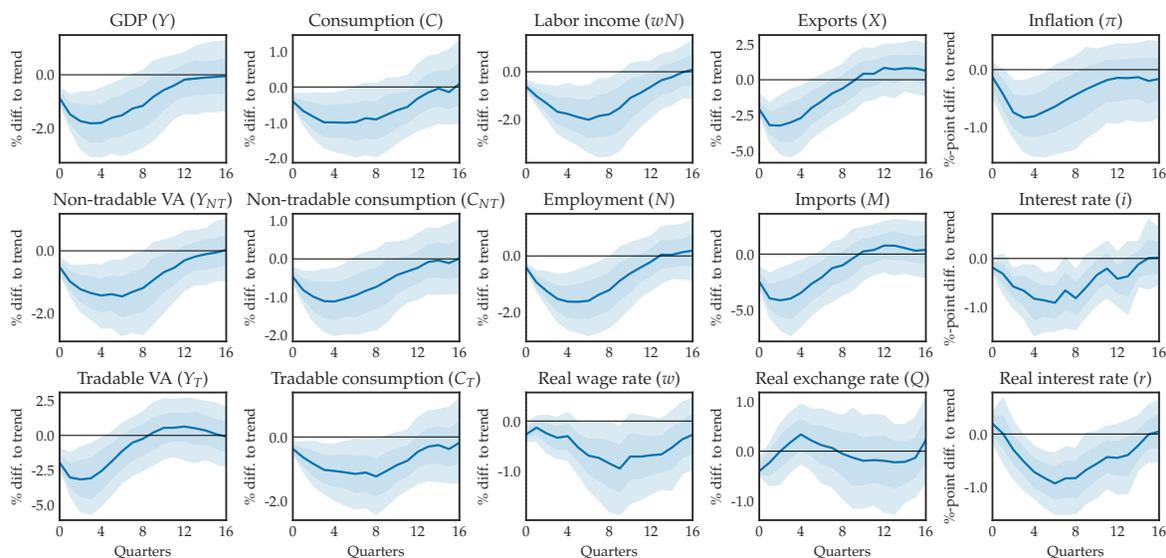


Figure A.6: LP results controlling for the CPB index.

Note: See Figure 2.

A.6.3 Controlling for OECD-wide GDP

We consider using OECD-wide GDP as a control variable in the main regressions. The IRFs are shown in Figure A.7.

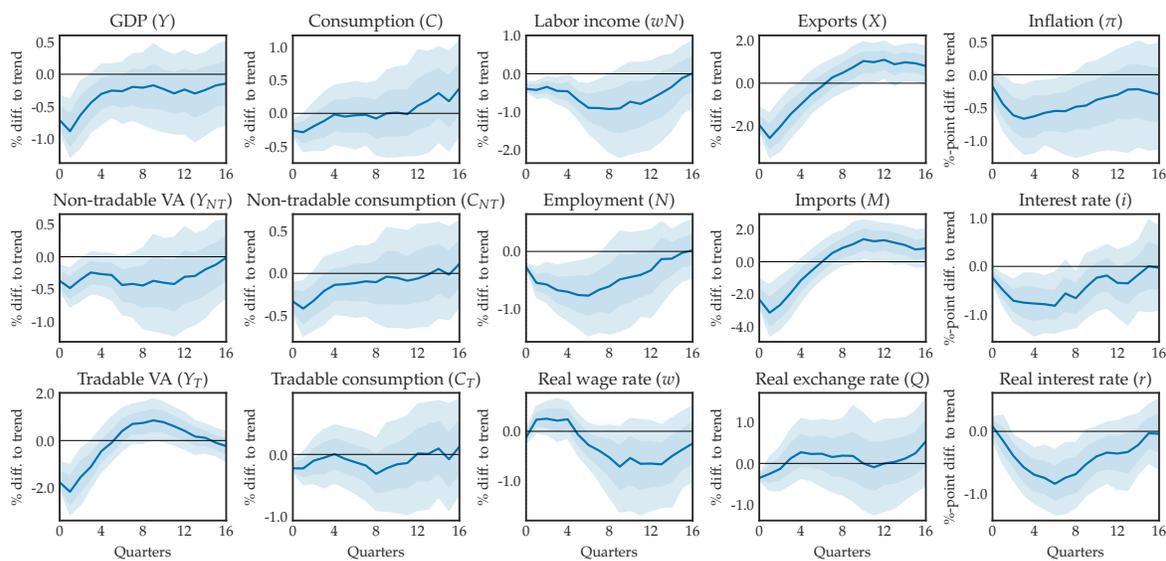


Figure A.7: LP results controlling for OECD GDP.

Note: See Figure 2.

A.6.4 Controlling for oil price

We consider using the oil price as a control variable in the main regressions. The IRFs are shown in Figure A.8.

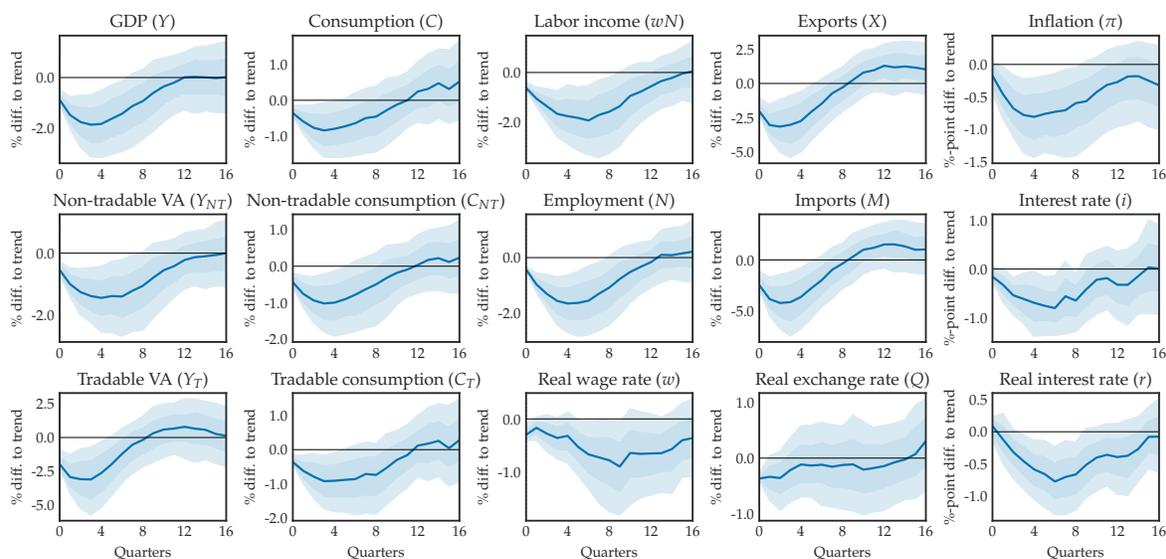


Figure A.8: LP results controlling for the oil price.

Note: See Figure 2.

A.6.5 Controlling for commodity price

We consider using commodity prices as a control variable in the main regressions. The IRFs are shown in Figure A.9.

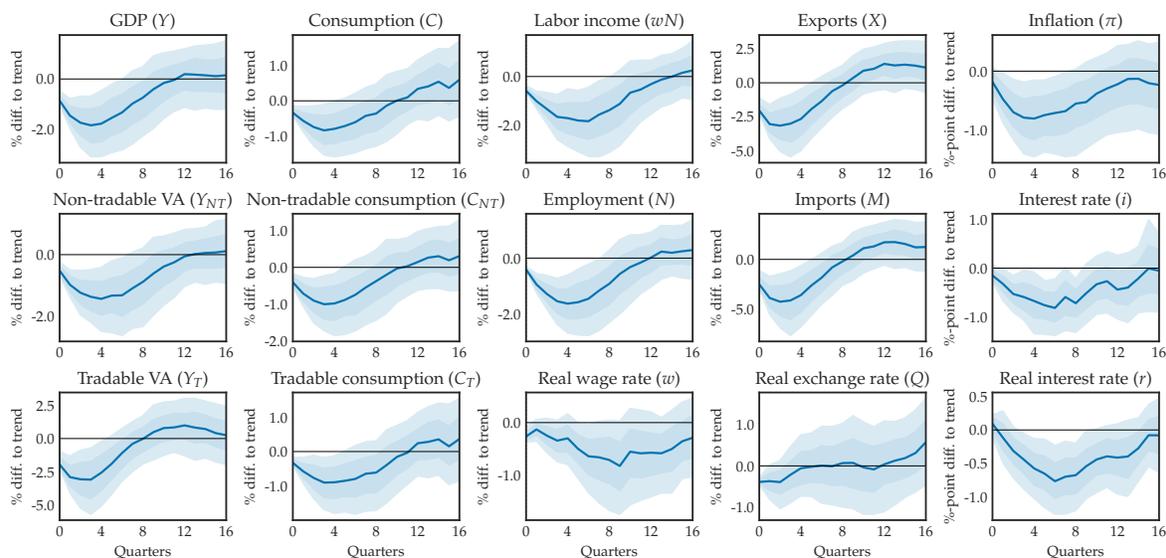


Figure A.9: LP results controlling for commodity prices.

Note: See Figure 2.

A.6.6 Controlling for Global Financial Crisis dummy

We consider using a dummy for the Global Financial Crisis as a control variable in the main regressions. The IRFs are shown in Figure A.10.

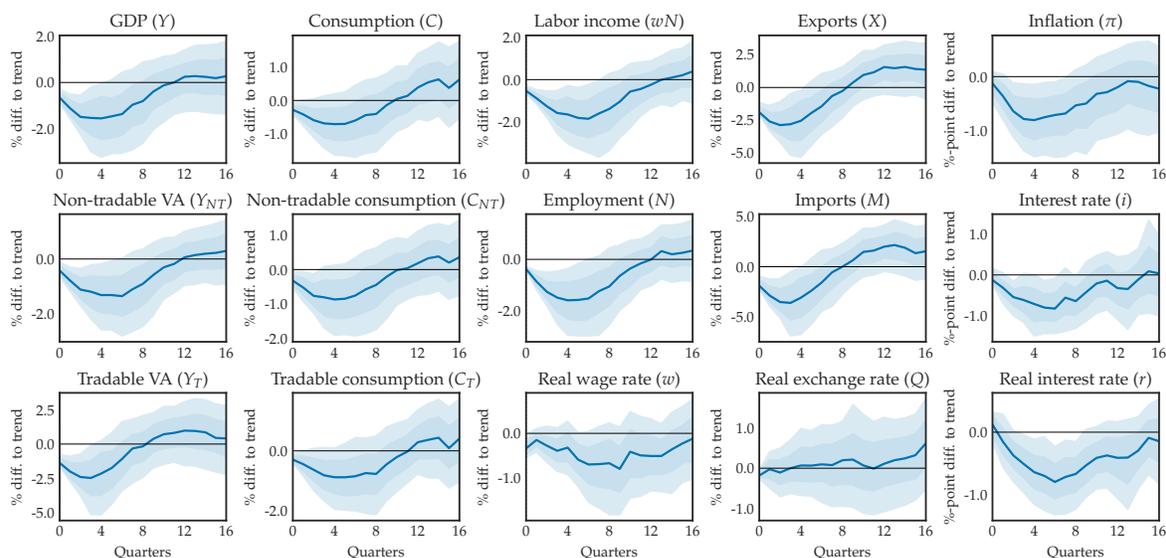


Figure A.10: LP results controlling for GFC dummy.

Note: See Figure 2.

A.6.7 Excluding the US

We consider a case where we set the weight of the US to zero in the construction of foreign variables, so as to exclude the U.S. economy entirely from our analysis.

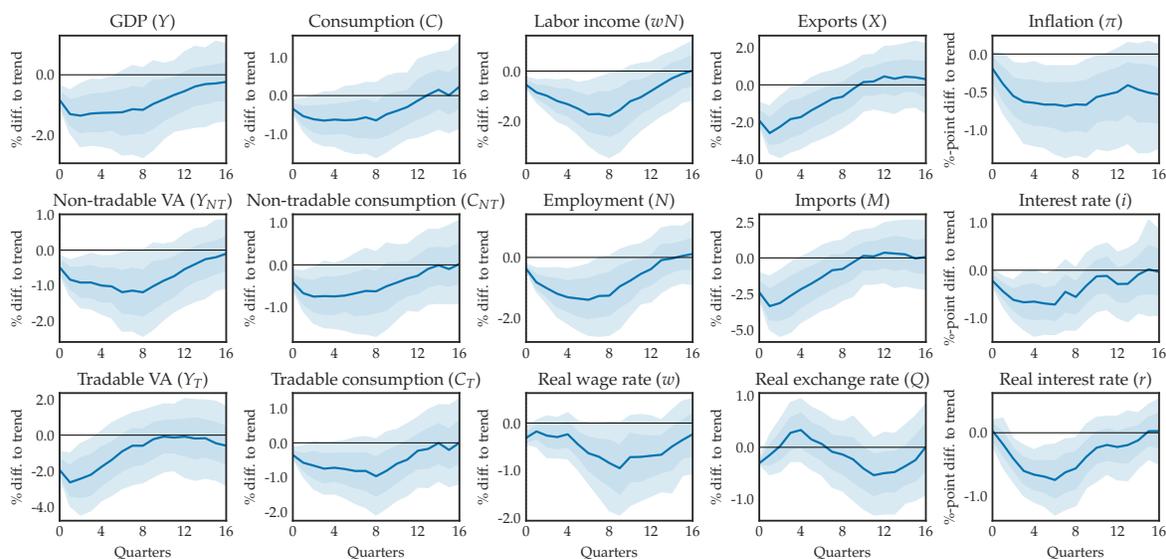


Figure A.11: LP results when excluding the US.

Note: See Figure 2.

A.6.8 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, and a floating exchange rate otherwise. The results for each sample are shown in Figures A.12 and A.13.

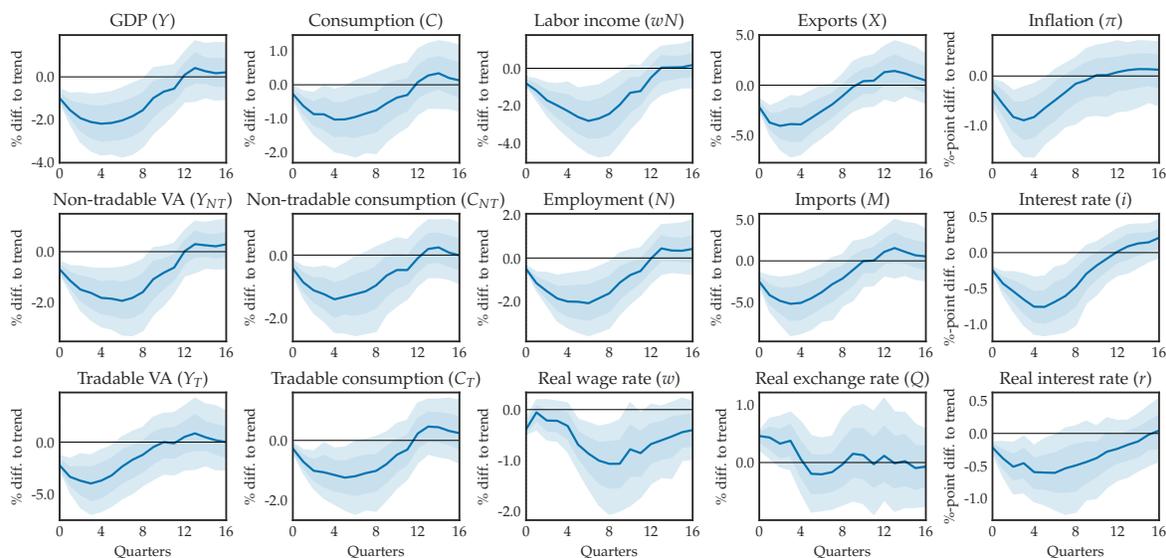


Figure A.12: LP results with fixed exchange rate countries only

Note: See Figure 2.

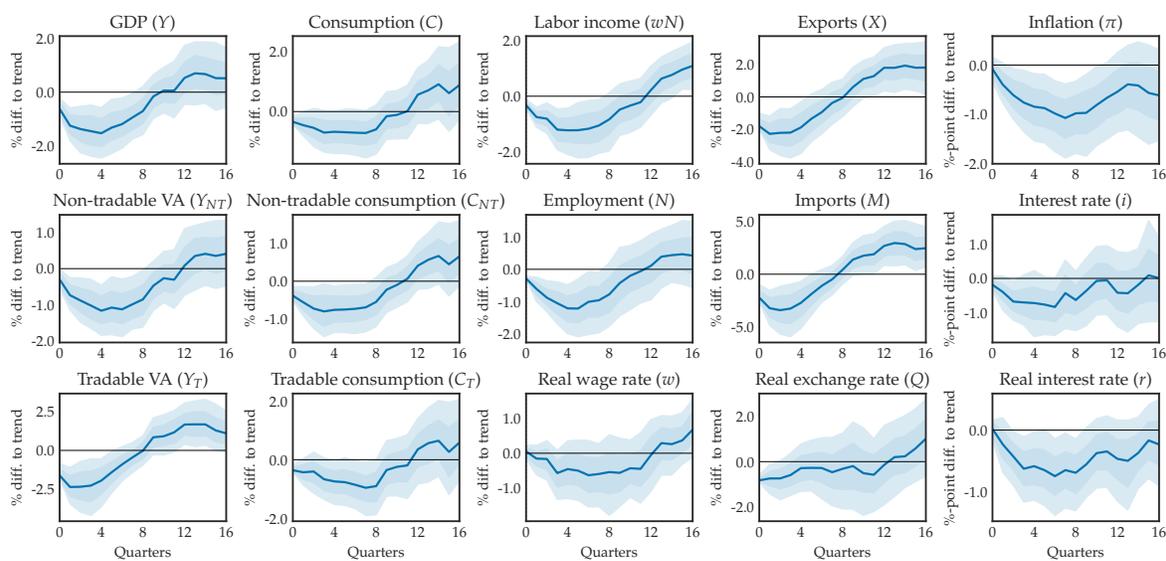


Figure A.13: LP results with floating exchange rate countries only

Note: See Figure 2.

A.6.9 Structural Vector Autoregression

We consider using a structural VAR model instead of local projections. The results are reported in Figure A.14 (solid blue lines). As seen from the figure, this produces results that largely appear like smoothed versions of our LP results (dashed black lines), consistent with the insights of Plagborg-Møller and Wolf (2021).

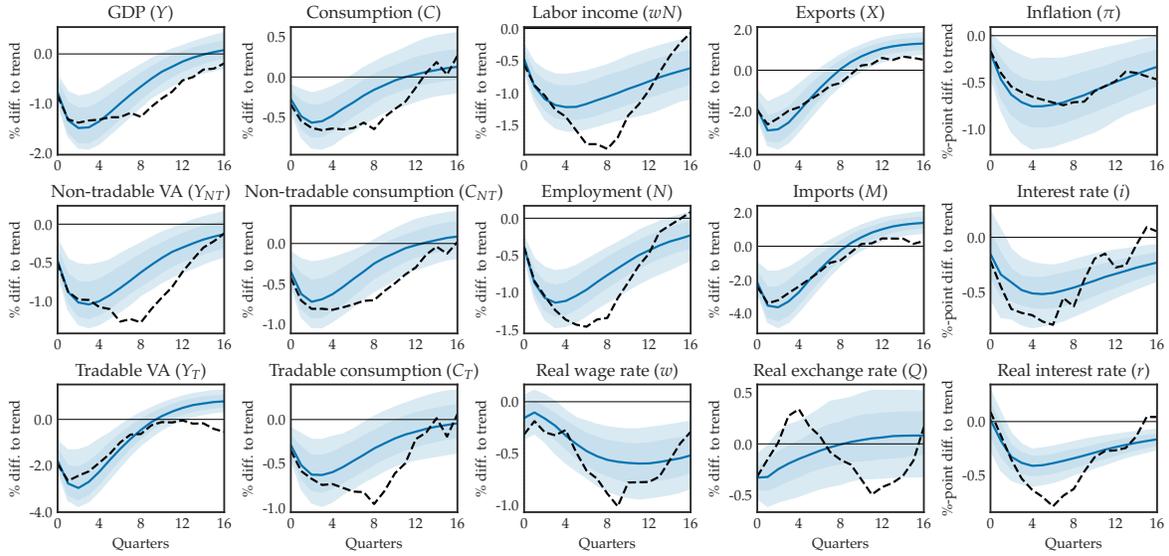


Figure A.14: SVAR IRFs

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). The SVAR does not include a global control.

A.6.10 More lags.

We use $p = 4$ lags instead of $p = 2$. The IRFs are shown in Figure A.15.

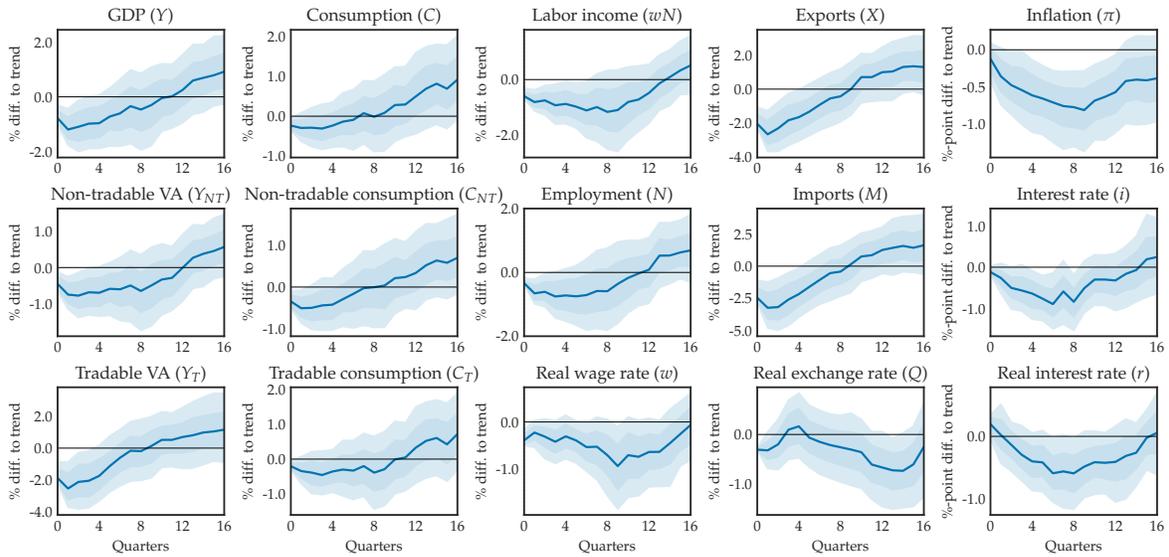


Figure A.15: LP results with 4 lags

Note: See Figure 2.

A.6.11 Balanced sample

We restrict the sample to a balanced panel starting in 1996. The IRFs are shown in Figure A.16.

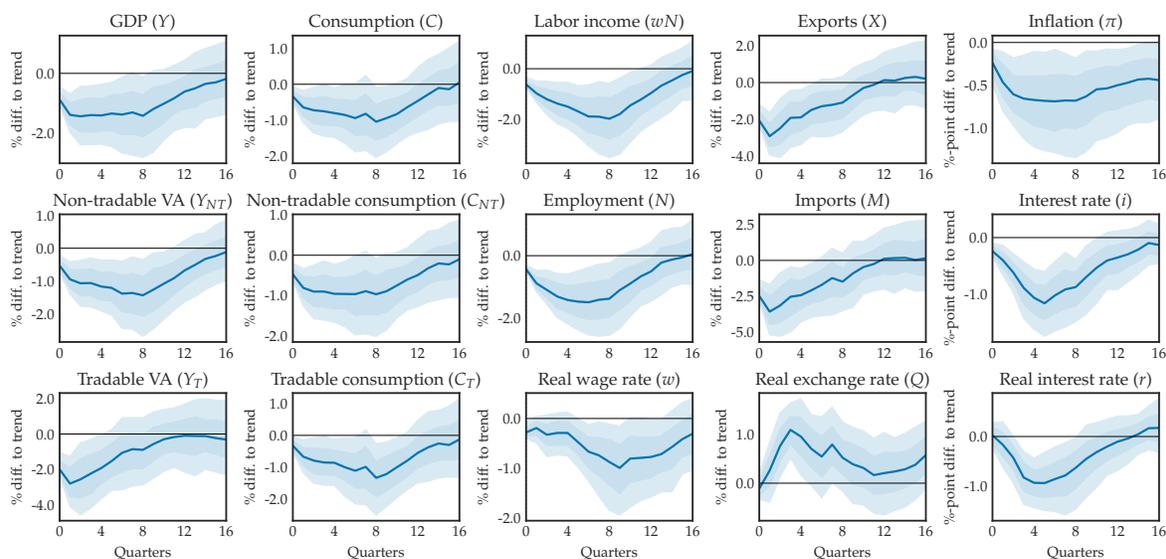


Figure A.16: LP results with balanced panel starting in 1996

Note: See Figure 2.

A.6.12 Only large economies on right-hand side.

We consider constructing $Y_{j,t}^*$ using only large economies (the G7). For the list of large economies, see Table A.1. The IRFs are shown in Figure A.17.

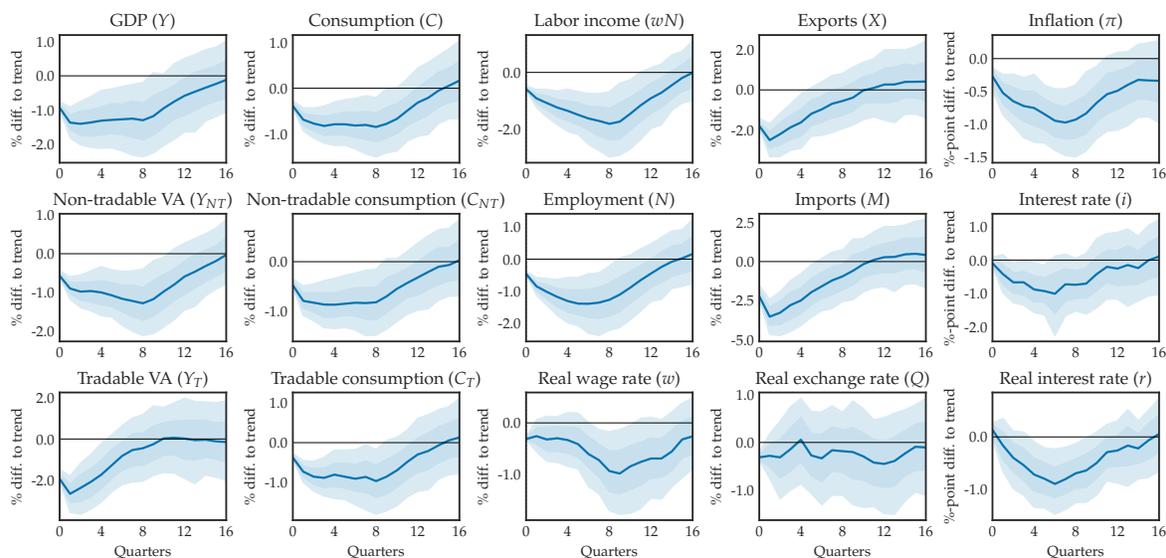


Figure A.17: LP results with only G7 economies used in the construction of Y_{jt}^* .

Note: See Figure 2.

A.6.13 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.18.

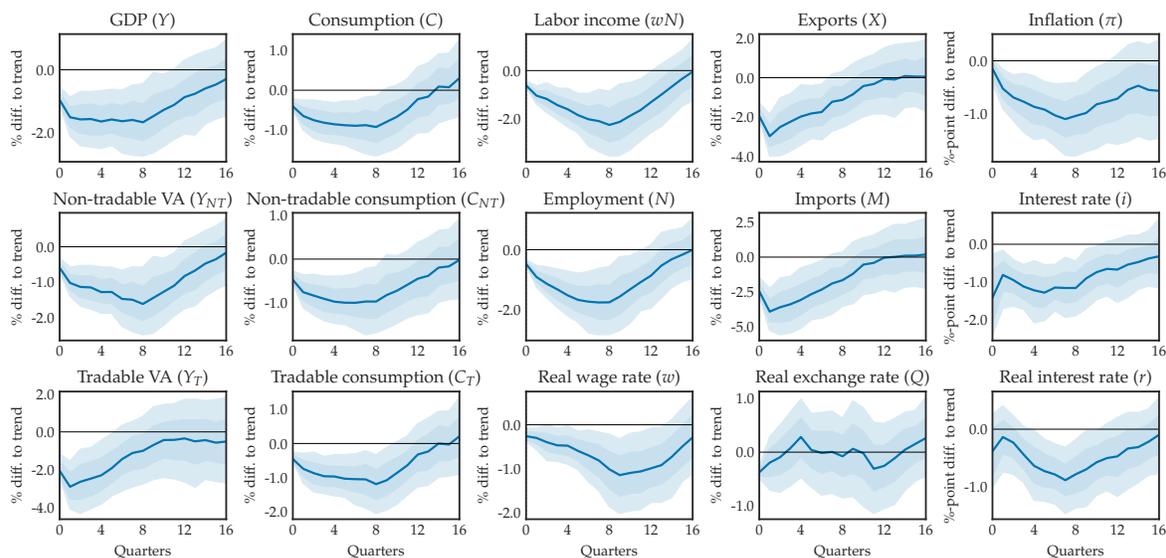


Figure A.18: LP results with a common foreign economy.

Note: See Figure 2.

A.6.14 No sign restrictions

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

$$Z_{j,t+h} = \beta_h Y_{j,t}^* + \sum_{k=1}^p \delta_{h,k}^Z Z_{j,t-k} + \sum_{k=1}^p \delta_{h,k}^{Y^*} Y_{j,t-k}^* + \gamma_h V_{t+h} + \varepsilon_{j,t,h}, \quad (\text{A.1})$$

The IRFs are shown in Figure A.19.

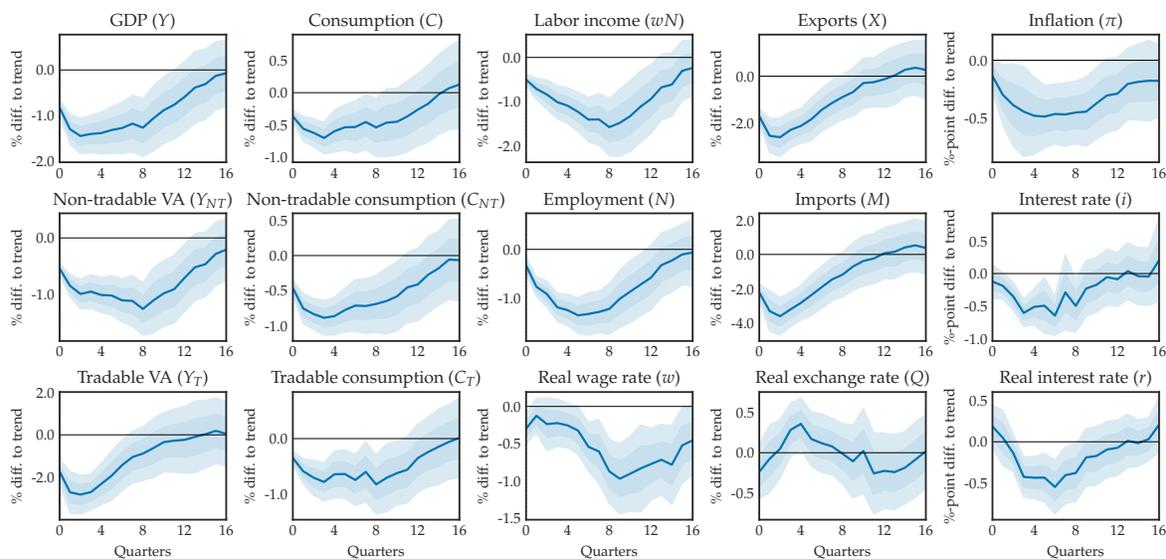


Figure A.19: LP results without sign restrictions.

Note: See Figure 2.

A.6.15 Long-run restrictions

We consider estimating the effects of foreign demand shocks with long-run restrictions. The IRFs are shown in Figure A.20.

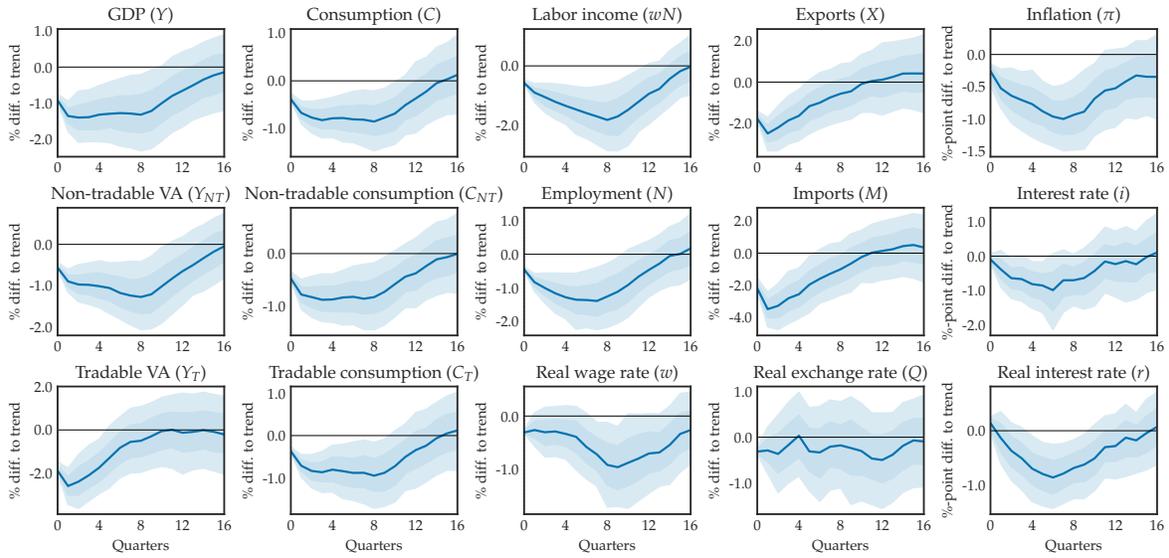


Figure A.20: LP results with long-run restrictions.

Note: See Figure 2.

A.6.16 Effects of foreign monetary policy

We now consider the effects of a foreign monetary policy shock.

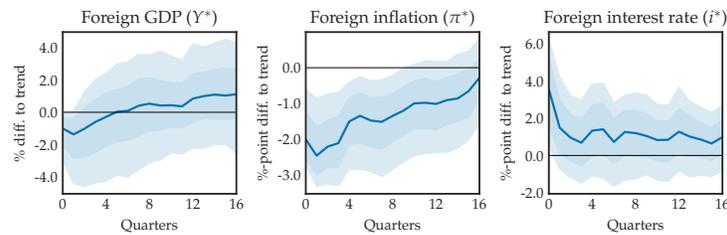


Figure A.21: Effects of foreign monetary policy shock in the foreign economy

Note: See Figure 2.

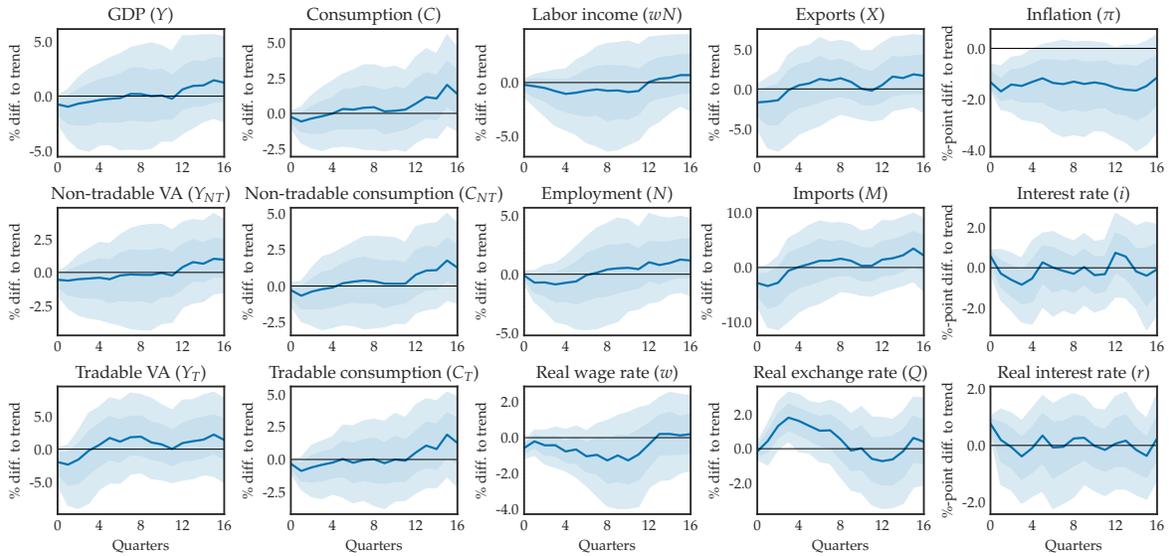


Figure A.22: Effects of foreign monetary policy shock in the small open economy

Note: See Figure 2.

A.6.17 Extra figures to fiscal consolidation shock

We report the results of our robustness checks in the analysis of foreign fiscal consolidations.

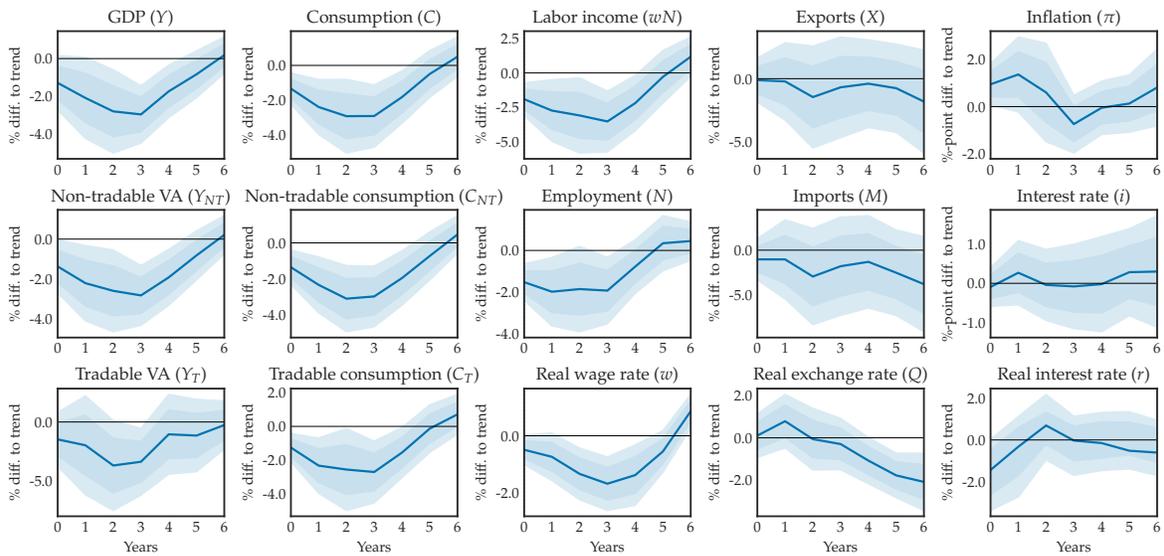


Figure A.23: Effects of fiscal consolidation in the small open economy when controlling for the Baumeister-Hamilton index

Note: See Figure 7.

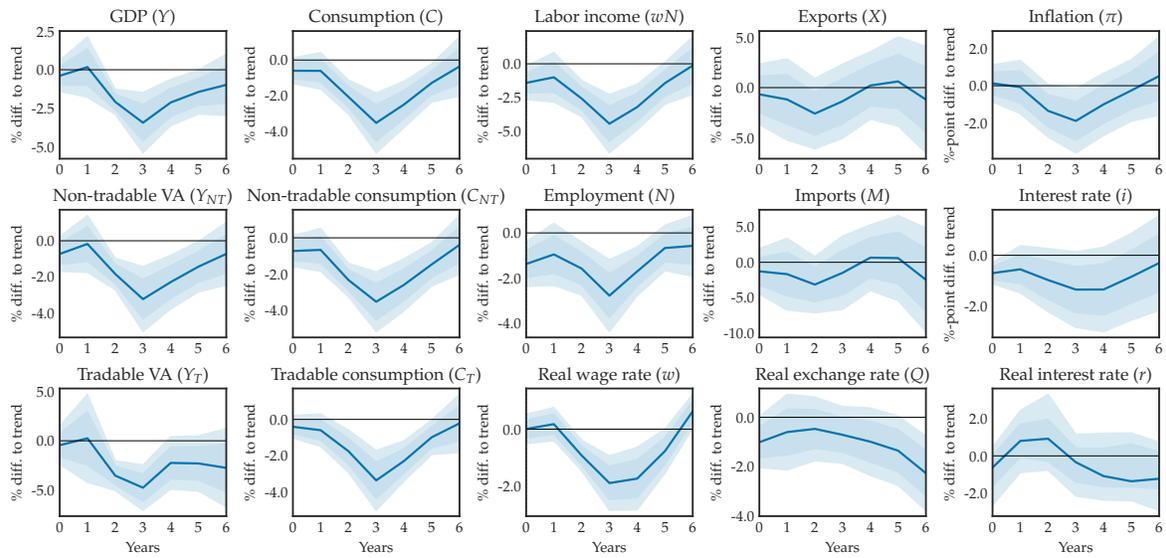


Figure A.24: Effects of fiscal consolidation in the small open economy when using the fiscal consolidation series of Alesina et al. (2019)

Note: See Figure 7.

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.

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

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

$$C_{H,t}^* = \alpha \left(\frac{P_{H,t}^*}{P^*} \right)^{-\eta^*} C_t^*, \quad (\text{B.3})$$

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

$$C_t = C_t \left(\left\{ r_s, Y_s^{hh} \right\}_{s=0}^{\infty} \right), \quad (\text{B.5})$$

$$Y_t^{hh} = \frac{W_t N_t}{P_t}, \quad (\text{B.6})$$

$$Y_t = Z_t N_t, \quad (\text{B.7})$$

$$W_t = P_{H,t} Z_t, \quad (\text{B.8})$$

$$w_t = \frac{W_t}{P_t}, \quad (\text{B.9})$$

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

$$Q_t = E_t \frac{P_t^*}{P_t}, \quad (\text{B.11})$$

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

$$P_{F,t} = E_t P_t^*, \quad (\text{B.13})$$

$$P_{H,t}^* = \frac{P_{H,t}}{E_t}, \quad (\text{B.14})$$

$$i_t = i_{ss} + \phi^\pi \mathbb{E}_t \pi_{H,t+1}, \quad (\text{B.15})$$

$$Y_t = C_{H,t}^* + C_{H,t}, \quad (\text{B.16})$$

$$1 + r_t = (1 + r_t^*) \frac{\mathbb{E}_t Q_{t+1}}{Q_t}. \quad (\text{B.17})$$

- 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. Since certainty equivalence holds under a first-order approximation we drop the expectation operator in the following derivations.

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:

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

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:

$$dP_{H,t} = dP_t - \frac{\alpha}{1 - \alpha} dQ_t. \quad (\text{B.18})$$

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

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

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):

$$\begin{aligned} dY_t^{hh} &= dY_t + (dP_{H,t} - dP_t) \\ dY_t^{hh} &= dY_t - \frac{\alpha}{1 - \alpha} dQ_t. \end{aligned} \quad (\text{B.20})$$

B.1.3 UIP and Taylor rule

Start with (B.19) forwarded one period:

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

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:

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

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

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

From here on we set $dr^* = 0$ for analytical clarity. In sequence space, the above can then be written as

$$(1 - \phi^\pi) d\pi_H = \frac{1}{1-\alpha} G^{r,Q} dQ, \quad (\text{B.23})$$

where

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

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

$$dr = -G^{r,Q} dQ. \quad (\text{B.24})$$

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:

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

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:

$$\Gamma d\pi_H = \frac{\kappa_w}{\varphi} dY + \kappa_w \frac{\alpha}{1-\alpha} dQ,$$

where

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

Finally, we can substitute out $d\pi_H$ using (B.23) to establish a link between the real exchange rate and output:

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

or equivalently, solving for dQ ,

$$dQ = -\mathbf{G}^{Q,Y} dY, \tag{B.25}$$

where

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

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

B.1.5 Households

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

$$dC = M^r dr + M dY^{hh},$$

where M^r and M are the Jacobians of 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

dY^{hh} from (B.20) yields

$$dC = M^r dr + MdY - \frac{\alpha}{1-\alpha} MdQ. \quad (\text{B.28})$$

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

$$\begin{aligned} dC &= M^r dr + MdY - \frac{\alpha}{1-\alpha} MdQ \\ &= M^r dr + MdY + \frac{\alpha}{1-\alpha} MG^{Q,Y} dY \\ &= -M^r G^{r,Q} dQ + MdY + \frac{\alpha}{1-\alpha} MG^{Q,Y} dY \\ &= \left(M + M^r G^{r,Q} G^{Q,Y} + \frac{\alpha}{1-\alpha} MG^{Q,Y} \right) dY \\ &= G^{C,Y} dY, \end{aligned} \quad (\text{B.29})$$

where

$$G^{C,Y} \equiv M + M^r G^{r,Q} G^{Q,Y} + \frac{\alpha}{1-\alpha} MG^{Q,Y}. \quad (\text{B.30})$$

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 $G^{C,Y}$ 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 dQ from (B.25) yields

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

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

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

where

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

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

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

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 $\mathbf{G}^{Q,Y}$, whose entries depend on the Taylor rule under a floating exchange rate. Note that the matrix $\mathbf{G}^{r,Q}$ 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:

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

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

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

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

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

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 Q, 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 $d\pi^* = 0$ we obtain the following expression for $G^{Q,Y}$ under a peg:

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

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

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:

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

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

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

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:

$$\begin{aligned} V_{s,t}^F &\equiv \max_{P_{s,t}, Z_{s,t}, X_{s,t}, L_{s,t}, K_{s,t}} \left\{ D_{s,t} + \frac{1}{1+r_t} \mathbb{E}_t V_{s,t+1}^F \right\} \\ &\text{s.t.} \\ Z_{s,t}^j &= \left(\frac{P_{s,t}^j}{P_{s,t}} \right)^{-\epsilon^P} Z_{s,t}, \end{aligned}$$

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

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

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

The first-order conditions for factor demands are:

$$\begin{aligned}
(1 - \tau_t^v) \frac{P_{s,t}}{P_t} \frac{\partial Z_{s,t}}{\partial X_{s,t}} - (1 - \tau_t^v) \frac{P_{s,t}^X}{P_t} - \lambda_{s,t} \frac{\partial Z_{s,t}}{\partial X_{s,t}} &= 0, \\
(1 - \tau_t^v) \frac{P_{s,t}}{P_t} \frac{\partial Z_{s,t}}{\partial L_{s,t}} - (1 - \zeta_t^p) \frac{W_{s,t}}{P_t} - \lambda_{s,t} \frac{\partial Z_{s,t}}{\partial L_{s,t}} &= 0, \\
(1 - \mathbb{E}_t \tau_{t+1}^v) \mathbb{E}_t \frac{P_{s,t+1}}{P_{t+1}} \frac{\partial Z_{s,t+1}}{\partial K_{s,t}} - \mathbb{E}_t r_{s,t+1}^K - \mathbb{E}_t \lambda_{s,t+1} \frac{\partial Z_{s,t+1}}{\partial K_{s,t}} &= 0.
\end{aligned}$$

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:

$$mc_{s,t} \frac{\partial Z_{s,t}}{\partial X_{s,t}} = (1 - \tau_t^v) \frac{P_{s,t}^X}{P_t}, \quad (\text{C.2})$$

$$mc_{s,t} \frac{\partial Z_{s,t}}{\partial L_{s,t}} = (1 - \zeta_t^p) \frac{W_{s,t}}{P_t}, \quad (\text{C.3})$$

$$\mathbb{E}_t mc_{s,t+1} \frac{\partial Z_{s,t+1}}{\partial K_{s,t}} = \mathbb{E}_t r_{s,t+1}^K. \quad (\text{C.4})$$

The marginal products of labor and capital are given by:

$$\begin{aligned}
\frac{\partial Z_{s,t}}{\partial X_{s,t}} &= \alpha_s^X \frac{Z_{s,t}}{X_{s,t}}, \\
\frac{\partial Z_{s,t}}{\partial L_{s,t}} &= (1 - \alpha_s^X) (1 - \alpha_s^K)^{\frac{1}{\eta_{KL}}} Z_s X_{s,t}^{\alpha_s^X} H_{s,t}^{\frac{1}{\eta_{KL}} - \alpha_s^X} L_{s,t}^{-\frac{1}{\eta_{KL}}}, \\
\frac{\partial Z_{s,t+1}}{\partial K_{s,t}} &= (1 - \alpha_s^X) (\alpha_s^K)^{\frac{1}{\eta_{KL}}} Z_s X_{s,t+1}^{\alpha_s^X} H_{s,t+1}^{\frac{1}{\eta_{KL}} - \alpha_s^X} K_{s,t}^{-\frac{1}{\eta_{KL}}}.
\end{aligned}$$

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

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

Imposing a symmetric equilibrium, we may rewrite this as:

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

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

C.2 Capital firms

In the model with capital, producers rent capital services from capital firms, which own and accumulate capital. The capital firm chooses investment I_t , capital K_t , debt b_t^{cap} , and dividends d_t^{cap} , all in units of the investment good. The latter is a CES aggregate of domestic and foreign investment goods with an import share of $0 < \alpha_I < 1$ and an elasticity of substitution equal to $\eta_{H,F}$. Domestic investment goods are simply final goods (from either of the two sectors in the economy) used for investment.

Let β_{t+1}^I denote the one-period discount factor between t and $t + 1$ (in units of the investment good), and define the cumulative discount factor:

$$B_t^I \equiv \prod_{j=1}^t \beta_j^I, \quad B_0^I \equiv 1. \quad (\text{C.5})$$

The factor B_t^I gives the discount from date 0 to date t as a product of future one-period discount factors. The discount factor is $\beta_{t+1}^I = \frac{1}{1 + \mathbb{E}_t r_{t+1}^I}$, where:

$$r_t^I \equiv \frac{1 + i_{t-1}}{1 + \pi_t^I} - 1, \quad (\text{C.6})$$

with π_t^I denoting the inflation rate of the price of investment goods.

The capital firm maximizes the discounted value of dividends:

$$\max_{\{K_t, I_t, b_t^{cap}, d_t^{cap}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} B_t^I d_t^{cap}, \quad (\text{C.7})$$

subject to a flow-of-funds constraint:

$$\frac{P_t}{P_{I,t}} r_t^K K_{t-1} - I_t - g \left(\frac{I_t}{I_{t-1}} \right) I_t - d_t^{cap} - \psi^{cap} (d_t^{cap} - \bar{d}^{cap})^2 + b_t^{cap} - (1 + r_t^I) b_{t-1}^{cap} = 0, \quad (\text{C.8})$$

where $\psi^{cap} > 0$ denotes the (quadratic) cost of deviating from the steady-state level of dividend payouts \bar{d}^{cap} , thus capturing the dividend-smoothing motive. They also face a standard capital accumulation equation:

$$K_t = (1 - \delta) K_{t-1} + I_t, \quad (\text{C.9})$$

and the borrowing constraint:

$$b_t^{cap} = \theta \frac{P_t}{P_{I,t}} r_t^K K_{t-1}. \quad (\text{C.10})$$

Here, r_t^K is the real rental rate of capital, and $g\left(\frac{I_t}{I_{t-1}}\right) = \frac{\phi^I}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2$ denotes quadratic investment adjustment costs, with $\phi^I > 0$. Moreover, $\delta > 0$ is the depreciation rate of capital, and $\theta > 0$ denotes the maximum debt-to-earnings ratio faced by capital firms. In the specification of the borrowing constraint (C.10), we follow the arguments in Drechsel (2023) and use real earnings without subtracting investment expenses or debt service costs of the firm.

Finally, the CES aggregator defining the price of investment goods is given by:

$$P_{I,t} = \left[(1 - \alpha_I) P_t^{1-\eta_{H,F}} + \alpha_I P_{F,t}^{1-\eta_{H,F}} \right]^{\frac{1}{1-\eta_{H,F}}}. \quad (\text{C.11})$$

In the following, we let λ_t^{cap} denote the multiplier on the flow-of-funds constraint, \mathcal{Q}_t the multiplier on capital accumulation, and ω_t^{cap} the multiplier associated with the borrowing constraint.

First-Order Conditions The first-order conditions for the optimal choices of capital, investment, debt, and dividends are as follows:

$$\mathcal{Q}_t = \beta_{t+1}^I \mathbb{E}_t \left[\lambda_{t+1}^{cap} \frac{P_{t+1}}{P_{I,t+1}} r_{t+1}^K + (1 - \delta) \mathcal{Q}_{t+1} + \theta \omega_{t+1}^{cap} \frac{P_{t+1}}{P_{I,t+1}} r_{t+1}^K \right], \quad (\text{C.12})$$

$$\frac{\mathcal{Q}_t}{\lambda_t^{cap}} = 1 + g\left(\frac{I_t}{I_{t-1}}\right) + g'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} - \mathbb{E}_t \beta_{t+1}^I \frac{\lambda_{t+1}^{cap}}{\lambda_t^{cap}} g'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2, \quad (\text{C.13})$$

$$\lambda_t^{cap} - \omega_t^{cap} = \mathbb{E}_t \beta_{t+1}^I (1 + r_{t+1}^I) \lambda_{t+1}^{cap}, \quad (\text{C.14})$$

$$\lambda_t^{cap} = \frac{1}{1 + 2\psi^{cap}(\bar{d}_t^{cap} - \bar{d}^{cap})}. \quad (\text{C.15})$$

Finally, in the model with capital, the sector-specific goods market clearing conditions, (4.25) and (4.26), and the definition of net exports (4.27) are augmented with investment.

C.3 Intermediate-good retailers

Demand for intermediate goods in sector s is:

$$X_{s \rightarrow s,t} = \Theta_{s \rightarrow s} \left(\frac{P_{s,t}}{P_{s,t}^X} \right)^{-\eta_X} X_{s,t}, \quad (\text{C.16})$$

$$X_{s' \rightarrow s,t} = \Theta_{s' \rightarrow s} \left(\frac{P_{s',t}}{P_{s,t}^X} \right)^{-\eta_X} X_{s,t}, \quad (\text{C.17})$$

$$X_{F \rightarrow s,t} = \Theta_{F \rightarrow s} \left(\frac{P_{F,t}}{P_{s,t}^X} \right)^{-\eta_X} X_{s,t}. \quad (\text{C.18})$$

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

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

C.4 Labor unions

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

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

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:

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

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.5 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

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

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.6 Debt-dependent discount factor

To close the RANK model and ensure stationarity, we assume that a debt-dependent interest rate premium ι_t enters the consumption Euler equation. That is, we subtract ι_t from the interest rate in the Euler equation:

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

To ensure comparability, we do the same in the HANK model, even though it is not necessary, since this model is already stationary. Note that our approach is equivalent to an endogenous discount factor or so-called Uzawa preferences (Schmitt-

Grohé and Uribe, 2003), which can be seen by rewriting the expression as follows:

$$\begin{aligned}
C_t^{-\sigma} &= \bar{\beta}_t \mathbb{E}_t (1 + r_{t+1}^a - \iota_t) C_{t+1}^{-\sigma} \Leftrightarrow \\
C_t^{-\sigma} &= \bar{\beta}_t \mathbb{E}_t \left(1 + r_{t+1}^a - \frac{\iota_t}{1 + r_{t+1}^a} (1 + r_{t+1}^a) \right) C_{t+1}^{-\sigma} \Leftrightarrow \\
C_t^{-\sigma} &= \bar{\beta}_t \mathbb{E}_t \left(1 - \frac{\iota_t}{1 + r_{t+1}^a} \right) (1 + r_{t+1}^a) C_{t+1}^{-\sigma} \Leftrightarrow \\
C_t^{-\sigma} &= \tilde{\beta}_t \mathbb{E}_t (1 + r_{t+1}^a) C_{t+1}^{-\sigma},
\end{aligned}$$

where $\tilde{\beta}_t \equiv \left(1 - \frac{\iota_t}{1 + r_{t+1}^a}\right) \bar{\beta}_t$ is now an endogenous discount factor. The discount factor is declining in ι_t , which in turn 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

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

Effectively, an improved net foreign asset position (a rise in NFA_t) raises ι_t and thus reduces the discount factor, making households more inclined to spend their wealth, and vice versa. 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	$\frac{(\text{Exports}+\text{Imports})/2}{\text{GDP}} = 42\%$
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	0.931	Foreign interest rate
$\bar{\beta}$, RA	Mean discount factor	0.995	Foreign interest rate
$\Delta\beta$	Discount factor dispersion	0.060	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	0.47	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			
$\frac{G}{\text{GDP}}$	Public consumption to GDP	0.20	Data
$\frac{B}{\text{GDP}}$	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	1.25	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	Depreciation rate of capital	0.025	Standard value
ϕ^I	Investment adjustment cost	1	Standard value
ψ	Dividend adjustment cost	0.146	Jermann and Quadrini (2012)
α_T^K	Capital share, T	0.22	$\frac{\text{Spending on K,T}}{\text{Spending on K,NT}} = \frac{0.09}{0.21}$
α_{NT}^K	Capital share, NT	0.24	$\frac{I}{Y} = 0.23$
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	$\frac{P_{NT}^X X_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}} = 0.46$
α_I	Import share of investment	0.40	OECD average
θ	Debt-to-earnings ratio	3.8	OECD average

Table D.2: Calibration of firms and sectors

D.1 Calibration details

We now describe some details of the calibration strategy.

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 depreciation 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 cali-

brate the parameters α_s^X to satisfy the equation:

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

For capital, we jointly calibrate α_T^K and α_{NT}^K to match an aggregate investment rate of 23%, and the ratio of capital spending between the two sectors:

$$\frac{\text{Spending on capital in T}}{\text{Spending on capital in NT}} = \frac{r_T^K K_T}{P_T^X X_T + W_T N_T + r_T^K K_T} \bigg/ \frac{r_{NT}^K K_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}}.$$

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:

$$\begin{aligned} X_T &= X_{NT \rightarrow T} + X_{T \rightarrow T} + X_{F \rightarrow T}, \\ X_{NT} &= X_{NT \rightarrow NT} + X_{T \rightarrow NT} + X_{F \rightarrow NT}. \end{aligned}$$

We then specify the IO matrix as:

$$\Theta = \begin{array}{c} \\ T \\ NT \\ F \end{array} \begin{array}{cc} T & NT \\ \left[\begin{array}{cc} \frac{X_{T \rightarrow T}}{X_T} & - \\ - & \frac{X_{NT \rightarrow NT}}{X_{NT}} \\ - & - \end{array} \right], \end{array}$$

where we have left four elements empty, namely the amount of intermediate goods purchased from the other domestic 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 $\frac{X_{F \rightarrow T}}{X_{F \rightarrow NT}}$. This allows us to pin two additional parameters in Θ . The remaining parameters are obtained from the restriction that the columns must sum to 1.³⁹

39. In principle we could calibrate the remaining entries in Θ 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%.

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 imports 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%.

Import content of investment. Our calibration of the import share of investment goods relies on the OECD's Trade in Value Added database. We use the origin shares for value added in gross fixed capital formation, and obtain the import share as 1 minus the domestic share. We compute the annual average value across the 31 small open economies in the OECD, and then take the average over time. This yields an average of 40%.

D.1.2 Jacobians

We now present some properties of the calibrated household structure.

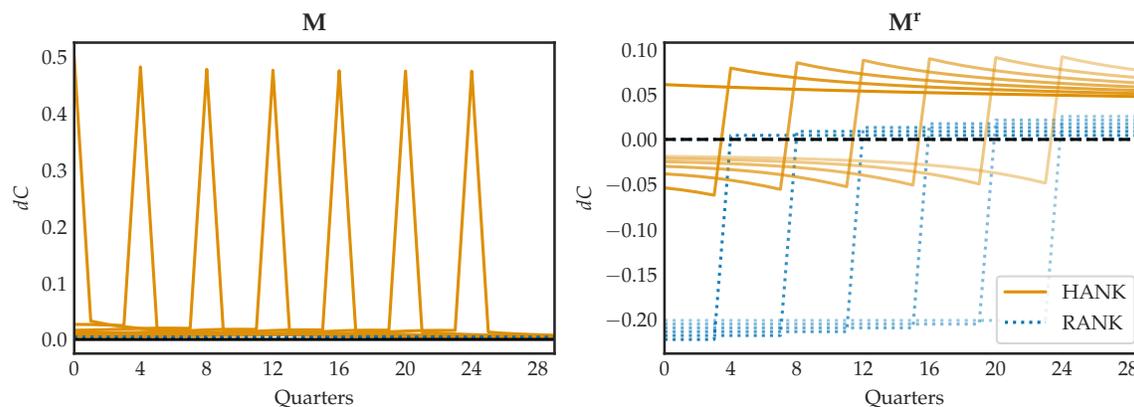


Figure D.1: Columns of Jacobians in HANK and RANK

Note: The left panel shows the columns of the intertemporal marginal propensities to consume (\mathbf{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.

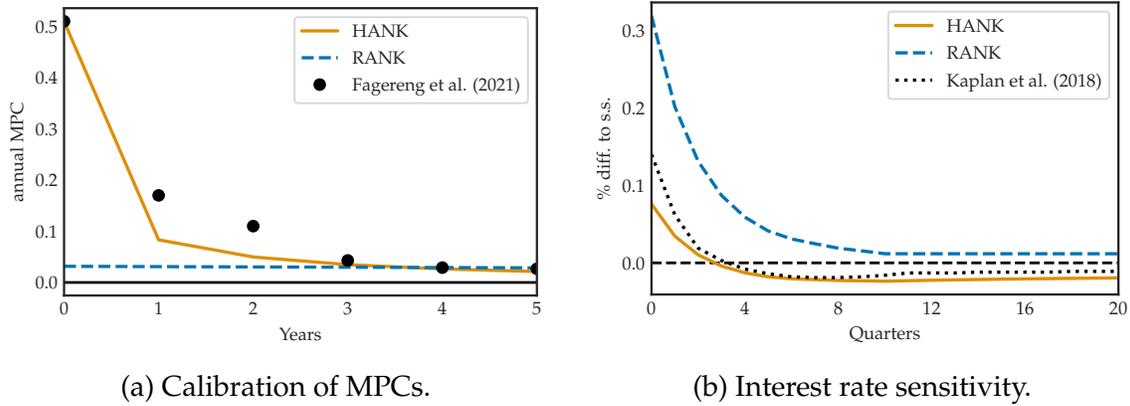


Figure D.2: Household calibration moments

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 Calibration of debt-to-earnings ratio

To pin down the relevant debt-to-earnings ratio for the sample of OECD countries, we rely on the following strategy. From the Financial Indicators database of the OECD, we obtain an annual measure of debt of non-financial corporations for each country. We obtain earnings from the STAN database in the form of gross operating surplus, and subtract earnings of financial and insurance activities from the total figure. We then divide these two series to obtain a measure of debt to earnings. We compute an annual average across the OECD economies, excluding the G7 countries (and Luxembourg, which is an outlier in this case), and then take the average value over time to arrive at a value of 3.8. In comparison, Drechsel (2023) uses a value of 4.6 for the US. The slightly lower figure we obtain is consistent with the fact that financial markets in the US are more developed than the OECD average.

D.1.4 Foreign economy responses

In Figure D.3 we plot the estimated IRFs for the foreign economy to a foreign demand shock in the LP 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^* , 13 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.

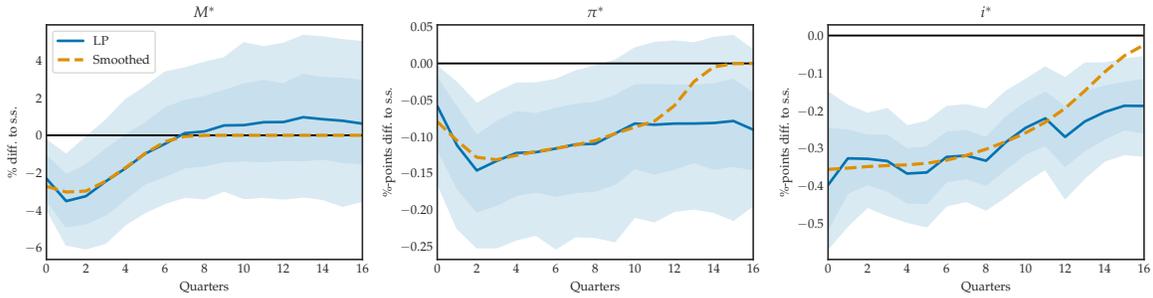


Figure D.3: Foreign demand shock

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

We then conduct a similar exercise for a foreign supply shock. Here the smoothing horizons are 10, 8, 5, respectively, and the smoothing parameters are unchanged. The results are reported in Figure D.4 below.

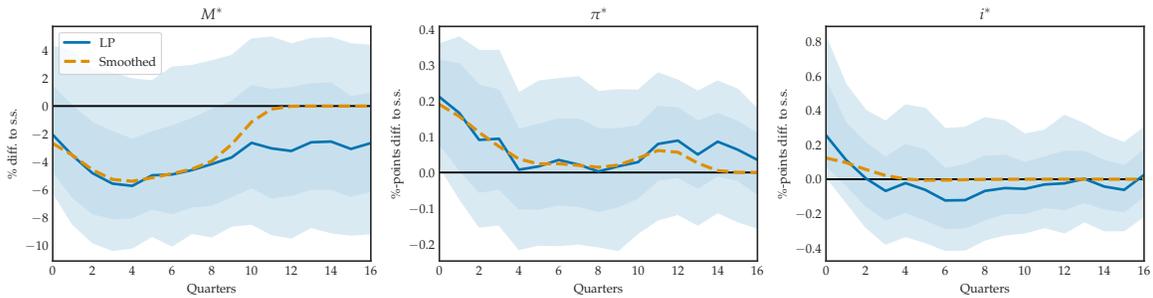


Figure D.4: Response in foreign economy to a foreign supply shock

Note: The figure reports the foreign supply 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.

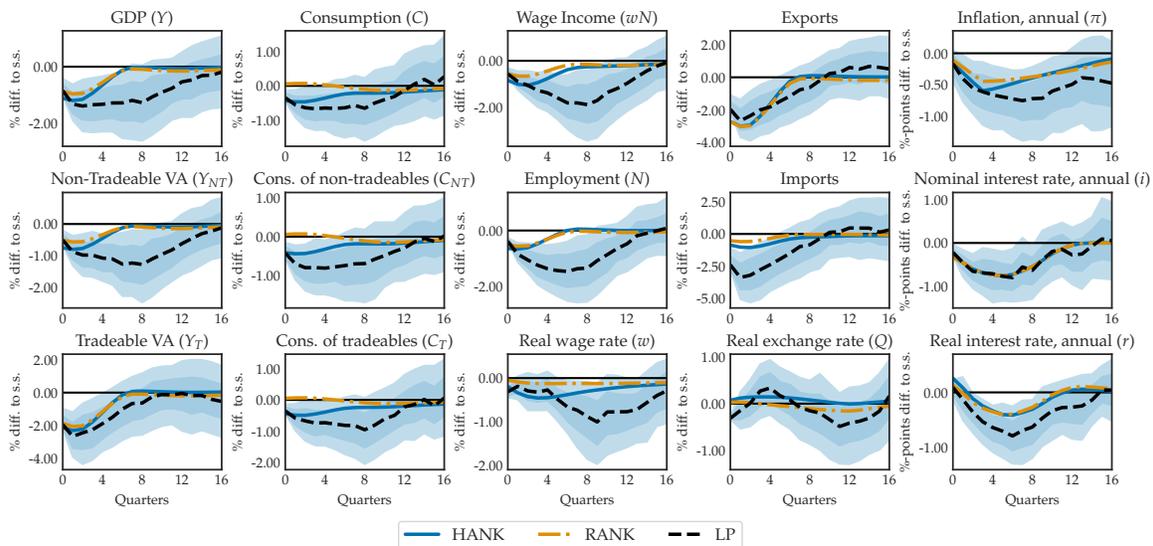


Figure E.1: Fixed exchange rate: Response of the domestic economy to a foreign demand shock

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.

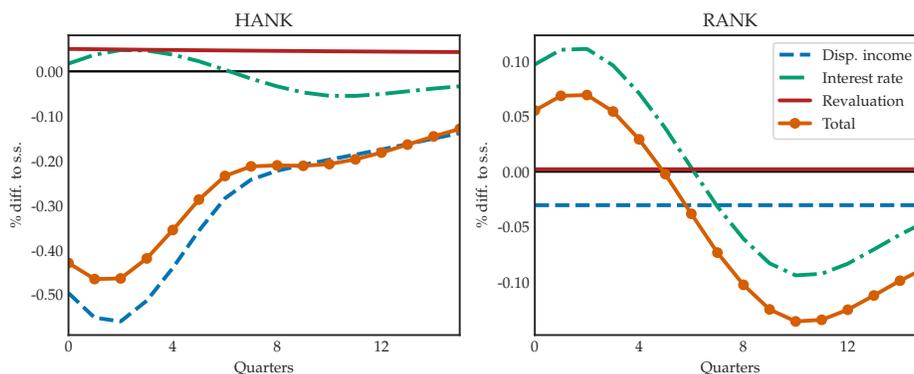


Figure E.2: Fixed exchange rate: Decomposed consumption response to a foreign demand shock

Note: See Figure 9.

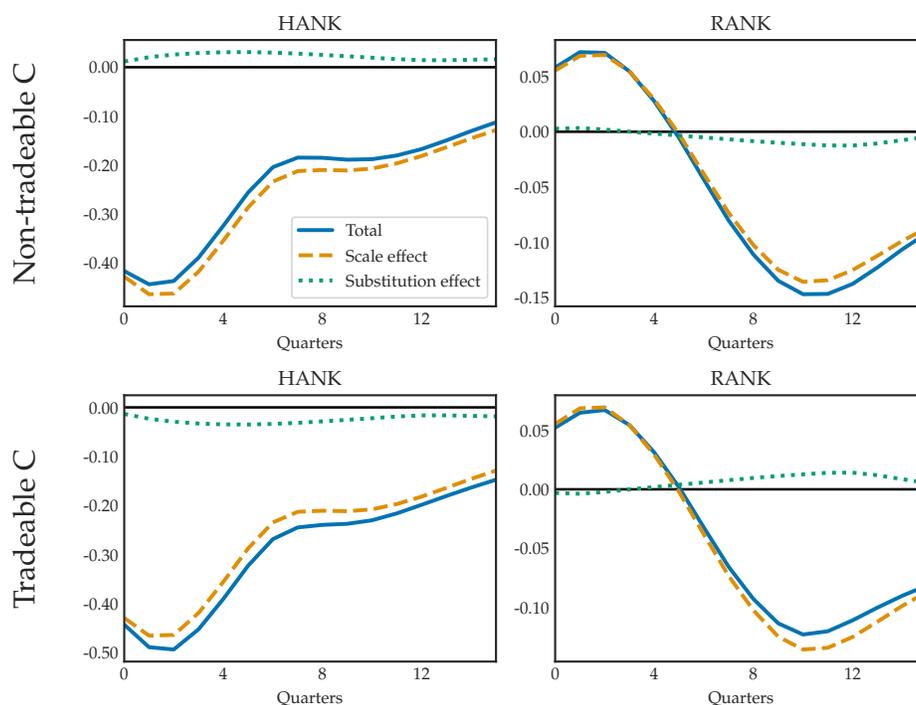


Figure E.3: Fixed exchange rate: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock

Note: See Figure 10.

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	11.20	10.07	12.77
Conditional	7.88	9.93	10.23
Model			
HANK	2.41	2.27	2.56
RANK	-0.09	-0.09	-0.10

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:

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

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 $d(a_{t-1})$ governs the transfer of resources from the illiquid asset to the liquid asset:

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

where \bar{a} is the long run target of illiquid assets, and χ determines the speed of tran-

sition to this level. The full problem faced by households is then given by:

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

s.t.

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

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

$$\ell_t \geq 0, \quad (\text{E.4})$$

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

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.

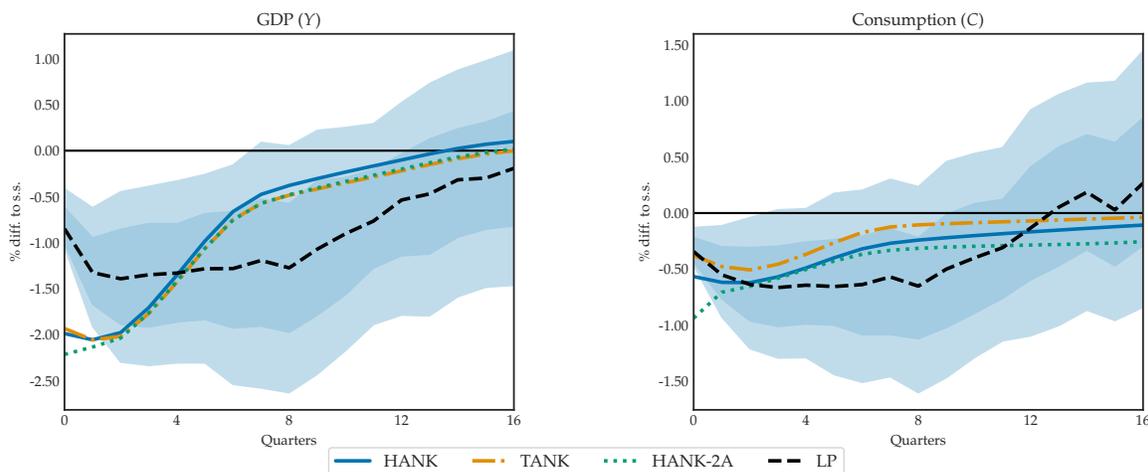


Figure E.4: Varying the household specification

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.

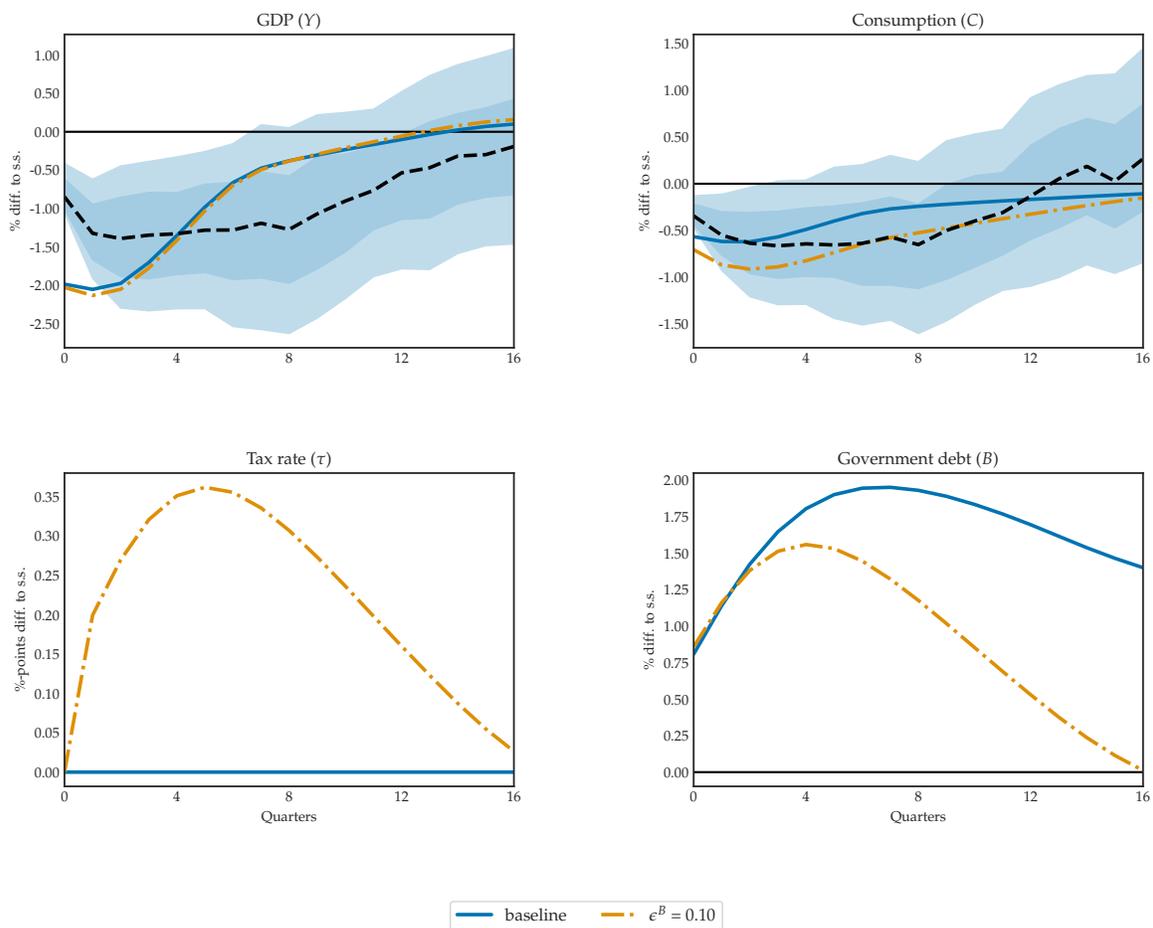


Figure E.5: Varying the budget rule

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.

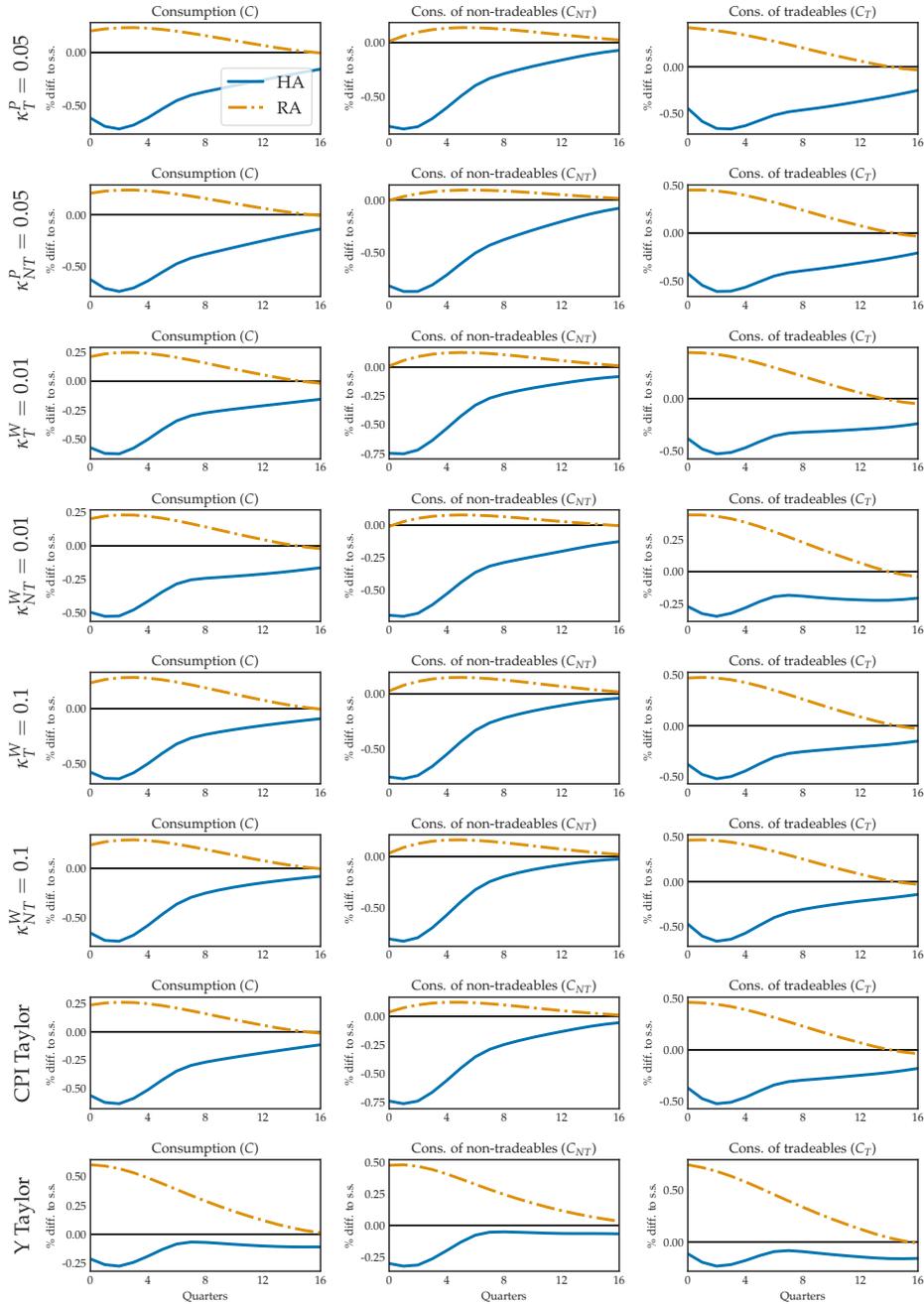


Figure E.6: Foreign demand shock responses under various NK calibrations

Note: The figure shows the response to a foreign demand shock under various different parametric assumptions. In rows 1 and 2 we change the slope of the NKPC in each sector. In rows 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 $\phi^Y = 0.25$.

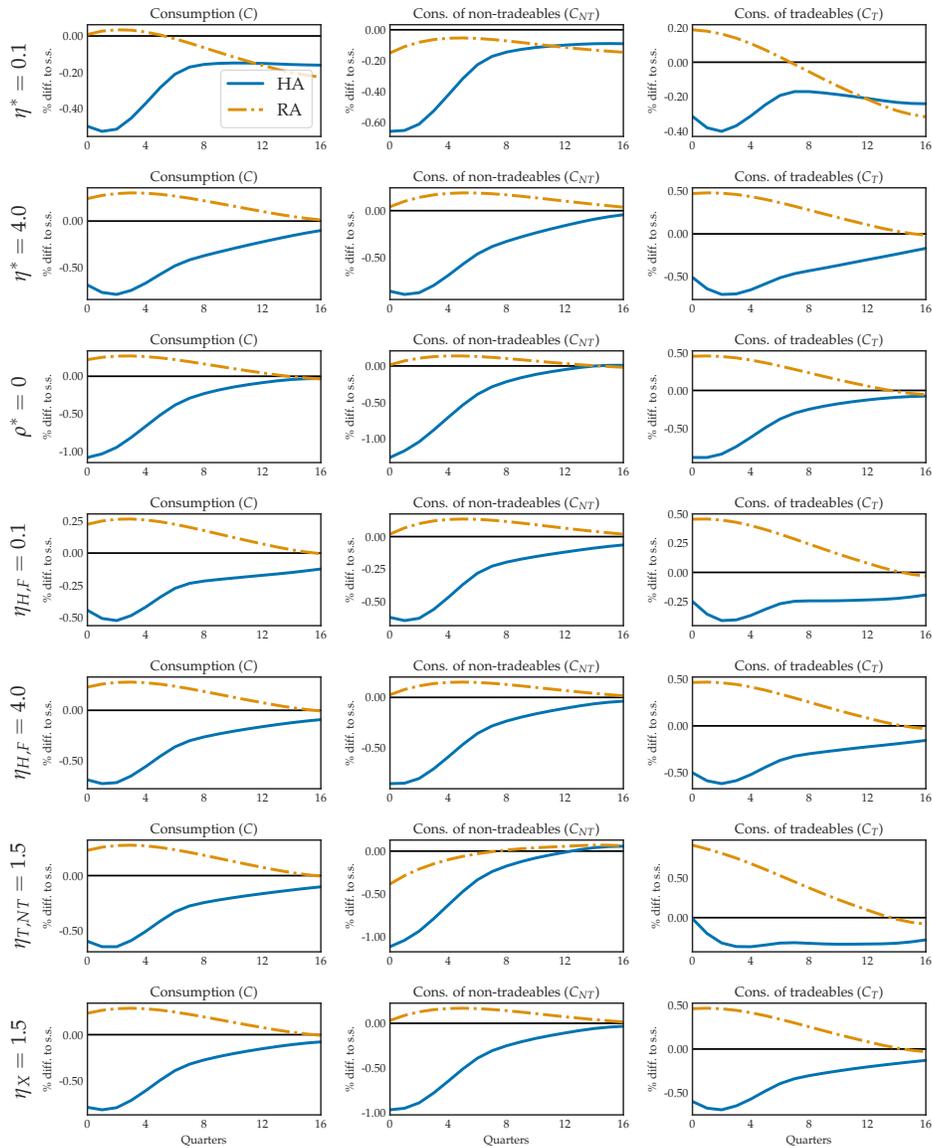


Figure E.7: Foreign demand shock responses with different trade elasticities

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.

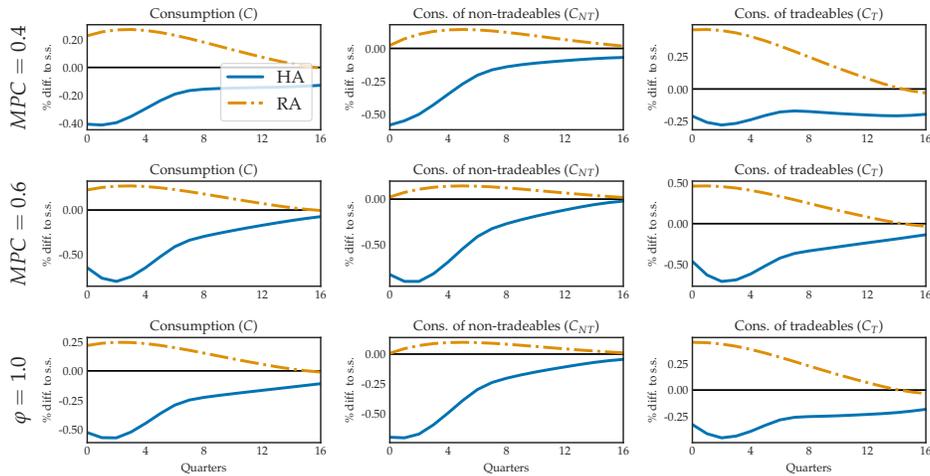


Figure E.8: Foreign demand shock responses with different calibration of households

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 additional results for the model with capital formation.

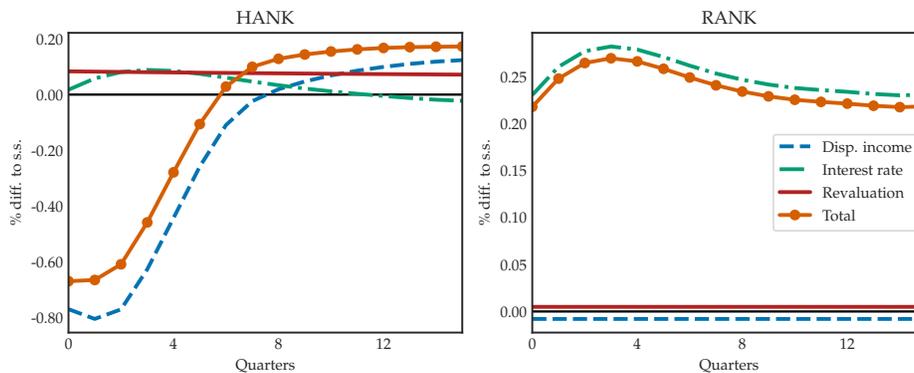


Figure E.9: Decomposed consumption response to a foreign demand shock with capital

Note: See Figure 9.

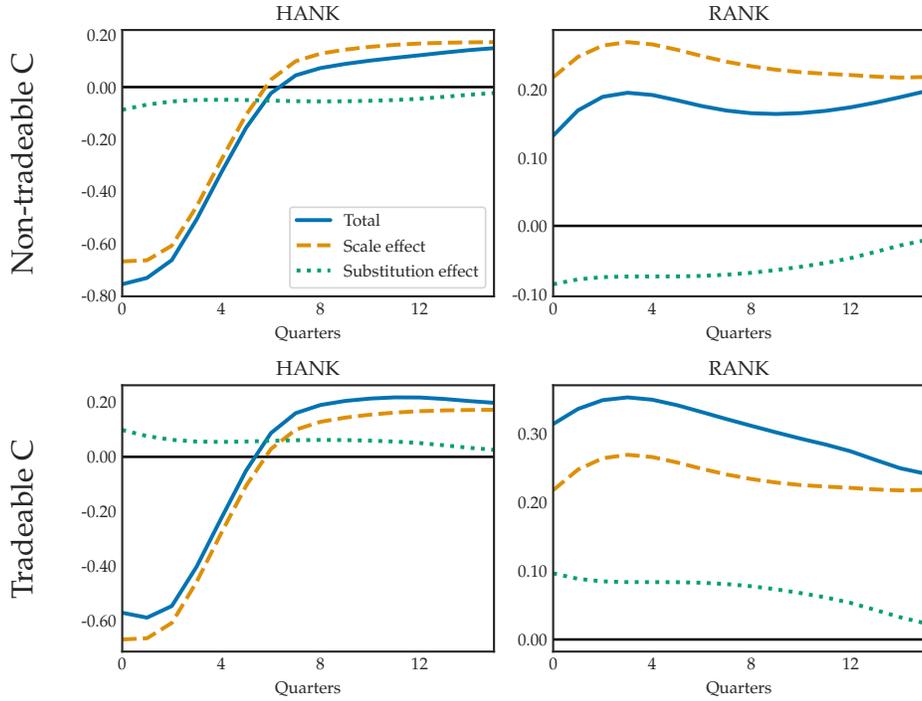


Figure E.10: Decomposed response of consumption of tradables and non-tradables to a foreign demand shock with capital

Note: See Figure 10.

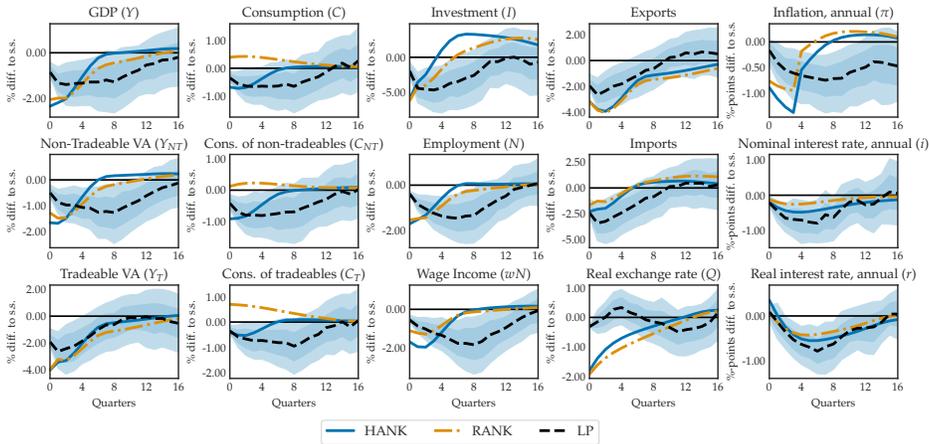


Figure E.11: Response of the domestic economy to a foreign demand shock with capital formation and no cognitive discounting

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, but with no cognitive discounting ($m = 1$).

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, β^*	-1.00	-2.69	-2.38	1.13	-1.00	-1.71	-1.72	0.99
Domestic demand, β	-1.00	-0.33	-0.72	0.46	-1.00	-0.31	-0.69	0.45
Public transfers, T	1.00	0.17	1.12	0.16	1.00	0.22	1.13	0.19
Public spending, G	1.00	0.62	2.23	0.28	1.00	0.70	2.31	0.31
Monetary policy, i	1.00	1.73	1.85	0.94	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	2.38	2.05	1.16
Fiscal devaluation	-	-	-	-	1.00	2.52	2.35	1.07

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.

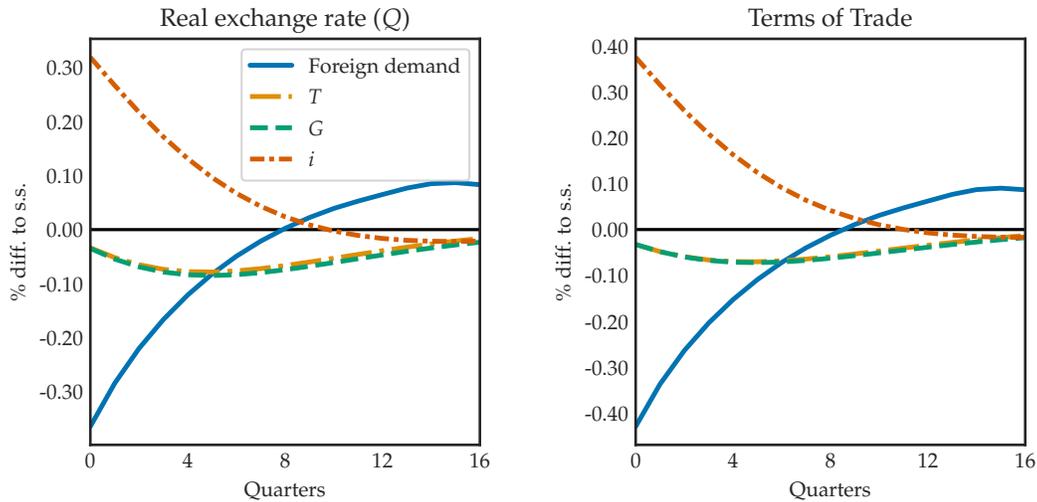


Figure E.12: International relative price dynamics under a floating exchange rate

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 $S_t = \frac{P_{F,t}}{P_{H,t}}$.

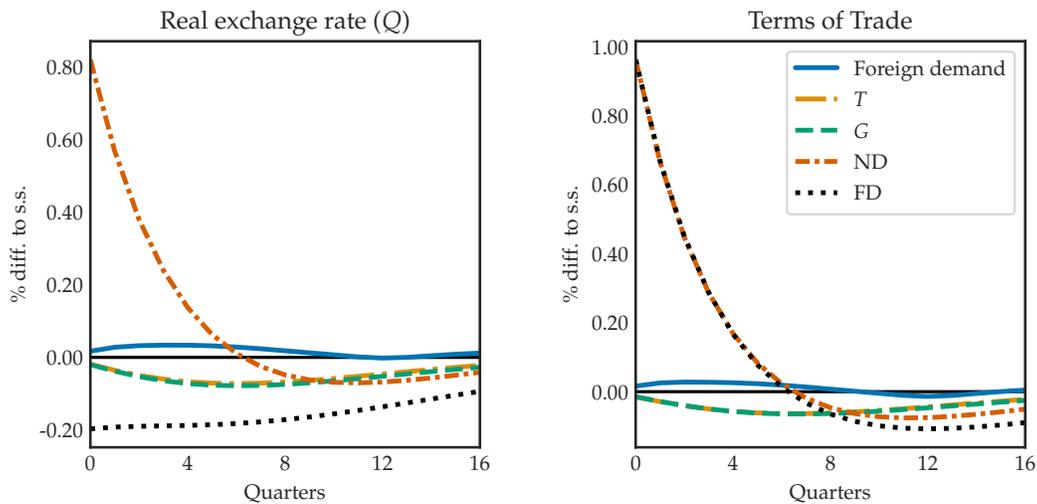


Figure E.13: International relative price dynamics under a fixed exchange rate

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 $S_t = \frac{(1-\tau_f^*)P_{F,t}}{P_{H,t}^* E_t} = \frac{P_{F,t}}{P_{H,t}}$.

Table E.3 presents the responses of inflation to foreign and domestic demand shocks and the policy instruments considered in Section 7.

	Floating				Fixed			
	π^{PP}	π_H	π_{NT}	$\frac{\pi_H}{\pi_{NT}}$	π^{PP}	π_H	π_{NT}	$\frac{\pi_H}{\pi_{NT}}$
Foreign demand, β^*	-0.32	-0.31	-0.33	0.94	-0.33	-0.32	-0.34	0.95
Domestic demand, β	-0.02	-0.02	-0.02	1.03	0.01	0.00	0.01	0.64
Public transfers, T	0.13	0.13	0.14	0.91	0.03	0.03	0.04	0.78
Public spending, G	0.16	0.15	0.17	0.89	0.04	0.03	0.04	0.69
Monetary policy, i	0.41	0.40	0.42	0.97	-	-	-	-
Nominal devaluation	-	-	-	-	0.07	0.07	0.07	1.01
Fiscal devaluation	-	-	-	-	0.12	0.11	0.13	0.87

Table E.3: Cumulative inflation of demand shocks and policy instruments.

Note: See notes to Table 2. π_H and π_{NT} denote the inflation rates of tradable and non-tradable goods, respectively.

Figure E.14 presents the impulse responses of producer price inflation.

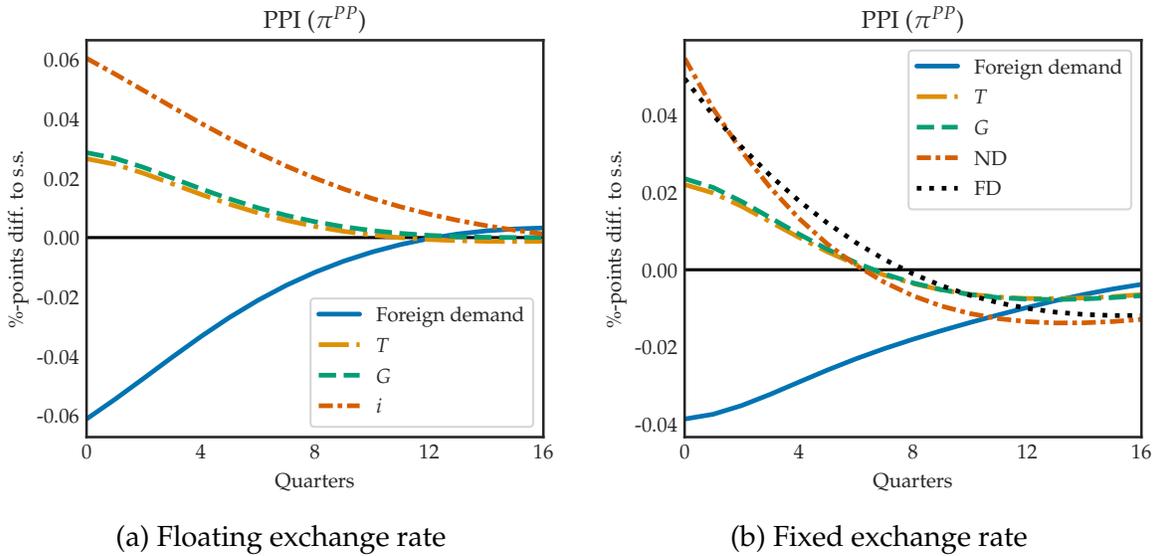


Figure E.14: Producer price inflation dynamics

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.

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:

$$P_{H,t}^* = (1 - \tau_t^v) \frac{P_{H,t}}{E_t},$$

$$P_{F,t}^* = (1 - \tau_t^v) \frac{P_{F,t}}{E_t}.$$

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:

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

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 the subsidy:

$$\tau_t^v = \omega^v \frac{\delta_t}{1 + \delta_t},$$

$$\zeta_t^p = (1 - \omega^v) \frac{\delta_t}{1 + \delta_t}.$$

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), it is possible—under certain conditions—to perfectly mimic a permanent, one-time unexpected nominal devaluation using the VAT and the 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 $\omega^v = 0.5$.