The Transmission of Foreign Demand Shocks*

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October 2022

Abstract

Introducing heterogeneous households into a New Keynesian model of a small open economy enables the model to fit a set of stylized empirical facts about the transmission of foreign demand shocks. In the absence of a strong labor income effect on consumption, the model counterfactually implies that domestic consumption decreases as the central bank raises the interest rate to curb domestic inflation. With plausible marginal propensities to consume, the model instead produces the observed increase in domestic consumption of both tradeable and non-tradeable goods. This implies that foreign demand shocks are more important for international business-cycle comovement than predicted by existing models. Our findings also have implications for stabilization policies: While monetary policy is well-suited to counteract foreign demand shocks, traditional fiscal policies are inadequate, as they do not provide sufficient stimulus to the tradeable sector. This poses a particular challenge for countries with a fixed exchange rate or in a monetary union.

*We thank Christian Hoeck, Christian Kastrup, John Kramer, Alaïs Martin-Baillon, Emil Partsch, Omar Rachedi, Emiliano Santoro, Christoffer Weissert, and seminar participants at the University of Copenhagen and Danmarks Nationalbank for helpful comments. The authors are grateful for financial support from the Carlsberg Foundation (Grant CF20-0546). Center for Economic Behavior and Inequality (CEBI) is a center of excellence at the University of Copenhagen, founded in September 2017, financed by a grant from the Danish National Research Foundation (Grant DNRF134).

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1 Introduction

In small open economies, external shocks are typically believed to be important drivers of domestic business cycle fluctuations. A prominent example is shocks to the foreign demand for domestic export goods. Yet, the existing open-economy business-cycle literature has not been able to produce a convincing account of the transmission mechanism of foreign demand shocks that fits the data. In this paper, we offer a detailed study of the transmission of such shocks, and the challenges they imply for stabilization policies.

We first characterize and quantify the empirical effects of foreign demand shocks in 39 small open (mostly advanced) economies. We use a pooled local projections design and a standard small open-economy assumption for identification. In response to a *positive* shock to foreign demand, we establish five key results for domestic variables:

1. Gross Domestic Product (GDP) increases
2. Aggregate consumption increases, thus contributing to the rise in GDP
3. Exports and imports *both* increase, dampening the response of net exports
4. Consumption of tradeable and non-tradeable goods co-move positively
5. Foreign demand explains a large share of fluctuations in domestic variables

Our main contribution is to develop a structural business-cycle model that can account for these facts. Through the lens of this model, it becomes clear that a high average marginal propensity to consume (MPC) out of transitory income is a necessary ingredient for explaining the increase in domestic consumption and observed comovements.

As a benchmark, we first show that open-economy representative-agent New Keynesian (RANK) models can only explain the first empirical fact, i.e. that GDP increases. On the other hard, such models are hard to reconcile with the remaining four facts. The intuition is as follows: When foreign demand for domestic goods increases, an inflation-targeting domestic central bank raises the interest rate to curb the increase in domestic inflation.[1] The real interest rate then increases, and the powerful in-

1. Likewise, under a fixed exchange rate, the uncovered interest rate parity (UIP) condition induces the domestic central bank to raise the interest rate in tandem with the foreign central bank, assuming, realistically, that foreign inflation also increases.

tertemporal substitution effect present in RANK models implies a *drop* in domestic consumption, including consumption of imported goods. This is in contradiction with the second and third facts.[2] At the same time, the increase in foreign demand drives up the relative price of tradeable to non-tradeable goods, inducing domestic households to substitute from the former to the latter, thus giving rise to a negative comovement between the two, in contrast to the fourth fact. Finally, since the unconditional correlation of aggregate consumption across countries is strongly positive in the data, whereas foreign demand shocks entail a negative correlation, standard RANK models attribute a very small role to foreign demand shocks in explaining domestic business cycles, as shown, e.g., by Justiniano and Preston (2010).

To account for our empirical findings, we instead propose a heterogeneous-agent New-Keynesian (HANK) model of a small open economy featuring idiosyncratic income risk and borrowing constraints, a distinction between tradeable and non-tradeable goods, and cross-country input-output linkages in production. Our model delivers a realistic and sizeable MPC. Consistent with the closed-economy HANK literature (see, e.g., Kaplan, Moll, and Violante, 2018 and Auclert, 2019), our model features strong direct income effects, which dominate the inter- and intratemporal substitution effects still present in the model.

In our HANK model, an increase in foreign demand induces domestic firms to hire more labor at higher wages. This stimulates household labor income. With a high average MPC, this gives rise to an *increase* in domestic households' consumption spending, more than offsetting the negative substitution effect. This increase in domestic consumption is what we find in the data (second fact). Part of the increase will be directed towards imports, which therefore increase, consistent with the third fact. Moreover, the presence of a quantitatively strong income effect overcomes the substitution from tradeables to non-tradeables, facilitating a simultaneous increase in both types of consumption, as held by the fourth fact. We first establish these results analytically in a stylized version of our model, and then corroborate them numerically in a calibrated and more detailed model.

Finally, the fact that our HANK model reproduces the positive correlation between foreign and domestic consumption *conditional* on a foreign demand shock paves the

2. RANK models can generate a positive co-movement between foreign and domestic consumption under the stark and empirically less plausible assumption of perfect international risk sharing. Perfect international risk sharing also creates other puzzles of its own (see, e.g., Corsetti, Dedola, and Leduc, 2008).

way for such shocks to 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 set the correlation to perfectly match the cross-country consumption correlations observed in the data. We find that the required size of the correlation is much smaller in our HANK model (0.19) compared to an otherwise identical RANK model (0.89). In other words, the HANK model is able to generate most of the required propagation of foreign shocks to domestic variables endogenously, in stark contrast to the RANK model.

We then turn our attention to the implications for macroeconomic policy aimed at stabilizing shocks originating either from abroad or domestically. As it turns out, the origin of the shock is of key importance. A negative foreign demand shock reduces income in both sectors due to spillover effects arising from high MPCs and the input-output structure of production. Monetary policy is therefore well-suited to stabilize the effects of such shocks: A monetary expansion simultaneously stimulates the non-tradeable sector and depreciates the terms of trade, thus stimulating the tradeable sector. In contrast, traditional fiscal policy tools are unable to generate the desired effects on the terms of trade, and therefore provide inadequate stimulus to the tradeable sector. Instead, fiscal policy mainly stimulates the non-tradeable sector, and is therefore better suited to stabilize domestic demand shocks, which primarily affect this sector, since the tradeable sector is less sensitive to domestic demand. We show that these findings obtain under both fixed and floating exchange rates.

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

1.1 Related Literature

Our work is most closely related to three branches of the existing literature.

First, we contribute to the empirical literature quantifying the effects of foreign demand shocks on small open economies. Studies in this vein typically utilize structural vector autoregression (VAR) models combined with a small open economy assumption and, in some cases, sign restrictions to identify foreign demand shocks. 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: Foreign demand shocks tend to increase domestic GDP, consumption, wages, and often prices, i.e., they create a boom in the domestic economy, while the effect on net exports is inconclusive. Our empirical results—while based on a different identification strategy—are thus consistent with the existing literature, though we also study the joint responses of foreign output, inflation, and interest rates, and add the findings of positive sectoral comovement and the quantitative importance of foreign demand shocks.

Second, we contribute to the literature on constructing models to explain these results. Early contributions to this literature typically constructed international Real Business Cycle (IRBC) models and focused on technology shocks.[3] In the last two decades, the literature on *New Open Economy Macroeconomics* has relied on 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 the variation in domestic variables at business-cycle frequencies, especially in small open economies, is closely related to our work. Models in this tradition—even those of large scale—typically imply that foreign shocks are largely unimportant for domestic business cycles; see, e.g., Adolfson et al. (2007), Justiniano and Preston (2010), Christiano, Trabandt, and Walentin (2011), and Bergholt (2015). A striking example is the study by Justiniano and Preston (2010), who find that in their estimated RANK model, all shocks originating in the US explain less than 3% of the variation in Canadian output and other macroeconomic aggregates at all forecast horizons. This is strongly at odds

3. The seminal paper is Backus, Kehoe, and Kydland (1992). In their model, the cross-country correlation of consumption was much higher than that of output, while the opposite is true in the data; the so-called *Backus–Kehoe–Kydland puzzle*. A large, subsequent literature has studied this issue, stressing among other things the importance of non-traded goods and trade in intermediate production inputs; two features included in our model (see, among others, Backus and Smith, 1993, Frankel and Rose, 1998, Obstfeld and Rogoff, 2000, Heathcote and Perri, 2002, Kose and Yi, 2006, and Burstein, Kurz, and Tesar, 2008), and later nominal frictions as in Huang and Liu (2007).

with the empirical evidence provided by the same authors, according to which U.S. shocks explain 40%-80% of the variation in the Canadian economy. The small role attributed by RANK models to foreign disturbances in explaining domestic variables is a reflection of the counterfactual responses of domestic variables to foreign shocks in some of these models. Christiano, Trabandt, and Walentin (2011) and Adolfson et al. (2013) both obtain a negative response of domestic consumption to a foreign demand shock in estimated structural models, while the model of Bergholt (2015) features negative responses of both output and consumption to this type of shock. Similarly, in the model of Lubik and Schorfheide (2007), a foreign boom causes domestic output to fall, i.e., business cycles are negatively correlated across countries.

Finally, our work is related to the recent literature studying traditional business-cycle questions through the lens of heterogeneous-agent (HANK) models. In general, the HANK literature has emphasized the importance of sizeable MPCs for the transmission of shocks, see e.g. Kaplan, Moll, and Violante (2018), Auclert, Rognlie, and Straub (2018), Hagedorn, Manovskii, and Mitman (2019), Auclert, Rognlie, and Straub (2020), Alves et al. (2020) and Luetticke (2021). We continue this tradition by focusing on the role of MPCs in the transmission of foreign demand shocks. A recently emerging branch of this literature studies the open-economy dimensions of HANK models. De Ferra, Mitman, and Romei (2020) study the macroeconomic and distributional implications of a current account reversal, reporting that a revaluation of foreign-currency debt has larger aggregate ramifications when debt and leverage are concentrated among poor, high-MPC households. Oskolkov (2021) and Zhou (2021) focus on the cross-country transmission of monetary policy shocks and their distributional effects, while Hong (2020) studies the business cycle of an emerging economy through the lens of a HANK model.

The papers most closely related to ours are those by Auclert et al. (2021b) and Guo, Ottonello, and Perez (2020). The former studies the effects of exchange rate shocks, highlighting the role of the so-called *real income channel*, through which an increase in import prices reduces consumption of high-MPC households. A similar channel is operative in our model. Motivated by our empirical analysis, however, we instead focus on the effects of foreign demand shocks. We also offer a systematic treatment of a range of policies aimed at stabilizing such shocks under various exchange-rate arrangements. Guo, Ottonello, and Perez (2020) consider foreign demand shocks like us, but our analysis differs from theirs in several important respects. First, we consider a realistic demand shock in line with our empirical analysis, where foreign inflation and interest rates also move, while Guo, Ottonello, and Perez (2020) consider a pure demand shock. Second, they focus on income inequality instead of business-cycle comovement. They therefore also let households differ in their access to foreign assets, whereas they abstract from input-output linkages in production.

All of the papers mentioned above share the common assumption of a small open economy structure. In contrast, Giagheddu (2020), Bayer et al. (2022), and Chen et al. (2022) consider two-country models in order to study, respectively, the distributional impact of fiscal devaluations, and the positive and normative aspects of monetary policy spillovers across countries. Aggarwal et al. (2022) offer a reinterpretation of a series of macroeconomic developments in the aftermath of the COVID-19 pandemic through the lens of a multi-country HANK model.

Structure The paper proceeds as follows. In the next section, we present our empirical findings. We then 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 conclude in Section 8.

2 Empirical results

In this section, we estimate the effects of foreign demand shocks on small open economies and establish the five empirical facts presented in the introduction.

2.1 Empirical strategy

We study the effects of a shock to foreign demand $Y^*_{i,t}$ on a domestic variable $Z_{i,t}$. To do this, we use pooled local projections (LP) (Jordà, 2005, Auerbach and Gorodnichenko, 2013, and Jordà and Taylor, 2016). Specifically, we estimate the following regression for $h = 0, \ldots, H$:

$$Z_{i,t+h} = \beta_h Y^*_{i,t} + \sum_{j=1}^{p} \gamma_{h,j} Z_{i,t-j} + \sum_{j=1}^{p} \delta_{h,j} Y^*_{i,t-j} + X_{t,h} + \varepsilon_{i,t,h}, \tag{1}$$

where p is the number of lags, $X_{t,h}$ are time fixed effects, and $\varepsilon_{i,t,h}$ is noise. $Y^*_{i,t}$ is a measure of total demand in the foreign economy for country i. We construct this as a weighted average of the gross domestic product (GDP) of its trading partners (see Appendix A.1 for details). Effectively, this implies that the relevant measure of foreign demand is specific to each small open economy. The weights are based on averages of annual bilateral OECD trade data for the period 1995-2018. The sequence $(\beta_s)_{h=0}^{H-1}$ constitutes the impulse-response function (IRF). We consider a horizon of $H = 20$ quarters and use $p = 2$ lags to mop up serial correlation.

Identification is based on a "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 identifying assumption is commonly made in the literature studying the domestic effects of foreign shocks, see, e.g., Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016). Furthermore, we use time fixed effects to control for common confounders, i.e. underlying variables driving business cycles across countries[4].

2.2 Data and estimation

We consider a panel of 39 small open OECD countries, and we use these and 7 large OECD countries to construct the foreign demand variables (see Appendix A.2 for a complete list of countries). For each country, the sample ends in 2019Q4 and starts between 1947 and 1996, depending on data availability for that country (with most countries starting in the latter part of this span). The effective number of countries and observations in the data set depends on the specific regression (with domestic GDP as the outcome variable, the total number of observations is 3795). We take logs of all variables (except for the real interest rate, r_t, inflation, π_t, and net exports, NX_t) and detrend by a country-specific regression on $(1, t, t^2, t^3, t^4)$. This is equivalent to including country fixed effects and country-specific time trends in the regression. A detailed description of the variables and their transformation is provided in Appendix A.3.

2.3 Results

We first consider the effects of a foreign demand shock on the foreign economy itself. The results are reported in Figure 1. This documents the nature of the shock faced

4. Examples include shocks to energy prices or global sentiment, pandemics, financial crises, or technology shocks.

by the small open economy: A prolonged expansion alongside higher inflation and higher interest rates in its trading partners. These findings are consistent with an interpretation of the shock to $Y^*_{i,t}$ as a demand shock in the foreign economy.

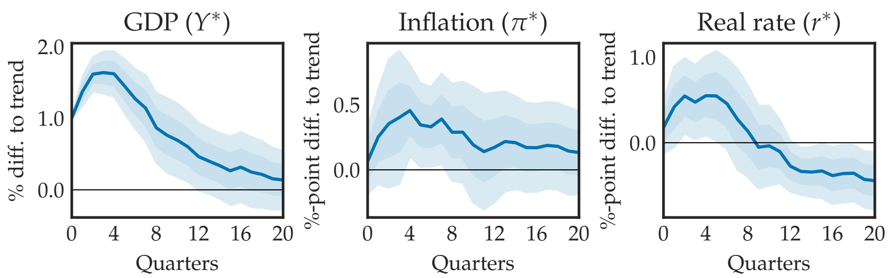

Figure 1: Effect of foreign demand shock on the large foreign economy

Note: The figure plots $(\beta_h)_{h=0}^{H_1}$ for $Z \in \{Y^*, \pi^*, i^*\}$ in eq. (1) (with the $\gamma_{h,j} Z_{i,t-j}$ terms excluded when $Z = Y^*$). The shock is to Y^*. No time fixed effects. The shaded areas indicate 95 and 68 pct. confidence intervals. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

We then turn to the main results: The effects of the shock to $Y^*_{i,t}$ on the 39 small open economies. These responses are shown in Figure 2, from which the first four empirical facts outlined in the introduction clearly emerge: The foreign demand shock causes a boom in domestic GDP (Fact 1), which is in part driven by an increase in consumption (Fact 2). Furthermore, domestic exports and imports *both* increase (Fact 3), giving rise to a fairly muted response of net exports. Lastly, consumption of tradeable and non-tradeable goods both increase, i.e., they display a positive comovement (Fact 4).[5] In addition to these findings, we observe that domestic inflation increases, while the real effective exchange rate tends to depreciate. The domestic real interest rate also displays a positive response at most horizons.[6]

To establish the fifth and final empirical fact, we quantify the importance of foreign demand shocks. To do this, we estimate the share of the forecast error variance in domestic variables explained by foreign demand shocks. To conduct the variance decomposition based on our local projection, we follow the approach of Gorodnichenko and Lee (2020) and employ the preferred estimator with best finite-sample properties. We adjust the estimator to take into consideration the pooled nature of the dataset. We also employ a VAR-based bootstrap to correct for small-sample bias and construct confidence intervals, as suggested by Gorodnichenko and Lee (2020)

5. In Appendix A.4, we report the cumulative multipliers.

6. We also observe a clear increase in domestic investment; see Appendix A.5. However, the model we propose in this paper abstracts from capital accumulation.

(see Appendix A.6 for details).

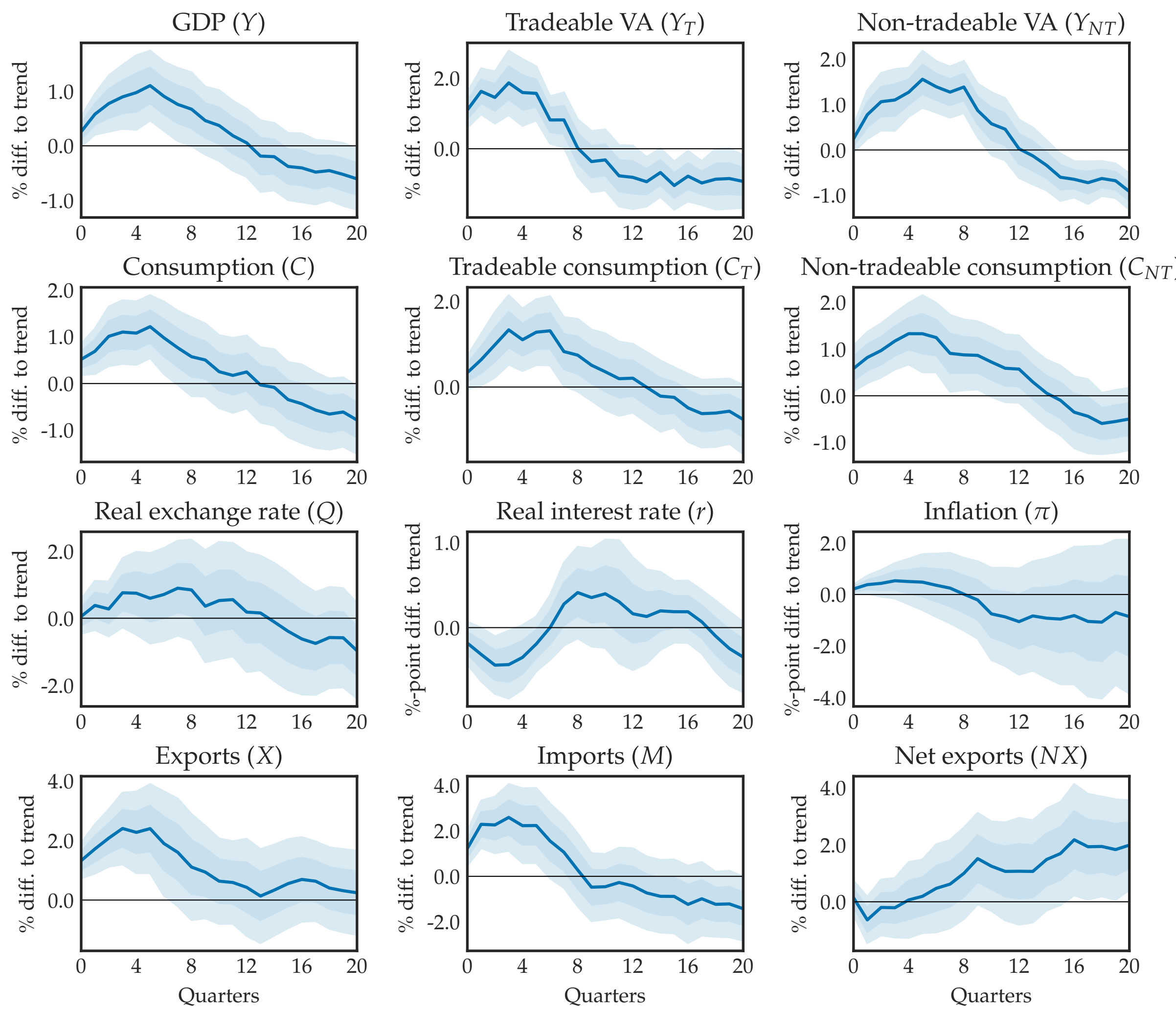

Figure 2: Effect of foreign demand shock on a small open economy

Note: The figure plots $(\beta_h)_{h=0}^{H_1}$ for different Z in eq. (1). The shock is to Y^*. With time fixed effects. To estimate time fixed effects, we drop observations such that each time period has at least 5 observations. The shaded areas indicate 95 and 68 pct. confidence intervals. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

Table 1 presents the decomposition. We find that foreign demand shocks account for up to 30% of domestic business cycles in a small open economy (Fact 5). According to our results, foreign demand shocks explain a substantial part of the variation in all the variables considered, and at all horizons. This finding is in line with existing empirical studies, e.g., the VAR-based evidence reported by Justiniano and Preston (2010).

h	Y	C	X	M	NX
4	21.7 (19.8,24.0)	21.8 (20.4,23.4)	16.0 (14.4,18.1)	15.0 (12.7,17.4)	14.5 (12.6,16.6)
8	27.9 (24.9,30.9)	26.4 (24.6,28.5)	20.3 (18.0,22.9)	19.6 (16.6,22.7)	19.9 (17.5,22.6)
∞	19.4 (15.2,23.2)	17.4 (13.7,19.9)	15.5 (10.9,19.1)	18.3 (14.0,22.4)	9.2 (4.6,13.1)

Table 1: Forecast error variance decomposition (FEVD) of foreign demand shocks

Note: $h \to \infty$ refers to $h = 40$. The FEVD has been adjusted for small-sample bias using a bootstrap. Parentheses indicate 95 pct. confidence intervals.

2.4 Robustness

We conduct a variety of sensitivity checks to confirm that our empirical results are robust. In particular, we consider three series of robustness checks in Appendix A.7.

We first follow most of the existing literature and use sign restrictions to separately identify demand and supply shocks to the foreign economy, as in Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016). We do this using a structural VAR model instead of LP. The IRFs to an identified foreign demand shock are shown in Appendix A.7.1. The results are very similar to those obtained above, except that the impulse responses are more "smooth", as is commonly the case for VARs compared to LPs. Importantly, we therefore conclude that all of the empirical facts established in the introduction also emerge when we follow the most common approach in the literature.

In the second set of robustness checks, we perform a range of changes to the variables in the LP regression. In particular, we consider alternative constructions of weights and thus $Y^*_{i,t}$: One in which only large economies are included in the construction of the country-specific foreign demand measure, and one in which the weights are based on shares of world GDP, such that there is only one world economy common to all small open economies, i.e., $Y^*_{i,t} = Y^*_t, \forall i$. Furthermore, we consider detrending the variables using an HP filter or a Hamilton filter (see Hamilton, 2018). We also consider a shock to foreign imports instead of foreign GDP in an attempt to capture more directly a shock to foreign demand for domestic goods. The IRFs are shown in Appendix A.7.2. In general, our findings turn out to be robust to all these changes.

We finally consider a variety of changes to the specification of the LP regression. Most importantly, we estimate separate responses for fixed and floating exchange-rate countries, obtaining very similar results in both cases (see Figure 21 and 22 in Appendix A.7.3). Moreover, we experiment with using more lags; excluding time-fixed effects; including time × region fixed effects; and considering only a balanced sample starting in 1996. The IRFs are shown in Appendix A.7.3. As with the previous series of robustness checks, our main results are unaltered by these different specifications.

In summary, the main results are robust to a battery of robustness checks. In particular, all specifications feature significant increases in both domestic GDP and consumption in response to a foreign demand shock; as well as a positive comovement between tradeable and non-tradeable consumption.

3 A stylized model of foreign demand shocks

To understand the effects of foreign demand shocks on the domestic economy, 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 is essentially a version of 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 equivalent to that of Auclert et al. (2021b), except for the assumptions regarding monetary policy.[7] For comparison, we also consider an otherwise identical representative-agent (RANK) version of the model, featuring complete domestic financial markets, but no international risk sharing.[8]

The model consists of domestic households that have CES preferences over bundles of home and foreign goods with a home bias of $1 - \alpha \in (0, 1)$; domestic firms that produce the home good under monopolistic competition with markup μ, facing sticky wages, and using a linear production technology with domestic labor as the

7. It should be noted that our framework features flexible prices and sticky wages, as in Auclert et al. (2021b), whereas Gali and Monacelli (2005) make the opposite assumption. However, given that we assume a linear production function, wage stickiness effectively carries over to prices. In the next section, we consider a model featuring both types of nominal rigidities.

8. We do not treat the case of perfect international risk sharing. While a model with this feature would generate a positive co-movement between foreign and domestic consumption by construction, perfect international risk sharing is an empirically less plausible case.

only input; and a domestic central bank that follows a Taylor rule targeting domestic price inflation. Foreign consumption demand is exogenous, and we treat it as the "foreign demand shock" in this stylized setting.

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

Denote the real exchange rate by $\mathbf{Q}$ and the total trade elasticity by χ.[9] Then the market clearing condition for domestic production, $\mathbf{Y}$, can be written in terms of linearized deviations from steady state, $dY_t = Y_t - Y_{ss}$, as follows:

$$d\mathbf{Y} = (1-\alpha)d\mathbf{C} + \alpha d\mathbf{C}^* + \frac{\alpha}{1-\alpha}\chi d\mathbf{Q}, \tag{2}$$

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

$$d\mathbf{Y}^{hh} = \frac{1}{\mu}d\mathbf{Y} - \frac{1}{\mu}\frac{\alpha}{1-\alpha}d\mathbf{Q}. \tag{3}$$

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

$$d\mathbf{C} = \mathbf{M}d\mathbf{Y}^{hh} + \mathbf{M}^r d\mathbf{r} + \mathbf{M}^v(d\mathbf{r}^a - d\mathbf{r}), \tag{4}$$

where $\mathbf{M}$ is the matrix of intertemporal marginal propensities to consume, and $\mathbf{M}^r$ is the matrix of intertemporal effects on consumption of changes in the real interest rate. The last term in (4) represents the asset revaluation channel, with $\mathbf{M}^v$ denoting the matrix of intertemporal effects on consumption from this channel, which arises because realized asset returns, $\mathbf{r}^a$, differ from expected returns, $\mathbf{r}$. Since the revaluation effect is present only in the period when a shock hits, and because the effect is concentrated at the top of the wealth distribution where the marginal propensity to consume is small, we can make the approximation $\mathbf{M}^v \approx \mathbf{0}$.

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

9. $\chi \equiv \eta(1-\alpha) + \gamma$, where η is the domestic consumers' elasticity of substitution between home and foreign goods, and γ the corresponding elasticity in foreign consumption.

rate and the real exchange rate:

$$d\mathbf{r} = -\mathbf{G}^{r,Q} d\mathbf{Q}. \tag{5}$$

Lastly, we combine (5) with the model's New Keynesian Phillips curve and the Taylor rule to obtain a relationship between domestic output and the real exchange rate:

$$d\mathbf{Q} = -\mathbf{G}^{Q,Y} d\mathbf{Y}. \tag{6}$$

As shown in Appendix B, the matrices $\mathbf{G}^{Q,Y}$ and $\mathbf{G}^{r,Q}$ are derived from the structural parameters of the model. While their entries generally have mixed signs, (5) implies that high domestic real interest rates are associated with a future real exchange rate appreciation, whereas we have found that, numerically, (6) implies a negative relationship between the domestic output gap and the real exchange rate.

Combining equations (2) through (6), we can show the following result:

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

$$d\mathbf{C} = \mathbf{G}^{C,Y} d\mathbf{Y}, \tag{7}$$

where

$$\mathbf{G}^{C,Y} \equiv \frac{1}{\mu}\mathbf{M} + \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M}\mathbf{G}^{Q,Y} + \mathbf{M}^r\mathbf{G}^{r,Q}\mathbf{G}^{Q,Y}, \tag{8}$$

and

$$d\mathbf{Y} = \mathbf{G}^{Y,C^*} d\mathbf{C}^*, \tag{9}$$

with $\mathbf{G}^{Y,C^*}$ 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 $\mathbf{G}^{Y,C^*}$ are such that domestic output rises in response to a foreign demand shock. Proposition 1 thus states that, conditional on a positive output response, the consumption response to a foreign demand shock is driven by three components.

The first term in (8) captures direct income and multiplier effects from higher labor income. Consumption rises because domestic households have more income due to the rise in foreign demand.

The second term in (8) captures effects of real exchange rate movements on consumption via household income what Auclert et al. (2021b) term the "real income channel": The rise in domestic inflation is associated with an appreciation of the real exchange rate, which increases the real income of domestic households, allowing them to spend more on relatively cheaper imports and expand their overall consumption basket.[10]

The third term —$\mathbf{M}^r \mathbf{G}^{r,Q} \mathbf{G}^{Q,Y}$— 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 $\mathbf{M}^r$ are negative. This channel thus tends to reduce consumption, as the domestic central bank responds to the increase in domestic inflation by raising the nominal interest rate, thus driving up also the real rate and inducing households to postpone consumption.

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, $\mathbf{M} \approx \mathbf{0}$, such as in representative agent models which operate under the permanent income hypothesis, equations (7) and (8) collapse to:

$$d\mathbf{C} \approx \mathbf{M}^r \mathbf{G}^{r,Q} \mathbf{G}^{Q,Y} d\mathbf{Y}. \tag{10}$$

Domestic consumption thus responds *negatively* to a foreign demand shock, in direct contrast to Empirical Fact 2. 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 (8).

In contrast, the presence of high-MPC households in our HANK model implies that $\mathbf{M} \approx \mathbf{0}$ no longer applies. Instead, the first and third terms in (8) will dominate, provided that the average MPC is sufficiently high. This paves the way for the model to generate a positive response of domestic consumption, thus reproducing Empirical Fact 2. Part of the increase in consumption will be directed towards foreign goods, giving rise to an increase in imports (along with exports), as established in Empirical Fact 3. Finally, as we show using the full model in the next section, the positive response of domestic consumption is also key to accounting for Empirical Fact 5; the importance of foreign demand shocks in determining fluctuations in domestic output.

10. In the quantitative model we propose in the next section, the real income channel instead exerts a negative impact on the consumption response to a foreign demand shock. This happens because, in line with our empirical evidence in Section 2, the shock also affects foreign inflation, which increases by more, so the real exchange rate depreciates.

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 $\mathbf{G}^{Q,Y}$ flips sign; see Appendix B). This implies that the RANK version of the model (with $\mathbf{M} \approx \mathbf{0}$) actually generates the desired, positive 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 increase in domestic inflation leads to a reduction of the real interest rate and an increase in consumption. In our full model in the next section—and in line with the data—foreign inflation also increases and the foreign central bank responds by raising the nominal interest rate, so that the positive responses of the nominal and real domestic interest rates are restored, and consumption in the RANK setup again displays the counterfactual drop.

3.1 Two-sector model and sectoral comovement

Finally, to address Empirical Fact 4, we now briefly consider an extension where the domestic economy produces both tradeable and non-tradeable goods. Consumers have CES preferences over these two goods, with a share $1 - \alpha_T$ of consumption going to non-tradeables, and α_T going to tradeables, which in turn consist of a CES composite of tradeables produced at home and abroad. Denoting by $\eta_{T,NT}$ the elasticity of substitution between tradeables and non-tradeables, the linearized CES demand functions are:

$$d\mathbf{C}_T = -\eta_{T,NT}\alpha_T d\left(\frac{\mathbf{P_T}}{\mathbf{P}}\right) + \alpha_T d\mathbf{C},$$

$$d\mathbf{C}_{NT} = -\eta_{T,NT}\left(1 - \alpha_T\right) d\left(\frac{\mathbf{P_{NT}}}{\mathbf{P}}\right) + \left(1 - \alpha_T\right) d\mathbf{C}.$$

The domestic demand for tradeable and non-tradeable goods depends on a substitution effect determined by the movements of relative prices, $d\left(\frac{\mathbf{P_T}}{\mathbf{P}}\right)$ and $d\left(\frac{\mathbf{P_{NT}}}{\mathbf{P}}\right)$, and an income effect which is determined (or scaled) by the response of aggregate consumption $d\mathbf{C}$. As argued above, the income effect is (counterfactually) weak in the RANK model, thus implying a dominant role for the substitution effect. In the case of a positive shock to foreign demand, the relative price of tradeables increases, inducing consumers to substitute towards the relatively cheaper non-tradeables. Thus, the substitution effect implies opposite movements in the consumption of tradeables and non-tradeables, giving rise to a negative comovement between these two in the RANK model, in contrast to Empirical Fact 4. In the HANK model, instead, the income effect is much larger, and therefore has the potential to dominate the substitution effect and generate a positive comovement between the two consumption goods.

4 Model

We now turn to a fully fledged calibrated business-cycle model of a small open economy. We start from the stylized model considered in the previous section, extended to account for the production of both tradeable and non-tradeable goods in the domestic economy. In addition, we introduce intermediate inputs in production, which is commonly used in the existing literature to obtain positive business-cycle comovement across sectors (see, e.g., Huang and Liu, 2007, or Bouakez, Cardia, and Ruge-Murcia, 2009), and a public sector to study fiscal policy. The foreign economy is a standard New Keynesian model as in Galí (2015).

4.1 Households

The economy consists of a continuum of households with unit measure indexed by i. Households are permanently heterogeneous in two dimensions: The sector in which they work (tradeable or non-tradeable) and with respect to 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 domestic households. We denote the composite discount factor for a household with permanent subjective discount factor β^k by $\beta_t^k = \beta^k \exp\left\{\epsilon_t^\beta\right\}$. The recursive consumption-saving problem faced by household i is given by:

$$V_t^{s,k}(e_t, a_{t-1}) = \max_{c_t, a_t} u\left(c_t\right) - \nu\left(n_t\right) + \beta_t^k \mathbb{E}_t\left[V_{t+1}^{s,k}(e_{t+1}, a_t)\right] \tag{11}$$

s.t.

$$c_t + a_t = \left(1 + r_t^a\right) a_{t-1} + w_{s,t} n_{s,t} e_t + T_t - \tau\left(\tau_t, e_t\right), \tag{12}$$

$$\ln e_t = \rho_e \ln e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim \mathcal{N}\left(0, \sigma_e^2\right), \tag{13}$$

$$a_t \geq 0, \tag{14}$$

with functional forms:

$$u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}, \quad \nu(n_t) = \xi \frac{n_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}},$$

where σ is the inverse intertemporal elasticity of substitution and φ is the Frisch elasticity of labor supply. Households maximize the expected discounted sum of lifetime utility given by the value function in (11) by choosing, each period, the consumption bundle c_t and the level of savings a_t subject to three constraints. The first constraint is the period budget constraint (12) (deflated by the domestic consumer price index). Households can save in a risk-free asset a_t which yields the return r_t^a. They earn real sector-specific labor income $w_{s,t} n_{s,t} e_t$, where $w_{s,t}$ is the real wage rate, $n_{s,t}$ is labor supply, and e_t captures the idiosyncratic part of earnings, which follows an AR(1) process in logs, as in (13). T_t denotes lump sum transfers received from the government, and $\tau(\cdot)$ is a progressive tax function depending on the taxation level τ_t. Finally, households face a no-borrowing constraint, equation (14).

Note that labor supply is not chosen by the individual household (and hence not a control variable of the consumption-saving problem). Instead, it is chosen by the labor union of which the household is a member, as described in Section 4.3. The fact that all households supply the same amount of labor is common in HANK models, and is typically obtained either through Greenwood, Hercowitz, and Huffman (1988) preferences (see, e.g., Bayer et al., 2019, Kaplan, Moll, and Violante, 2018), or by assuming the presence of a labor union which dictates labor supply for the households (e.g., Auclert, Rognlie, and Straub, 2018, De Ferra, Mitman, and Romei, 2020). See Auclert, Bardóczy, and Rognlie (2021) for an analysis of the implications of this choice. As they argue, this allows the model to capture realistic labor supply adjustments in response to income shocks while still matching high average MPCs.

Let $\mathcal{D}_t$ be the distribution of households over states $\{a_{t-1}, e_t, \beta, s\}$. Denoting by capital letters aggregate quantities we have:

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

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

4.1.1 Portfolio choice

The total amount of real assets A_t owned by households is invested in a mutual fund, which in turn can invest in three types of financial assets, implying the following balance sheet relation:

$$A_t = B_t + B_t^* + p_t^D, \tag{15}$$

where B_t and B_t^* denote domestic and foreign government bonds, respectively, and p_t^D denotes the value of equity shares issued by domestic firms. Domestic bonds pay the nominal policy rate i_t set by the central bank and generate the real return $r_t \equiv \frac{1+i_t}{1+\pi_{t+1}} - 1$. Firm shares pay dividends D_t each period and the period-by-period gross return is given by $\frac{p_{t+1}^D + D_{t+1}}{p_t^D}$. Lastly, foreign bonds B_t^* pay the foreign interest rate i_t^*. Denoting by $Q_t = E_t \frac{P_t^*}{P_t}$ the real exchange rate, the real return to foreign assets is $(1 + r_t^*) \frac{Q_{t+1}}{Q_t}$. Given that there is no aggregate uncertainty and that all assets are perfect substitutes, the real returns on each of the three assets need to be equal in equilibrium, which leads to the following no-arbitrage conditions:

$$1 + r_t = \frac{p_{t+1}^D + D_{t+1}}{p_t^D}, \tag{16}$$

$$1 + r_t = (1 + r_t^*) \frac{Q_{t+1}}{Q_t}, \tag{17}$$

where $r_t = \mathbb{E}_t r_{t+1}^a$ denotes the ex-ante real return.[11] The first condition equates the return on domestic bonds and stocks. The second is the real UIP condition: Domestic and foreign returns must be equal when converted to the appropriate currency due to free capital movements across borders.

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

$$r_t^a = \frac{p_t^D + D_t + \frac{i_{t-1}}{1+\pi_t} B_{t-1}}{A_{t-1}} - 1,$$

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

4.1.2 Complete markets and income sharing: The representative agent case

In addition to our incomplete markets model, which features idiosyncratic risk and a borrowing constraint, we also consider the complete markets benchmark. The assumption of complete markets with perfect risk-sharing and no preference heterogeneity implies the existence of a representative agent, with aggregate consumption determined by the aggregate Euler equation:

$$u'(C_t) = (1 + r^a_{t+1})\bar{\beta}_t u'(C_{t+1}).$$

The HANK model with idiosyncratic income risk is stationary by design due to the presence of a precautionary savings motive. This is not the case for the RANK version of the model. To make the two models comparable, we follow Schmitt-Grohé and Uribe (2003) and most of the ensuing literature by incorporating a debt-elastic interest rate premium Γ_t on foreign assets. The return on foreign assets is then $(1 + r^*_t)\frac{Q_{t+1}}{Q_t}\Gamma_t$, where $\Gamma_t \equiv \exp\left\{-\varepsilon^D\left(\frac{Q_t B^*_t}{GDP_{ss}} - \frac{Q_{ss} B^*_{ss}}{GDP_{ss}}\right)\right\}$, so as to capture that domestic investors must pay a premium on foreign bonds when the share of foreign assets increases above its steady-state level and the net foreign asset position declines. With this formulation, the only difference to the HANK model is an extra factor in the real UIP condition; $1 + r_t = (1 + r^*_t)\frac{Q_{t+1}}{Q_t}\Gamma_t$.

4.1.3 Consumption goods

Consumption C_t is a CES aggregate of tradeable goods $C_{T,t}$ and non-tradeable goods $C_{NT,t}$:

$$C_t = \left[\alpha_T^{\frac{1}{\eta_{T,NT}}} C_{T,t}^{\frac{\eta_{T,NT}-1}{\eta_{T,NT}}} + (1-\alpha_T)^{\frac{1}{\eta_{T,NT}}} C_{NT,t}^{\frac{\eta_{T,NT}-1}{\eta_{T,NT}}}\right]^{\frac{\eta_{T,NT}}{\eta_{T,NT}-1}}, \tag{18}$$

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

$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\eta_{T,NT}} C_t, \tag{19}$$

$$C_{NT,t} = (1-\alpha_T)\left(\frac{P_{NT,t}}{P_t}\right)^{-\eta_{T,NT}} C_t, \tag{20}$$

where P_t is the consumer price index (CPI), and $P_{T,t}$ and $P_{NT,t}$ are the price of tradeables and non-tradeables, respectively. The CPI is given by:

$$P_t = \left[\alpha_T P_{T,t}^{1-\eta_{T,NT}} + (1-\alpha_T) P_{NT,t}^{1-\eta_{T,NT}}\right]^{\frac{1}{1-\eta_{T,NT}}}. \tag{21}$$

Tradeable goods $C_{T,t}$ is itself a composite good made up of foreign and home goods $C_{F,t}, C_{H,t}$ bundled through a CES aggregator with parameters $0 \leq \alpha_F \leq 1, \eta_{H,F} > 0$. The demand functions for these goods are:

$$C_{F,t} = \alpha_F \left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\eta_{H,F}} C_{T,t}, \tag{22}$$

$$C_{H,t} = (1-\alpha_F) \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\eta_{H,F}} C_{T,t}, \tag{23}$$

with $P_{T,t} = \left[\alpha_F P_{F,t}^{1-\eta_{H,F}} + (1-\alpha_F) P_{H,t}^{1-\eta_{H,F}}\right]^{\frac{1}{1-\eta_{H,F}}}$. Foreign demand for home tradeables is given by an Armington relation:

$$C_{H,t}^* = \alpha^* \left(\frac{P_{H,t}^*}{P_{F,t}^*}\right)^{-\eta^*} C_t^*, \tag{24}$$

where $P_{H,t}^*$ is the price of home tradeables denominated in foreign currency units, and where $0 \leq \alpha^* \leq 1$ and $\eta^* > 0$. Similarly, $P_{F,t}^*$ is the price of the foreign good in foreign currency. We assume a law of one price for foreign and domestic tradeables such that prices are equalized across countries, once converted to the appropriate currency: $P_{H,t}^* = \frac{P_{H,t}}{E_t}$ and $P_{F,t}^* = \frac{P_{F,t}}{E_t}$.

4.2 Firms

We now turn to the production sector of the economy.

4.2.1 Wholesalers

The domestic supply side is composed of two sectors: A tradeable and a non-tradeable 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. The representative wholesaler in sector s uses a CES production technology with elasticity of substitution $\epsilon_s^P > 0$, so the demand for output from producer j is given by:

$$Z_{s,t}^j = \left(\frac{P_{s,t}^j}{P_{s,t}}\right)^{-\epsilon_s^P} Z_{s,t}, \tag{25}$$

where $Z_{s,t}$ is gross output of sector s.

4.2.2 Producers

$Z_{s,t}$ is produced with labor $N_{s,t}$ and an intermediate goods bundle $X_{s,t}$:

$$Z_{s,t} = X_{s,t}^{\alpha_s^X} N_{s,t}^{1-\alpha_s^X} - F_s, \tag{26}$$

where F_s is a fixed cost. Each sector is characterized by monopolistic competition between a continuum of firms facing the demand function of wholesalers (25). Firms choose $N_{s,t}, X_{s,t}, P_{s,t}$ to maximize real dividends given by:

$$D_{s,t} = \frac{P_{s,t}Z_{s,t} - W_{s,t}N_{s,t} - P_{s,t}^X X_{s,t}}{P_t} - \frac{\theta_s^P}{2}\left(\frac{P_{s,t}}{P_{s,t-1}} - 1\right)^2 Z_{s,t}, \tag{27}$$

where the last term is a Rotemberg price adjustment cost. The first-order conditions for labor demand, intermediate goods demand and price setting are:

$$P_{s,t}mc_{s,t}\left(1-\alpha_s^X\right)\frac{Z_{s,t}}{N_{s,t}} = W_{s,t}, \tag{28}$$

$$P_{s,t}mc_{s,t}\alpha_s^X\frac{Z_{s,t}}{X_{s,t}} = P_{s,t}^X, \tag{29}$$

$$\theta_s^P\pi_{s,t}(1+\pi_{s,t}) = (1-\epsilon_s^P) + \epsilon_s^P mc_{s,t} + \frac{1}{1+r_t}\theta_s^P\pi_{s,t+1}(1+\pi_{s,t+1})\frac{Z_{s,t+1}}{Z_{s,t}}, \tag{30}$$

where $mc_{s,t}$ is the real marginal cost in sector s.

4.2.3 Intermediate-good retailers

The intermediate-good bundle $X_{s,t}$ is assembled by retailers operating in a perfectly competitive environment. The retailers operate using a CES technology:

$$X_{s,t} = \left[\Theta_{s\to s}^{\frac{1}{\eta_X}} X_{s\to s,t}^{\frac{\eta_X-1}{\eta_X}} + \Theta_{s'\to s}^{\frac{1}{\eta_X}} X_{s'\to s,t}^{\frac{\eta_X-1}{\eta_X}} + \Theta_{F\to s}^{\frac{1}{\eta_X}} X_{F\to s,t}^{\frac{\eta_X-1}{\eta_X}}\right]^{\frac{\eta_X}{\eta_X-1}}, \tag{31}$$

where $X_{s\to s,t}$ and $X_{s'\to s,t}$ denote the input materials produced in sectors s and s', respectively, and used as input for the intermediate-good bundle in sector s, and where $\eta_X > 0$ is the elasticity of substitution between input types. Likewise, $X_{F\to s,t}$ denotes intermediate inputs imported from the foreign economy. Note that $[\Theta_{s\to s}, \Theta_{s'\to s'}]'$ is the diagonal of a domestic input-output matrix. The price of the intermediate-good bundle is then given by:

$$P^X_{s,t} = \left[\Theta_{s\to s}\left(P_{s,t}\right)^{1-\eta_X} + \Theta_{s'\to s}\left(P_{s',t}\right)^{1-\eta_X} + \Theta_{F\to s}\left(P_{F,t}\right)^{1-\eta_X}\right]^{\frac{1}{1-\eta_X}}. \tag{32}$$

Demand for intermediate goods in sector s is:

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

4.2.4 Aggregates

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

$$Y_{s,t} = \frac{P_{s,t}Z_{s,t} - P^X_{s,t}X_{s,t}}{\mathcal{P}_t}, \tag{33}$$

and aggregate VA, Y_t, as:

$$Y_t = \sum_s Y_{s,t} = Y_{T,t} + Y_{NT,t}. \tag{34}$$

For future use, we define real GDP in units of the CPI: $GDP_t \equiv Y_t \frac{\mathcal{P}_t}{P_t}$.

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

4.3 Labor supply and wage setting

Labor supply is determined by unions. In each sector, there is a continuum of unions, and each household i in that sector provides $n^j_{i,s,t}$ hours of work to union j in sector s. Total labor supply of household i is then $n_{i,s,t} = \int n_{i,s,t} dj$. Each union assembles individual labor supply to a union-specific task $N^j_{s,t} = \int e_{i,t} n^j_{i,s,t} di$, and aggregate labor supply is assembled from these union-specific tasks using a CES technology:

$$N_{s,t} = \left(\int_j \left(N^j_{s,t} \right)^{\frac{\epsilon^W_s - 1}{\epsilon^W_s}} \right)^{\frac{\epsilon^W_s}{\epsilon^W_s - 1}},$$

where $\epsilon^W_s > 0$ is the (sector-specific) elasticity of substitution between labor types. Union j in sector s maximizes the discounted sum of future utility of its members less a Rotemberg adjustment cost on nominal wages:

$$\sum_{t=0}^{\infty} \beta^U_t \left(\int \{ u(c_{i,s,t}) - \nu(n_{i,s,t}) \} d\mathcal{D}_t - \frac{\theta^W_s}{2} \left(\frac{W^j_{s,t}}{W^j_{s,t-1}} - 1 \right)^2 \right),$$

where β^U_t denotes the discount factor of the union, which we set to $\beta^U_t = \frac{1}{1+r_t}$ as in Hagedorn, Manovskii, and Mitman (2019). The problem yields a symmetric solution such that all unions choose the same wage and households supply the same amount of labor. Hence we obtain aggregate sector-specific New Keynesian wage Phillips Curves:

$$\pi^w_{s,t}\left(1 + \pi^w_{s,t}\right) = \frac{\epsilon^w_s}{\theta^w_s} N_{s,t} \left\{ \nu'\left(N_{s,t}\right) - \frac{\epsilon^w_s - 1}{\epsilon^w_s} \frac{W_{s,t}}{P_t} U'\left(C_{s,t}\right) \right\} + \beta^U_t \pi^w_{s,t+1}\left(1 + \pi^w_{s,t+1}\right), \tag{35}$$

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.

4.4 Monetary policy

In our benchmark framework, we assume that the domestic economy maintains a floating exchange rate vis-a-vis the foreign economy. The domestic central bank is assumed to conduct monetary policy according to a Taylor rule featuring interest rate smoothing:

$$i_t = \left(i_{ss} + \phi^{\pi}\pi^{PP}_{t+1}\right)(1-\rho^r) + \rho^r i_{t-1} + \epsilon^r_t, \tag{36}$$

where π^{PP}_t is inflation based on the domestic producer price index (PPI) defined as the Laspeyres index over $C_{H,t}, C_{NT,t}$.[13] We follow Galí (2015) and assume that the central bank responds to movements in the PPI rather than the CPI.

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 (36) with the condition that the nominal exchange rate remains fixed at the steady-state level at all times:

$$E_t = E_{ss}. \tag{37}$$

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 lump-sum taxes τ_t. The period real budget constraint (measured in terms of the CPI) is:

$$B_t + \tau_t = T_t + \frac{P^G_t}{P_t}G_t + \frac{1+i_{t-1}}{1+\pi_t}B_{t-1}, \tag{38}$$

where P^G_t is the price of public spending, which depends on the composition of government expenditures. We assume that a constant fraction s^G_T of public consumption goes to home tradeables:[14]

$$G_{HT,t} = s^G_T G_t,$$
$$G_{NT,t} = (1-s^G_T)G_t.$$

Public consumption and transfers are treated as exogenous. We assume that in steady state, the budget is balanced by changing the lump-sum tax τ_t. Outside of steady state, discretionary fiscal policy along with changes in interest expenses re-

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

14. With this formulation, the price of government spending is simply $P^G_t = P_{H,t}s^G_T + P_{NT,t}(1-s^G_T)$. The assumption that the government does not purchase foreign tradeables is empirically well founded, as discussed in Section 5.

quires financing. We assume that the government finances deficits by issuing bonds for the first t_B quarters after a shock. From period t_B and onwards the government smoothly adjusts the lump-sum tax τ_t to ensure that the debt level converges to the initial steady-state level.

4.6 The foreign economy

The foreign economy is modelled as a simple New-Keynesian model as in Galí (2015). The household block consists of an Euler equation and a labor supply curve:

$$\left(C_t^*\right)^{-\sigma^*} = (1 + r_t^*)\beta_t^* \left(C_{t+1}^*\right)^{-\sigma^*}, \tag{39}$$

$$w_t^* = \frac{\nu^* \left(N_t^*\right)^{\frac{1}{\varphi^*}}}{\left(C_t^*\right)^{-\sigma^*}}. \tag{40}$$

We allow for a shock to the foreign discount factor, $\beta_t^* = \beta^* \exp\left\{\epsilon_t^{\beta^*}\right\}$, which will be the primary source of foreign demand fluctuations. The firm block consists of the production function, the labor demand curve, and a forward looking Philips curve:

$$Y_t^* = Z_t^* N_t^*, \tag{41}$$

$$w_t^* = Z_t^* mc_t^*, \tag{42}$$

$$\theta^* \pi_{F,t}^* (1 + \pi_{F,t}^*) = \epsilon^* mc_t^* + \frac{1}{1 + r_t^*} \theta^* \pi_{F,t+1}^* (1 + \pi_{F,t+1}^*) \frac{Y_{t+1}^*}{Y_t^*} + (1 - \epsilon^*). \tag{43}$$

The foreign central bank sets the nominal interest rate following the Taylor rule:

$$i_t^* = i_{ss}^* + \phi \pi_{F,t+1}^*, \tag{44}$$

where the nominal rate i_t^* and the real rate r_t^* are related by the Fisher equation $1 + r_t^* = \frac{1+i_t^*}{1+\pi_{t+1}^*}$. Lastly, the model features the simple market clearing condition:

$$Y_t^* = C_t^*. \tag{45}$$

4.7 Domestic market clearing

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

$$Z_{NT,t} = C_{NT,t} + G_{NT,t} + X_{NT\to T,t} + X_{NT\to NT,t}, \tag{46}$$

$$Z_{T,t} = C_{H,t} + C^*_{H,t} + G_{HT,t} + X_{T\to T,t} + X_{T\to NT,t}. \tag{47}$$

We define net exports and the net foreign asset position as:

$$NX_t = GDP_t - C_t - G_t, \tag{48}$$

$$NFA_t = B^*_t = A_t - p^D_t - B_t. \tag{49}$$

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):

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

4.8 Shocks and equilibrium

Below we consider only perfect-foresight shocks to the model. However, given that we only study small shocks, the dynamics of the model are approximately linear, and the impulse responses are identical to those obtained in the model with aggregate risk (Boppart, Krusell, and Mitman, 2018). We consider shocks to the following set of variables: $\{\epsilon^{\beta^*}_t, \epsilon^{\beta}_t, G_t, T_t, \epsilon^r_t\}$. A shock to β^*_t through $\epsilon^{\beta^*}_t$ is our main shock of interest; a shock to foreign demand generated by variation in the foreign discount factor. ϵ^{β}_t is a domestic demand shock; G_t, T_t, and ϵ^i_t are policy shocks.

Due to our small open economy assumption, the foreign economy operates independently of the domestic economy (though the reverse obviously does not apply), so we can define equilibrium in the foreign economy separately:

Definition 1 (Foreign equilibrium)**.** *Given a sequence for the foreign discount factor shocks* $\{\epsilon^{\beta^*}_t\}$*, a competitive equilibrium in the foreign economy is a sequence of prices* $\left\{w^*_t, P^*_{F,t}, i^*_t, r^*_t\right\}$ *and aggregate quantities* $\{C^*_t, N^*_t, Y^*_t\}$ *such that all households and firms optimize, the central bank implements the Taylor rule* (44)*, and the goods market* (45) *clears.*

The home economy is not directly affected by a shock to the foreign discount factor β_t^*, but by the movements in $\left\{C_t^*, P_{F,t}^*, i_t^*\right\}$ caused by variation in β_t^*. The exogenous sequences from the perspective of the domestic economy are thus $\{C_t^*, P_{F,t}^*, i_t^*, \epsilon_t^\beta, G_t, T_t, \epsilon_t^i\}$, where the first three are those associated with foreign demand shocks.

Definition 2 (Domestic equilibrium)**.** *Given sequences for* $\{C_t^*, P_{F,t}^*, i_t^*, \epsilon_t^\beta, G_t, T_t, \epsilon_t^r\}$, *an initial household distribution over assets, earnings, discount factors and sectors* $\mathcal{D}_0(a, e, \beta, s)$*, and an initial portfolio allocation between foreign and domestic assets, a competitive equilibrium in the domestic economy is a path of household policies* $\{c_t(a, e, s), a_t(a_{t-1}, e, s)\}$*, distributions* $\mathcal{D}_t(a, e, s)$*, prices:*

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

and quantities:

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

such that all households and firms optimize, monetary and fiscal policy follow their rules, and the goods markets, (46) *and* (47)*, clear.*

4.9 Solution method

We solve the households' dynamic programming problem using the endogenous grid method of Carroll (2006). We then 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.[15]

5 Calibration

We calibrate the model using a mix of internally and externally calibrated parameters. The goal is to have the model describe the average small open economy in our sample of OECD countries, which our empirical results are based on. For comparability, we calibrate the HANK and RANK models as similarly as possible. This

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

means that all parameters except those describing households' income and preferences are identical.

5.1 Households

We first focus on the calibration of the household sector.

5.1.1 Preferences

We set the elasticity of intertemporal substitution $1/\sigma$ to 0.5. This value is well within the range of estimates commonly used in the literature, and it allows the HANK model to closely match the consumption response to interest rate shocks in the more elaborate, two-asset HANK model of Kaplan, Moll, and Violante (2018), c.f. Figure 26 in Appendix C. 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.

In the HANK model, we calibrate the average discount factor $\bar{\beta}$ to match a quarterly wealth-to-income ratio of 10. This corresponds to the average among OECD countries over our sample period 1996-2019. In the RANK model, β is pinned down by our choice of the steady state real interest rate, which we set to 2% p.a. We maintain the same wealth-to-income in the initial steady state of the RANK model to be consistent with the calibration of the HANK model.

We allow for discount factor heterogeneity in the HANK model in order to match the large MPCs estimated in micro studies. We assume that discount factors are uniformly distributed on $\left[\overline{\beta} - \Delta\beta, \overline{\beta} + \Delta\beta\right]$, where $\Delta\beta$ is the discount factor dispersion. We calibrate $\Delta\beta$ to match an annual first-year MPC of 0.55 following the estimates from Fagereng, Holm, and Natvik (2021), c.f. Figure 26 in Appendix C.

Finally, we set the interest rate elasticity of debt, ϵ^D, so that it is just large enough to ensure stationarity in the RANK model, but small enough to not significantly affect our results. We find that $\epsilon^D = 0.0001$ is sufficient for this purpose. This elasticity is zero in the HANK model.

5.1.2 Income process

For the idiosyncratic income process, we set the standard deviation of innovations σ_e to 0.25 and the persistence to $\rho_e = 0.95$ 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 (McKay, Nakamura, and Steinsson, 2016, Guerrieri and Lorenzoni, 2017, De Ferra, Mitman, and Romei, 2020 etc.). We approximate the AR(1) process with a discrete Markov process using the method from Rouwenhorst (1995). For the tax function $\tau(\tau_t, e_t)$, we simply assume that households are taxed proportionally with their idiosyncratic productivity e_t: $\tau(\tau_t, e_t) = \frac{\tau_t e_t}{\mathbb{E}_t e_t}$.

5.1.3 Domestic consumption baskets

The CES share parameters α and α_T are based on OECD data on consumption composition. We fix the steady-state share of tradeables in the consumption basket to match the average ratio in the OECD sample used in Section 2, where we take consumption of non-durables to be tradeables and consumption of services to be non-tradeables. We find that tradeables make up 41% of the basket, $\alpha_T = 0.41$. We set α (the share of foreign tradeables in the tradeable consumption basket of domestic households) to match the average share of imports going to final consumption in our OECD sample. This yields $\alpha = 0.4$.

The elasticities of substitution $\eta_{T,NT}$ and $\eta_{H,F}$ are less easily disciplined by the data. Evidence on the elasticity between tradeable and non-tradeable goods is sparse. Estimates of the elasticity of substitution between different *varieties* of goods are often around 3 to 5 (Feenstra et al., 2018), but given that the data used in the estimation reflects tradeable goods more than non-tradeables, these estimates do not carry over to our case. Ostry and Reinhart (1992) and Akinci (2011) estimate the elasticity between tradeables and non-tradeables directly and find it to be in the range of 0.5 to 1.5. In our baseline calibration we set $\eta_{T,NT} = 1.5$. Regarding the elasticity of substitution between home and foreign tradeables $\eta_{H,F}$, we fix this at 1.5. This is in the lower range of the estimates of Feenstra et al. (2018), and closer to the estimate in Gallaway, McDaniel, and Rivera (2003), reflecting that the former is a medium-run estimate, and the latter a short-run estimate.

5.2 Firms

The supply side of our model is characterized by extensive input-output (IO) linkages. We discipline these linkages using the OECD IO tables along with the STAN database and target average moments over the period 1990-2021. We proxy the non-tradeable sector by the service sector and the tradeable sector by the industries in the

OECD STAN database. We calibrate the output elasticities of intermediate goods, α_T^X and α_{NT}^X, such that the cost of buying intermediate goods is 80% and 55% of total costs in the sectors respectively, which are the averages among the OECD countries in the STAN database. 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 used in the literature (Boehm, Flaaen, and Pandalai-Nayar, 2019, Atalay, 2017). Finally, we assume that 30% of households are employed in the tradeables sector to match the average *Trade-in-Employment* shares in the STAN database. The input-output matrix of the model is given by:

$$\mathbf{\Theta} = \begin{matrix} \\ NT \\ T \\ F \end{matrix} \begin{matrix} \begin{matrix} NT & \quad T \end{matrix} \\ \begin{bmatrix} 0.60 & 0.32 \\ 0.4 & 0.48 \\ 0 & 0.20 \end{bmatrix} \end{matrix},$$

where columns represent input and rows output. According to the STAN database, the non-tradeables sector gets 60% of intermediate inputs from itself and the remaining 40% from other domestic sectors, here taken to be the domestic tradeable sector. For the tradeable sector we calibrate the amount of imported intermediate goods such that firm imports make up 70% of total imports, implying that $\Theta_{F,T} = 0.20$, with the remaining 30% going to imports for final goods consumption by households. The remaining two IO parameters of the tradeable sector are calibrated to match the fact that 60% of domestic intermediate goods are obtained from the domestic tradeable sector itself.

5.3 Monetary and fiscal policy

We use conventional values for the inflation response and interest-rate smoothing in the Taylor rule: $\phi^{\pi} = 1.5, \rho^{r} = 0.85$. Regarding public consumption and debt we set $\frac{G}{GDP} = 0.17$ and $\frac{B}{GDP} = 0.95$ (annualized), as these are the average values in our sample. For the debt dynamics in response to transitory shocks, we assume fully debt-financed fiscal policy for the first 50 quarters, with gradually increasing taxation afterwards to ensure that the public debt level returns to the steady state level, see appendix C.1.1 for the exact specification. Regarding the composition of government spending, we set $s_T^G = 0.2$ following Cardi and Restout (2021), implying that 80% of government spending goes to the non-tradeable sector with the remaining

20% going to the domestic tradeables sector.[16]

5.4 Nominal rigidities

We set the markup on final goods to 10% in both sectors, implying elasticites of substitution for final goods of $\epsilon_T^P = \epsilon_{NT}^P = 11$. We pick the Rotemberg costs $\theta_T^P, \theta_{NT}^P$ to match a Philips curve slope of 0.15. For the wage Philips curve, we set the markups equal to the final goods markups, $\epsilon_T^w = \epsilon_{NT}^w = 11$, as is common in the literature. We set the Rotemberg adjustment cost on wages to match a slope of 0.03, such that wages are significantly more sticky than prices. This allows the model to generate procyclical profits, which has been found to have desirable implications in HANK models (see Broer et al., 2020).

5.5 Foreign economy

The foreign economy calibration is standard and summarized in Table 4, with most of the parameters equal to their domestic counterparts. Two parameters deserve special mention. We allow for more rigid prices abroad compared to the home economy, as the domestic economy also features highly rigid wages. Second, we set the export elasticity η^* to 1.5 (and hence equal to the import elasticity of domestic households). This value is close to the ones typically used in short run DSGE models (Christiano, Trabandt, and Walentin, 2011, Bergholt, 2015), but well below the values estimated in the trade literature (Broda and Weinstein, 2006, Soderbery, 2015).

16. Cardi and Restout (2021) find that on average 18% of public spending is directed to domestic tradeables, while 2% is directed towards foreign tradeables. For simplicity we assume that the public sector does not purchase foreign tradeables.

Parameter	Description	Value	Target
	Households		
$1/\sigma$	Intertemporal elasticity of substitution	0.5	Standard value
φ	Frisch elasticity	0.5	Chetty et al. (2011)
$\bar{\beta}$ (HANK)	Mean discount factor	0.972	$\frac{A}{Income} = 2.5$ (annual)
$\bar{\beta}$ (RANK)	Mean discount factor	0.995	$r = 2\%$ p.a.
$\Delta\beta$	Discount factor dispersion	0.02	$MPC = 0.55$ (annual)
ε^D	Elasticity of r to NFA/GDP	0.0001	RANK stationarity
ρ_e	persistent of idiosyncratic income	0.95	Standard value
σ_e	Std. of idiosyncratic income	0.25	Standard value
s_T	Share of households working in tradeable sector	0.30	OECD average
η_T	Elasticity of sub. between C_T and C_{NT}	1.5	See text
η	Elasticity of sub. between C_F and C_H	1.5	See text
α_T	Share of tradeables in home basket	0.41	OECD average
α	Share of foreign tradeables in home basket	0.40	$\frac{CF}{Imports} = 40\%$
	Government and monetary policy		
$\frac{G}{GDP}$	Public consumption to GDP	0.17	17%
$\frac{B}{GDP}$	Government debt to GDP	0.95	95% (annual)
s_T^G	Share of G going to tradeables	0.2	Cardi and Restout (2021)
ϕ^π	Taylor rule coefficient	1.5	Standard value
ρ^r	Degree of interest rate smoothing	0.85	Standard value

Table 2: Calibration of the domestic economy

Parameter	Description	Value	Target
Production and intermediate goods			
α_T^X	Intermediate goods share	0.8	$\frac{P_T^X X_s}{P_s^X X_s + W_s N_s} = 0.8$
α_{NT}^X	Intermediate goods share	0.55	$\frac{P_s^X X_s}{P_s^X X_s + W_s N_s} = 0.55$
η_x	Elasticity of sub. between intermediate goods	0.5	See text
Phillips curves			
$\epsilon_T^P, \epsilon_{NT}^P$	Elasticity of substitution for final goods	11	Markup=10%
$\epsilon_T^w, \epsilon_{NT}^w$	Elasticity of substitution for labor	11	Markup=10%
$\theta_T^P, \theta_{NT}^P$	Rotemberg price parameter	73.3	Slope of NKPC = 0.15
$\theta_T^w, \theta_{NT}^w$	Rotemberg wage parameter	366.6	Slope of NKWPC = 0.03

Table 3: Sectoral calibration

Parameter	Description	Value	Target
$1/\sigma^*$	Intertemporal elasticity of substitutio	0.5	Standard value
φ^*	Frisch elasticity	0.5	Chetty et al. (2011)
β^*	Discount factor	0.995	$r^* = 2\%$ p.a.
ϕ^*	Taylor rule coefficient	1.5	Standard value
ϵ^*	Elasticity of substitution for final goods	11	Markup=10%
θ^*	Rotemberg price parameter	366.6	Slope of NKPC = 0.03
η^*	Export elasticity	1.5	See text

Table 4: Calibration of the foreign economy

6 Transmission of foreign demand shocks

We are now ready to study the transmission of foreign demand shocks in the domestic economy. We consider a shock which encompasses a simultaneous rise in output, inflation, and the nominal interest rate in the foreign economy. This parallels the shock we studied empirically in Section 2. Specifically, we consider a drop in the foreign discount factor of the form

$$(\beta_t^* - \beta^*) = \rho(\beta_{t-1}^* - \beta^*), \quad \text{for } t = 1, 2, \ldots, \infty, \tag{50}$$

with $\beta_0^* < \beta^*$ and persistence $\rho = 0.8$. We scale the shock such that foreign demand Y_t^* increases by 1% on impact. The response of foreign variables to the shock are shown in Figure 3. The shock makes foreign households more impatient, so that their current demand increases. This directly affects the demand for domestically produced tradeables. In the foreign economy, the excess demand furthermore pushes up foreign inflation, inducing the foreign central bank to raise the interest rate.

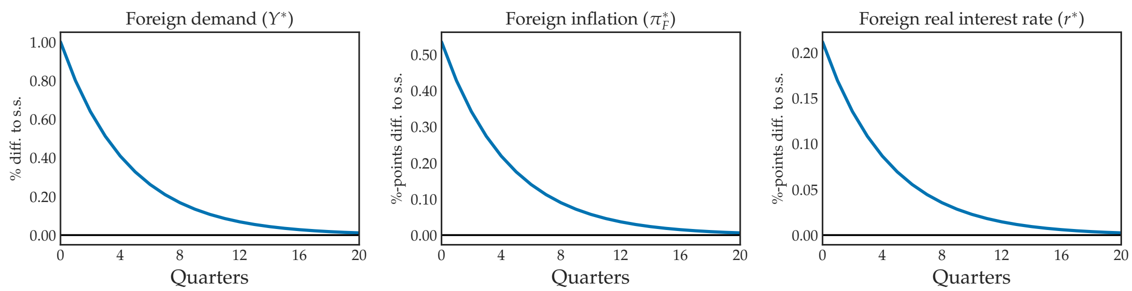

Figure 3: Response of the foreign economy to a foreign demand shock

Note: The figure shows the response of foreign variables to a foreign demand shock. The foreign demand shock is a drop in the discount factor, β_t^*, as given by eq. (50), scaled such that foreign demand increases by 1 pct. on impact.

6.1 Matching the Empirical Facts: HANK vs. RANK

We now turn our attention to the response of the domestic economy. Figure 4 shows the response of domestic variables in the HANK and RANK models. The two models deliver a similar positive output response, consistent with Empirical Fact 1. The HANK model also delivers a positive consumption response, in line with Empirical Fact 2. For the RANK model, instead, the consumption response is negative. The explanation is fundamentally the same as in our analytical model in Section 3. The boom in domestic production pushes domestic inflation up, which in turn induces the central bank to raise the nominal interest rate, leading to an increase also in the real rate. A negative intertemporal substitution effect then drags down consumption in the RANK model.[17] The positive response of consumption in the HANK model, on the other hand, is driven by the increase in labor income of domestic households, as the shock leads to an increase in employment and wages. In the presence of high-MPC households at or close to the borrowing constraint, this rise in labor income leads to a positive response of consumption, which dominates the negative substitution effect.

Since foreign inflation increases by more than domestic inflation, the real exchange rate depreciates in both models. This pushes exports up and imports down. The stronger demand response in the HANK model, however, implies a smaller depreciation. This dampens the response of exports and imports, and because of the direct demand effect, imports increase in the HANK model. This is consistent with Empirical Fact 3. In contrast, imports decline in the RANK model. While the response of net exports is attenuated in the HANK model, it is not fully consistent with the flat response we observe in the data (see Figure 2).

Behind the increase in imports in the HANK model, we also have an increase in consumption of tradeables, and we therefore observe a positive comovement with consumption of non-tradeables. This is consistent with Empirical Fact 4. In the RANK model, the intratemporal substitution effect from the increase in the relative price of tradeables to non-tradeables (see Figure 27 in Appendix C.2) dominates, and consumption of tradeables decreases, inducing a negative comovement.

Despite the differences in consumption dynamics, both models deliver an increase of output in both the non-tradeable and the tradeable sector. The increase in foreign demand directly stimulates the production of domestic tradeables. To satisfy the additional demand, producers in this sector employ more labor as well as more intermediate inputs, with the latter effect directly leading to a boom also in the non-tradeables sector. This shows how the presence of sectoral input-output linkages may generate positive business-cycle comovement across sectors, as in Huang and Liu (2007) and Bouakez, Cardia, and Ruge-Murcia (2009).

17. This finding is largely consistent with the existing RANK literature, see Christiano, Trabandt, and Walentin (2011), Adolfson et al. (2013), and Bergholt (2015).

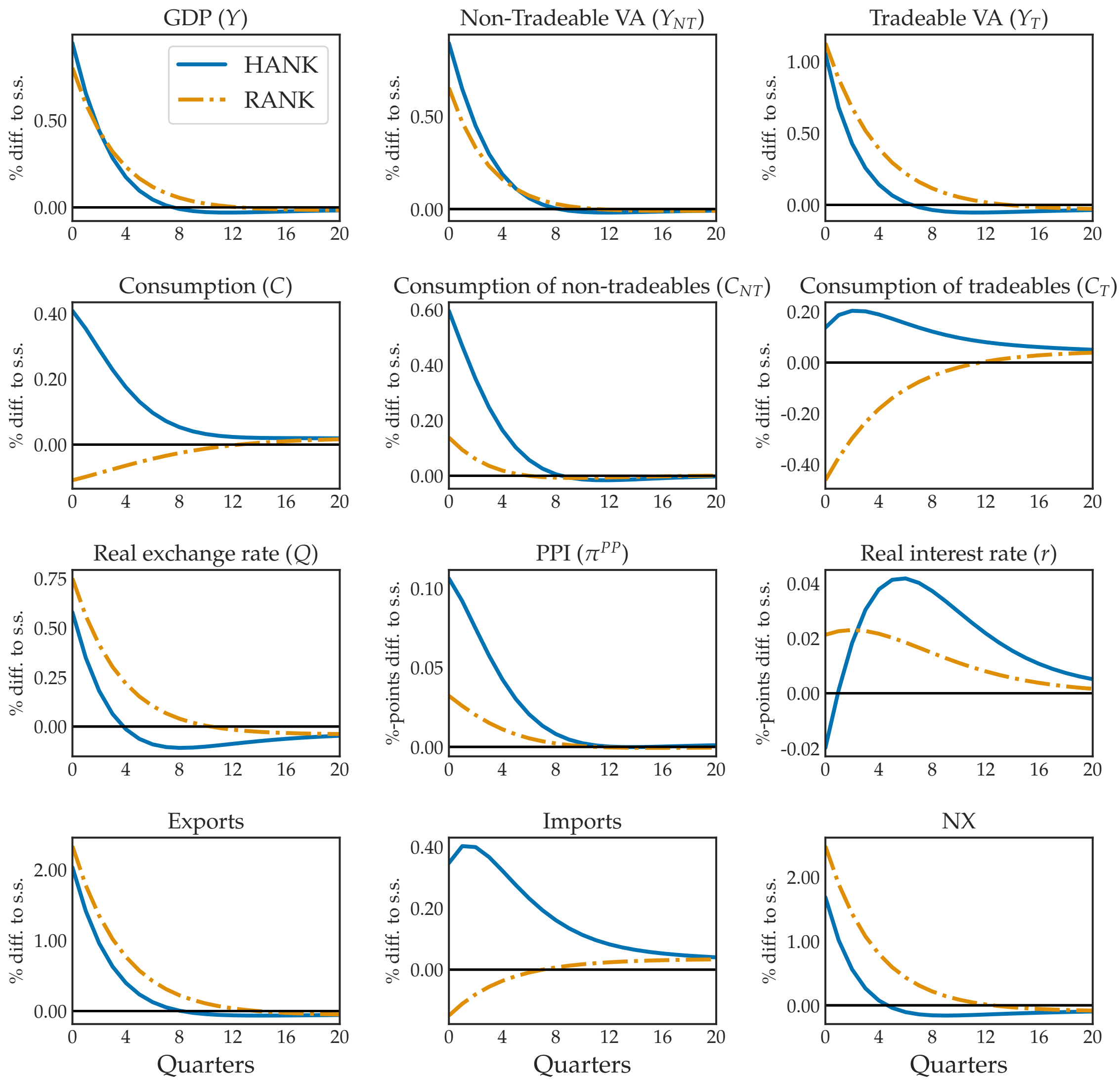

Figure 4: Response of the domestic economy to a foreign demand shock

Note: The figure shows the response of domestic variables to a foreign demand shock. The foreign demand shock is a drop in the foreign discount factor, β_t^*, as given by eq. (50), scaled such that foreign demand increases by 1 pct. on impact.

6.2 Drivers of aggregate consumption

To analyze the drivers of the consumption response in more detail, we decompose it using the linearized consumption function, equation (4) from Section 3, which we restate here for convenience:

$$dC = \underbrace{\mathbf{M} d\mathbf{Y}^{hh}}_{\text{Disp. income}} + \overbrace{\mathbf{M}^r d\mathbf{r}}^{\text{Interest rate}} + \underbrace{\mathbf{M}^v \left(d\mathbf{r^a} - d\mathbf{r}\right)}_{\text{Revaluation}}. \tag{51}$$

Recall that the first term represents the effects on consumption of disposable labor income (i.e., labor income minus taxes; $Y^{hh} = wN - \tau$). The second term measures the effects of future expected interest rates and hence primarily captures intertemporal substitution. The third term represents the 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).

While this decomposition applies to both the HANK model and the RANK model—it only requires the existence of a consumption function with inputs $\{d\mathbf{Y}^{hh}, d\mathbf{r^a}, d\mathbf{r}\}$—the relative importance of the channels differs markedly across models. This is shown in Figure 5, which plots the three components from equation (51) following a foreign demand shock. In the RANK model, the response of consumption is driven predominantly by the interest rate channel, with a higher real rate inducing the household to engage in intertemporal substitution out of current consumption. In the HANK model, instead, the consumption response is driven predominantly by the increase in disposable labor income, which passes through to consumption because of the realistically high aggregate MPC.

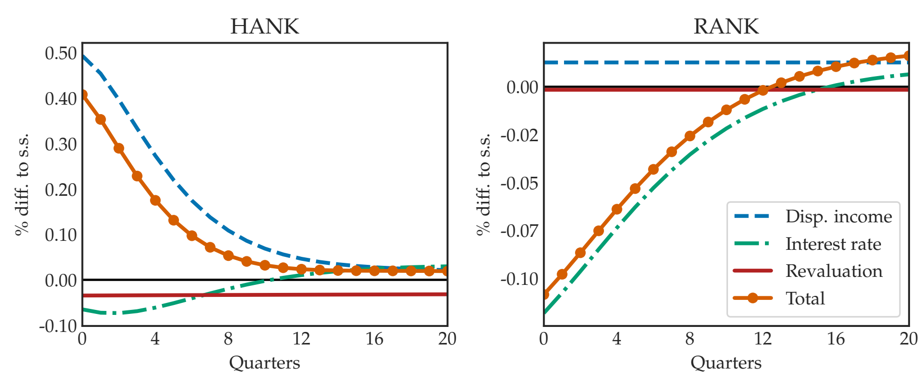

Figure 5: Decomposed consumption response to a foreign demand shock

Note: The figure shows the decomposed response of domestic consumption to a foreign demand shock according to eq. (51). The foreign demand shock is a drop in the foreign discount factor, β_t^*, as given by eq. (50), normalized such that foreign demand increases by 1 pct. on impact.

Note that the intertemporal substitution channel is also operative in the HANK model, with the higher real interest rate exerting a negative effect on aggregate consumption on impact, though this channel is negligible compared to the labor income channel. Likewise, the labor income channel is also present in the RANK model. Its contribution here is small but extremely persistent, reflecting the extensive consumption smoothing characteristic of 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, Moll, and Violante (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 negative effect in the HANK model.[18]

6.3 Consumption of tradeables and non-tradeables

To understand the consumption of tradeables and non-tradeables in more detail, we consider the decomposition from Section 3, repeated here for convenience:

$$dC_{T,t} = \underbrace{-\alpha_T \eta_{T,NT} d\left(\frac{P_{T,t}}{P_t}\right)}_{\text{Substitution effect}} + \underbrace{\alpha_T dC_t}_{\text{Income effect}}, \tag{52}$$

$$dC_{NT,t} = \underbrace{-(1-\alpha_T)\eta_{T,NT} d\left(\frac{P_{NT,t}}{P_t}\right)}_{\text{Substitution effect}} + \underbrace{(1-\alpha_T) dC_t}_{\text{Income effect}}. \tag{53}$$

The substitution effect in these equations refers to changes in the consumption of tradeables and non-tradeables induced by relative price changes. The income (or level) effect represents consumption changes due to movements in the level of total consumption (and may therefore in turn be further decomposed according to equation (51)). Figure 6 shows the decompositions. As discussed above, the shock drives up the relative price of domestic tradeable goods. Thus, the substitution effect exerts a negative impact on consumption of tradeables, and a positive impact on non-tradeables, in both models. The different responses of the two models can therefore be ascribed to the income effect, which coincides with the response of aggregate consumption in Figure 4. In the RANK model, the income effect is small and

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

negative, and is therefore dominated by the substitution effect. In the HANK model, the income effect is large and positive, and therefore overcomes the substitution effect, inducing a positive response of both components of consumption, as seen in the data. The ability of the HANK model to account for Empirical Fact 4 therefore follows from its ability to generate an increase in total consumption via the presence of high-MPC households. Our model can therefore resolve the puzzle encountered by Stockman and Tesar (1995). They observe that, empirically, movements in relative prices (P_T/P_{NT}) are very weakly correlated with relative consumption (C_T/C_{NT}), in contrast with the predictions of a workhorse two-country RBC model. While that model emphasizes the substitution effect, our results indicate that models featuring a strong income effect, such as ours, may be able to account for the weak relationship between relative prices and relative consumption in the data.

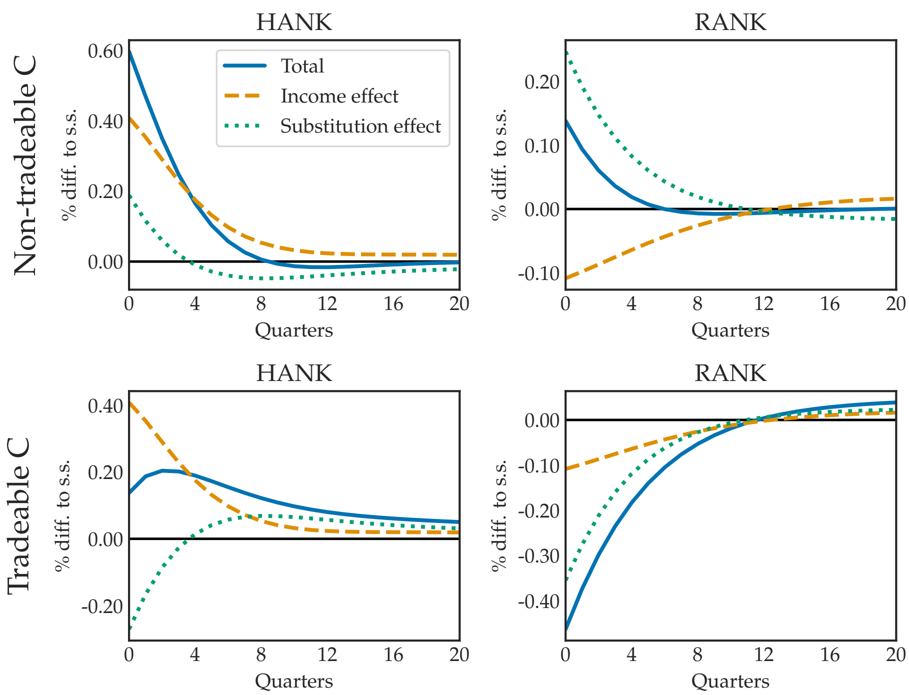

Figure 6: Decomposed response of consumption of tradeables and non-tradeables to a foreign demand shock

Note: The figure shows the decomposition of the responses of tradeable and non-tradeable consumption following a foreign demand shock according to equations (52) and (53). The foreign demand shock is a drop in β_t^* as given by eq. (50), normalized such that foreign demand increases by 1 pct. on impact.

6.4 Correlated shocks

Next, we turn to Empirical Fact 5: The observation that foreign demand shocks account for a large share of business-cycle fluctuations in domestic output and other aggregate variables. We have documented that the RANK model exhibits a negative correlation between foreign and domestic consumption conditional on foreign demand shocks. Yet, the *unconditional* correlation of aggregate consumption is strongly positive in the data. For the 39 small open economies considered in Section 2, the average unconditional correlation between domestic and foreign consumption is 0.34. As a result, foreign demand shocks cannot be a main driver of business-cycle dynamics in RANK models. This echoes the puzzle encountered by Justiniano and Preston (2010), who first document empirically that shocks originating in the U.S. economy explains a large share of the fluctuations in the Canadian economy, and then show that an estimated representative-agent small open economy model fails to account for this fact.[19] In contrast, in our HANK model, foreign demand shocks generate a positive comovement between foreign and domestic consumption, in accordance with the unconditional observation. This suggests that the HANK model is better equipped to account for Empirical Fact 5.

To shed further light on this issue, we consider an experiment in which we allow for the shocks in the model to be correlated across countries. This is a common feature in calibrated open-economy models in the RANK tradition that contributes to positive output and consumption correlations in these models; see, e.g., Backus, Kehoe, and Kydland (1992), Kose and Yi (2006), or Justiniano and Preston (2010). We then ask the question: Which degree of correlation between foreign and domestic demand shocks is required to match the cross-country consumption correlation found in the data? The answer to this question offers a quantification of the amount of endogenous propagation of foreign demand shocks inherent in the model. This provides an indication of the importance of the role played by foreign demand shocks in explaining business cycle fluctuations. Specifically, we allow movements in the average domestic discount factor ($\bar{\beta}_t$) to be correlated with the foreign discount factor (β_t^*) according to:

$$(\bar{\beta}_t - \bar{\beta}) = \lambda(\beta_t^* - \beta^*), \quad \text{for } t = 0, 1, \ldots T, \tag{54}$$

19. Likewise, Adolfson et al. (2007) and Christiano, Trabandt, and Walentin (2011) present estimated representative-agent models for Sweden attributing a very small role to foreign shocks for explaining domestic macroeconomic dynamics.

with λ being a measure of the degree of correlation between demand shocks across countries. We then back out the value of λ required for each of the HANK and RANK models to match the ratio of the cumulative response of aggregate consumption (relative to output) reported in Figure 2 in Section 2 (that is, $\frac{\sum_{t=0}^{8} dC_t}{\sum_{t=0}^{8} dY_t}$), which equals 0.92. This exercise yields $\lambda = 0.19$ for the HANK model, and $\lambda = 0.89$ for the RANK model. The fact that the HANK model requires a low degree of exogenous comovement indicates that this model is able to generate most of the required propagation and amplification of foreign shocks on domestic variables endogenously. Effectively, correlated shocks are barely needed in this model (with $\lambda = 0$, the HANK model produces a cumulative C/Y ratio of 0.67). In contrast, $\lambda = 0.89$ implies that the RANK model requires a high degree of exogenous correlation to match the data, and that the endogenous propagation mechanisms in this model are far from sufficient (with $\lambda = 0$, the implied C/Y ratio is -0.20). This leads us to conclude that the puzzling lack of comovement between domestic and foreign business cycles found by Justiniano and Preston (2010) is confirmed in a RANK model, whereas our HANK model can resolve this puzzle by generating substantial international comovement in aggregate consumption.

6.5 Fixed exchange rate

In the empirical analysis of Section 2, we documented that all of our findings are confirmed irrespective of the exchange rate regime of the domestic country. So far, our theoretical analysis has been carried out under the assumption of a floating exchange rate. We now investigate whether our theoretical conclusions survive in the context of a fixed exchange rate regime.

As discussed above, the responses of the domestic nominal and real interest rates play a crucial role in the RANK model. In particular, the counterfactual decline in aggregate domestic consumption in that model can be attributed to the increase in the real interest rate, which in turns 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.

Under a peg, with $E_t = E_{ss}$ for all t, domestic monetary policy is instead dictated by the UIP condition, and the domestic real interest rate is therefore given by $dr_t = di_t^* - d\pi_{t+1}$. In other words, for the domestic real rate to increase, the foreign nominal interest rate needs to increase, and by more than domestic inflation.

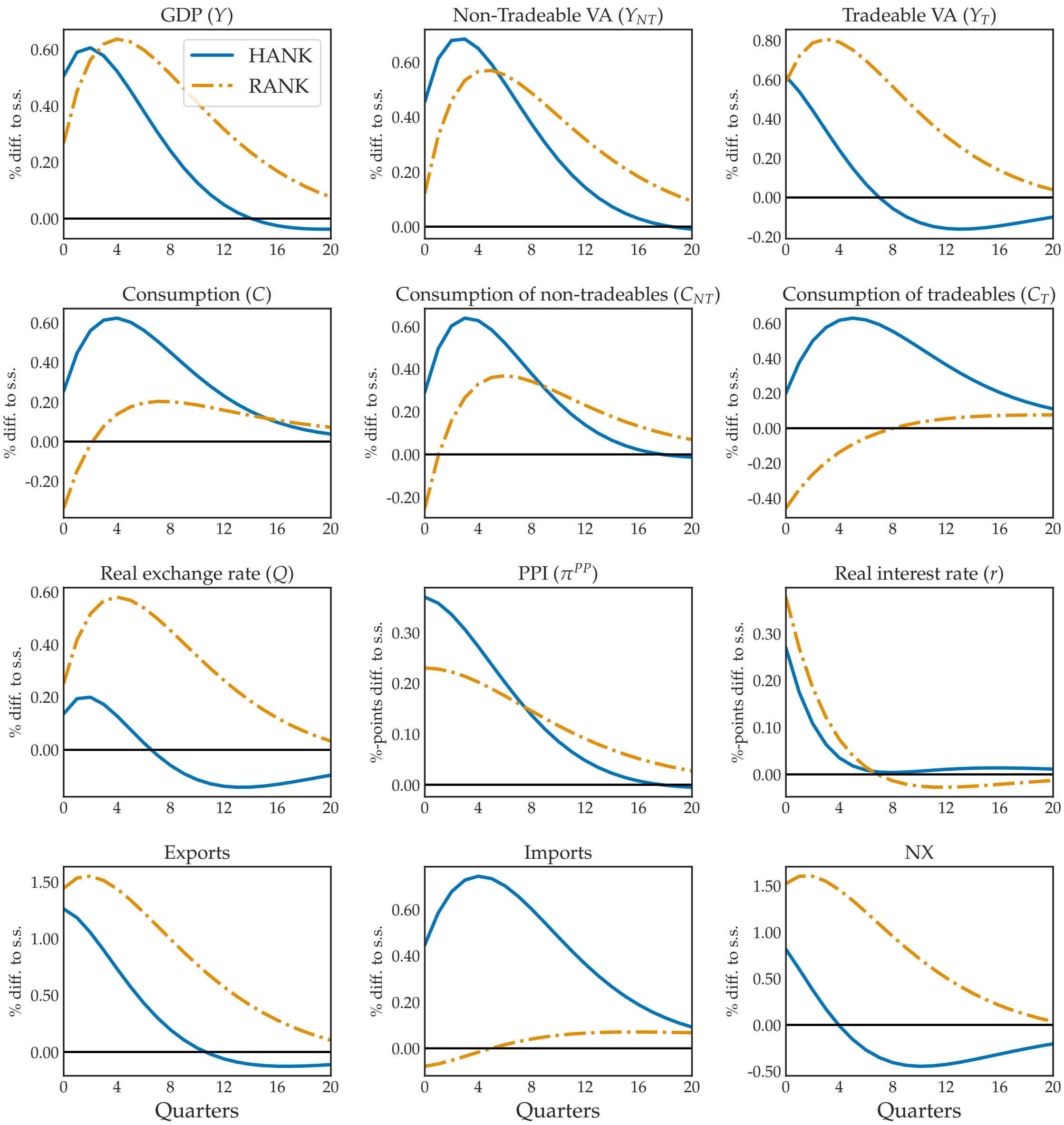

Figure 7: Response of the domestic economy to a foreign demand shock with a fixed exchange rate

Note: See notes to Figure (4). In this figure, the exchange rate is fixed instead of floating.

As shown in Figure 7, this condition is indeed satisfied in both the RANK and the HANK model. This highlights the importance of modelling the foreign demand shock properly: Had we considered only a shift in the foreign demand component C_t^*, keeping the remaining foreign variables fixed, we would have not captured the resulting increase in the foreign nominal interest rate i_t^*. This would have flipped the sign of the response of domestic consumption in the RANK model. In the realistic case where also foreign inflation and the foreign interest rate increase, in line with our empirical findings, our HANK model can replicate the main empirical findings also under a fixed exchange rate.

6.6 Robustness

Our main findings are robust to a range of modelling choices and parameter values. This is documented in Figure 28 and 29 in Appendix C.3. While the presence of input-output linkages in production is realistic, we show that it is not crucial for our results. Removing this feature from both models does not change the fact that the HANK model can account for the empirical facts, while the RANK model cannot.[20] Furthermore, we show that assuming that the domestic central bank responds to consumer prices instead of producer prices does not change our main findings, since foreign inflation also increases, thus driving up the domestic CPI. Likewise, since output increases, adding an output response to the Taylor rule (36) does not change the sign of the interest-rate response. We also assess the robustness of our findings with respect to the values of the trade elasticities in the model, which are discussed at length by Auclert et al. (2021b). Since our findings generally emphasize income over substitution effects, they are not particularly sensitive to realistic variations of these parameter values, as indicated by Figure 29.

7 Challenges for Stabilization Policy

Having developed our quantitative model and shown that it is a useful laboratory to analyze the transmission of foreign shocks, we now turn to policy analysis within this framework. This is a potentially important question for small open economies, as our empirical analysis showed the quantitative importance of foreign demand shocks for domestic fluctuations in economic activity. We first contrast the effects of foreign demand shocks with those of domestic shocks of the same type. We will then show how and why policy options differ depending on the origin of the shock.

20. The input-output structure facilitates a stronger positive sectoral comovement in value-added in the RANK model, but not in consumption, whereas the HANK model produces a large, positive sectoral comovement in both variables even in the absence of input-output linkages, see Figure 28.

7.1 Foreign vs. domestic shocks

The effects of the two shocks are shown in the first two rows of Table 5. We scale the shocks to generate a one percent cumulative drop in aggregate consumption in both cases (column 1), and assume both follow AR(1) processes with a persistence of 0.8. We then report the implied drop in consumption of households working in the tradeable and non-tradeable sectors, respectively (columns 2-3), and the ratio between the two (column 4).[21]

	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	-1.23	-0.90	1.37	-1.00	-0.95	-1.02	0.92
Domestic demand, β	-1.00	-0.69	-1.14	0.60	-1.00	-0.71	-1.13	0.63
Public transfers, T	1.00	0.57	1.19	0.48	1.00	0.64	1.16	0.55
Public spending, G	1.00	0.01	1.44	0.01	1.00	0.23	1.34	0.17
Monetary policy, i	1.00	0.95	1.02	0.93	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.05	0.98	1.07
Fiscal devaluation	-	-	-	-	1.00	1.03	0.99	1.04

Table 5: Cumulative effects of demand shocks and policy instruments.

Note: Both demand shocks and all policy instruments follow AR(1) processes with a persistence of 0.80. 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 tradeable and non-tradeable sectors, respectively. The fiscal devaluation combines an increased VAT with a reduced payroll tax. Details are in Appendix C.5.

In the first row, we see that the consumption response to a foreign demand shock under a floating exchange rate is rather symmetric across the two sectors, although households in the tradeable sector are hit hardest. In the second row, we report the effects of a *domestic* demand shock. Here we instead see that the households in the tradeable sector are hit substantially less. The explanation is twofold: First, the tradeable sector is less sensitive to domestic demand and is therefore affected less by the domestic shock in itself. Second, the fall in domestic demand causes a decline in domestic inflation, which leads to a depreciation of the real exchange rate, and

21. A full analysis of optimal policy, including e.g. the disutility of labor and additional distributional issues, is beyond the scope of this paper. For papers studying optimal monetary and/or fiscal policy in closed-economy HANK models, see, e.g., Acharya, Challe, and Dogra (2020), Le Grand, Martin-Baillon, and Ragot (2021), or Nuno and Thomas (2021).

therefore an increase in foreign demand for domestic tradeables. In sum, after-tax labor income falls much less for households in the tradeable sector.[22] They therefore reduce their consumption by less. Under a fixed exchange rate (columns 5-8), these findings are largely confirmed: Households in the two sectors are hit almost symmetrically by a foreign demand shock, whereas domestic demand shocks hit households in the non-tradeable sector much harder. This raises the question whether policies targeted at stabilizing aggregate consumption also stabilize consumption of households in each sector.

7.2 Policy instruments with a floating exchange rate

Under a floating exchange rate, we consider three traditional policy instruments:[23]

1. **Public transfers**, T_t. Distributed equally.
2. **Public spending**, G_t. With 80 percent directed to the tradeable sector and 20 percent directed to the non-tradeable sector, as in Section 5.3.
3. **Monetary policy rate**, i_t. Controlled through ϵ_t^r in the Taylor rule (36).

We assume all policy instruments follow AR(1) processes with a persistence of 0.8, and scale them to fully stabilize the cumulative response of aggregate consumption. The results are reported in rows 3 to 5 of Table 5.

We first observe that both public transfers (row 3) and public spending (row 4) primarily affect consumption of households working in the non-tradeables sector. For G_t this reflects the sectoral distribution of the spending, while for T_t the explanation is fundamentally the same as for the domestic demand shock. For public transfers, the ratio of the consumption response in the two sectors is rather close to the ratio induced by the domestic demand shock. Transfers can thus simultaneously stabilize aggregate consumption and consumption of the households in both sectors in response to such shocks.

22. This is documented in Appendix C.6, where we report a table corresponding to Table 5, but focused on the responses of labor income instead of consumption.

23. Public transfers targeted to households in a specific sector is rarely seen in practice, though fully possible in theory. Public spending is, as discussed in Section 5, almost always and everywhere directed much more towards the non-tradeable sector. We discuss the effects of more targeted policies in Appendix C.7, where we also show that our results are robust to varying the persistence of the shocks and policy instruments.

Monetary policy (row 5) has a more symmetric effect on consumption of the households in both sectors. This makes it less appropriate for stabilizing domestic demand shocks, and more appropriate for stabilizing foreign demand shocks. The symmetric effect is due to the ability of monetary policy to stabilize the terms of trade. As seen from Figure 8, expansionary monetary policy generates a *depreciation* of the real exchange rate and a rise in the terms of trade, which through expenditure switching stimulates foreign demand for domestically produced tradeables. Additionally, domestic demand is also stimulated, partly due to income and multiplier effects of higher foreign demand, and partly because of intertemporal substitution effects. As a result, income and consumption in the two sectors increase almost in tandem. An increase in government spending or transfers—while exerting a stimulative impact on domestic demand—appreciates the real exchange rate (and the terms of trade), thus reinforcing the appreciation induced by the negative foreign demand shock; not dampening it.[24] This explains why fiscal policy does not provide sufficient stimulus to the tradeables sector.

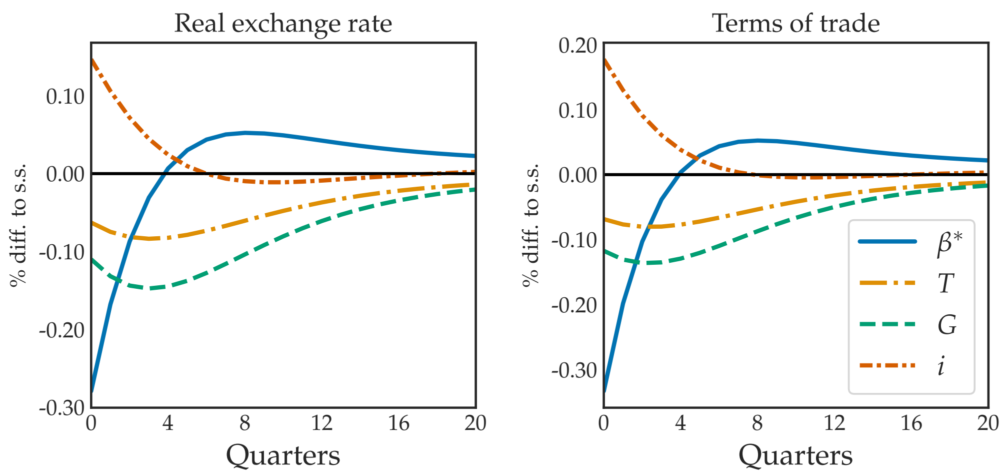

Figure 8: International relative price dynamics under a floating exchange rate

Note: The foreign demand shock, β_t^*, and all policy instruments follow AR(1) processes with a persistence of 0.80. The foreign demand shock is scaled to generate a cumulative 1% decrease in aggregate consumption, 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 $S_t = P_{F,t} / (P_{H,t}^* E_t)$.

24. The extent to which the loss in international competitiveness dampens the activity in the domestic tradeables sector depends on the amount of expenditure switching in the foreign economy. Auclert et al. (2021b) argue that this channel is weak in the short run. In this case, we have found that fiscal policy exerts a somewhat more symmetric effect on income across domestic sectors, but still significantly less so than monetary policy.

7.3 Policy instruments with a fixed exchange rate

Our results carry over to the case of a currency peg: We again find that public transfers and public spending are well-suited to stabilizing domestic demand shocks, but not foreign demand shocks, because they stimulate spending of households in the tradeables sector too little. This is shown in rows 3-4 and columns 5-8 of Table 5. This is also reflected in the impulse responses reported in Figure 9, which show that public transfers, T_t, and public spending, G_t, fail to stabilize the movements in the real exchange rate and the terms of trade arising from the foreign shock.[25]

The absence of an independent monetary policy under a fixed exchange rate therefore leaves domestic policymakers without any conventional instruments well-suited to stabilizing foreign demand shocks. As shown in the sixth row of Table 5, a nominal exchange rate devaluation is able to stabilize consumption in both sectors at once, effectively working in the same way as a monetary expansion under a floating rate. However, these results emerge under the likely unrealistic 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 might 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, Gopinath, and Itskhoki (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 tax into our baseline HANK model.[26] We then conduct a fiscal devaluation scaled to generate a cumulative increase in aggregate consumption of 1 percent under the assumption of a fixed exchange rate. The results are reported in the bottom row of Table 5. It shows that a fiscal devaluation is successful at stimulating both domestic sectors at once, with the ratio of the responses of consumption of households in the two sectors not too far from unity.

These results can be explained as follows: A fiscal devaluation entails a reduction

25. Under a fixed exchange rate, the real exchange rate is too smooth compared to the case of a floating exchange rate, as discussed by Gali and Monacelli (2005).

26. We describe the implementation in detail in Appendix C.5.

in payroll taxes, reducing the domestic cost of production. At the same time, the associated increase in the 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. Taken together, this leads to expenditure switching from foreign to domestic tradeables by domestic as well as foreign consumers.

The left panel of Figure 9 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, 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, $S_t = \frac{P_{F,t}(1-\tau_t^v)}{P_{H,t}^* E_t}$, 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 tradeables cheaper relative to foreign tradeables. In addition, the price of domestic non-tradeables relative to tradeables declines, thus stimulating economic activity also in the former sector. The bottom line, therefore, is that fiscal devaluations are relatively successful at stabilizing foreign demand shocks in countries with a fixed exchange rate or in a currency union.

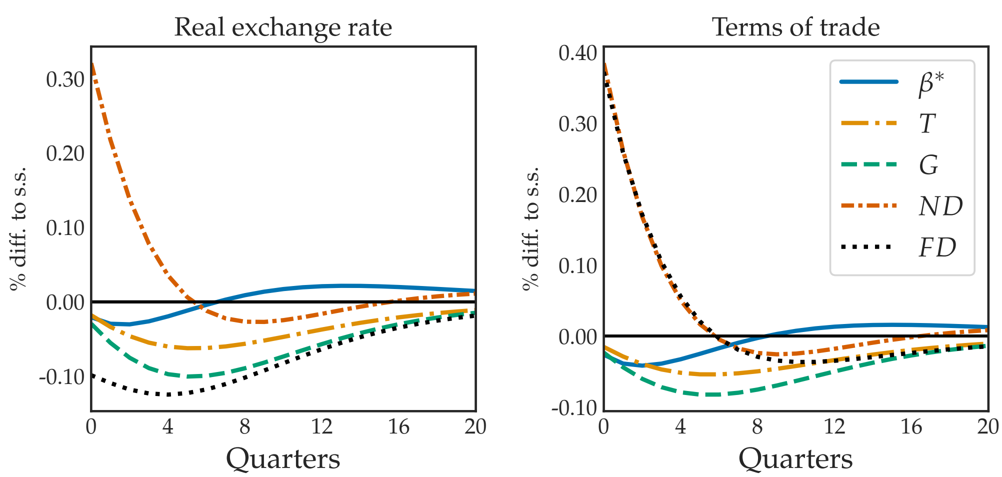

Figure 9: International relative price dynamics under a fixed exchange rate

Note: The foreign demand shock, β_t^*, and all policy instruments follow AR(1) processes with a persistence of 0.80. The foreign demand shock is scaled to generate a cumulative 1% decrease in aggregate consumption, 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 C.5. The *real exchange rate* is $Q_t = E_t P_t^* / P_t$. The *terms of trade* is $S_t = \frac{P_{F,t}(1-\tau_t^v)}{P_{H,t}^* E_t}$.

8 Concluding remarks

In this paper, we have proposed a HANK model of a small open economy featuring a distinction between tradeable and non-tradeable goods, and cross-country input-output linkages in production. We have shown that the model with a realistic average MPC can match a series of central empirical facts regarding the domestic response to a foreign demand shock. The key insight is that a strong direct income effect dominates both inter- and intratemporal substitution effects. Hereby the model can explain the observed positive response of not just aggregate consumption, but also the consumption of tradeable goods, and therefore imports. In the absence of high-MPC households, the increasing real interest rate would bring aggregate consumption down, while movements in relative prices would imply a further negative effect on the consumption of tradeable goods.

First, our findings have strong implications for the quantitative importance of foreign demand shocks in accounting for business-cycle fluctuations in small open economies. Our model implies that foreign and domestic consumption are strongly positively correlated, conditional on a foreign demand shock. Since the unconditional correlation of foreign and domestic consumption is also strongly positive, this makes it more likely than previously believed that foreign demand shocks are important drivers of the observed business-cycle fluctuations.

Second, 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 tradeable sector. Monetary policy therefore plays a crucial role because of its ability to depreciate the terms of trade and stimulate both the tradeable and non-tradeable sector. Clearly, these results constitute an important challenge for countries with a fixed exchange rate or in a monetary union, who cannot set an independent monetary policy. We show that 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 may therefore be a good "substitute" for monetary policy.

Our findings call for further research in a number of directions. As a next step, it would be interesting to consider a full palette of shocks to both demand and supply, potentially correlated across regions and groups of countries. An obvious candidate would be technology shocks, which are widely studied in the existing open-economy literature. This would make it possible to derive further results on how our model affects the international transmission of business cycles, and the relative importance of various shocks. Capital accumulation and financial linkages would represent important dimensions to account for in this regard. Moreover, 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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Appendix

A Empirical Appendix

A.1 Foreign variables

A.1.1 Definition of foreign variables

For each small open economy i, we define the foreign variable $Z^*_{i,t}$ as a weighted average of the gross domestic product (GDP) of its trading partners:

$$Z^*_{i,t} = \sum_{i=1}^{N} w_{i,j} Z_{j,t}, \quad \text{where } \sum_{i=1}^{N} w_{i,j} = 1 \text{ for all } i = 1, \ldots, N, \tag{55}$$

for $t = 1, \ldots, T$, weights $w_{i,j} \in [0, 1]$ measuring how much country i exports to country j, and some variable Z_t. For instance, when $Z_t = Y_t$, we interpret $Y^*_{i,t}$ as a measure of demand in the foreign economy. At this stage, we do not take a stand on the type of shock driving the change in foreign GDP, but as will become clear below, our findings support the interpretation of the shock as being demand-driven in nature.

Our empirical design bears resemblance to a "shift-share" research design. Though one can think of our design in this framework, there are a few differences. First of all, we do not have a distinction between regions and sectors as in traditional shift-share (see, e.g., Adão, Kolesár, and Morales, 2019). Second, identification is not necessarily based on the variation in the weights in (55) as in a shift-share design. Instead, eq. (55) is simply used to construct a foreign economy. This should be clear from the fact that we also consider a version with fixed weights, so that $Y^*_{i,t} = Y^*_t$, which may be interpreted as "the world economy". As documented in Appendix A.7.2, this specification yields very similar results.

A.1.2 Construction of foreign variables

Note that the panel is not balanced, i.e. all variables are not available for the full time period for all countries. To deal with this, we do as follows: For each country i and foreign variable $Z^*_{i,t}$, we begin constructing $Z^*_{i,t}$ in the first period where $Z_{j,t}$ is available for at least 5 of country i's trading partners. We then construct $Z^*_{i,t}$ using weights for these trading partners normalized to sum to one. The trading partners (and weights) are kept constant over the whole sample.

This approach balances three concerns: Creating as long a time series as possible, creating the index based on as many trading partners as possible, and having a fixed set of trading partners over the whole sample. For most countries, the index is based on significantly more than 5 trading partners.

As an example, consider constructing $Y^*_{i,t}$ for a country i with $Y_{i,t}$ being available starting in 1960Q1. If $Y_{j,t}$ is available for at least 5 countries in 1960Q1, we construct $Y^*_{i,t}$ based on these countries. If less than 5 are available, we begin constructing $Y^*_{i,t}$ in the first period where at least 5 countries are available.

A.1.3 Weights

To estimate the effects of shocks to foreign variables, we construct the empirical weight matrix,

$$W = \begin{pmatrix} 0 & w_{1,2} & w_{1,3} & \dots & w_{1,N} \\ w_{2,1} & 0 & w_{2,3} & \dots & w_{2,N} \\ w_{3,1} & w_{3,2} & 0 & \dots & w_{3,N} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{N,1} & w_{N,2} & w_{N,3} & \dots & 0 \end{pmatrix}.$$

To do this, we use annual bilateral trade data for 1995-2018 from the OECD. $w_{i,j}$ is then calculated as how much country i exports to country j as a fraction of country i's total exports. This is calculated as an average over the time period.

A.2 Countries

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

Table 6: Countries

A.3 Variable description

Variable	Description	Transformation
Y	GDP	Log
C	Consumption	Log
I	Investment	Log
X	Exports	Log
M	Imports	Log
Y_T	Tradeable VA	Log
Y_{NT}	Non-tradeable VA	Log
C_T	Tradeable consumption	Log
C_{NT}	Non-tradeable consumption	Log
Q	Real effective exchange rate	Log
P	Consumer price index	—
i	Short nominal interest rate	—
NX	Net exports	$NX = X - M$
π	Inflation	$\pi = P/P_{-4}$
r	Short real interest rate	$r = (1+i)/(1+\pi_{+4}) - 1$

Table 7: Variable description

Note: All data is taken from the OECD database and is quarterly. All variables except Q, P, i, π, and r are chained volume estimates and are seasonally adjusted. Production of tradeables and non-tradeables is measured as the production of manufacturing and services. Consumption of tradeables and non-tradeables is measured as the consumption of non-durables and services (see Stockman and Tesar, 1995). All variables are detrended by a country-specific regression on $(1, t, t^2, t^3, t^4)$ after they have been transformed, except for NX, which is computed directly using X and M after they have been transformed and detrended.

A.4 Cumulative multipliers

To compare IRFs with the theoretical model, we compute cumulative multipliers (Ramey, 2016). To do this, we estimate the following regression,

$$\sum_{h=0}^{S-1} Z_{i,t+h} = \beta \sum_{h=0}^{S-1} Y^*_{i,t+h} + \sum_{j=1}^{p} \gamma_j Z_{i,t-j} + \sum_{j=1}^{p} \delta_j Y^*_{i,t-j} + X_t + \varepsilon_{i,t}, \tag{56}$$

for $S = 8$ (i.e. a 2 year horizon). β then measures the cumulative multiplier of $Z_{i,t}$ with respect to changes in $Y^*_{i,t}$ over a 2-year horizon. The cumulative multipliers are given in Table 8.

Y	C	I	X	M
0.85 (0.40,1.30)	0.78 (0.27,1.29)	2.49 (0.83,4.15)	2.51 (1.78,3.23)	1.81 (0.91,2.72)
NX	Y_T	Y_{NT}	C_T	C_{NT}
0.61 ($-$0.23,1.46)	1.11 (0.61,1.61)	0.74 (0.31,1.17)	0.80 (0.30,1.30)	0.91 (0.33,1.50)

Table 8: Cumulative multipliers

Note: Cumulative multipliers of given variables in response to a change in Y^* over $S = 8$ quarters. Estimated as β in eq. (56). Parentheses indicate 95 percent confidence intervals. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

A.5 Investment response

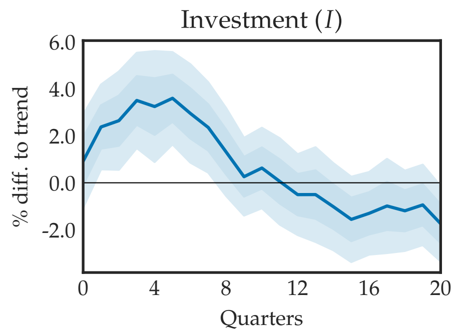


Figure 10: LP results for investment

Note: See Figure 2

A.6 Variance decompositions with Local Projections

We estimate the FEVD using the augmented R^2 method from Gorodnichenko and Lee (2020). They suggest to estimate the FEVD of $Z_{i,t+s}$ explained by $(Y^*_{i,t+h})^s_{h=0}$ by the partial R^2 of $(Y^*_{i,t}, \dots, Y^*_{i,t+s})$ in the following regression:

$$Z_{i,t+s} = \sum_{j=1}^{p} \gamma'_{s,j} Z_{i,t-j} + \sum_{j=1}^{p} \delta'_{s,j} Y^*_{i,t-j} + \sum_{j=0}^{s} \rho_{s,j} Y^*_{i,t+j} + F'_{t,s} + f_{i,t,s}. \tag{57}$$

Because we are using a pooled dataset, there is a problem with this approach. To see this, note that β has no subscript i in the LP regression in eq. (1). Similarly, there is no subscript i on $\rho_{s,j}$ in eq. (57). This is not an issue, even if β is heterogeneous across countries: We simply interpret $\hat{\beta}$ as estimating an average of the country-specific β's.[27] When estimating the FEVD, however, this can be an issue. Then, the R^2 estimator of the FEVD can be severely downwards biased. This is because we are computing the R^2 based on the average $\hat{\beta}$ instead of the country-specific β, and thus under-estimating how much of $Z_{i,t}$ is explained by $Y^*_{i,t}$ for each country.

As an example, consider $Z_{i,t}$ and $Y^*_{i,t}$ being perfectly correlated. If β varies across countries, R^2 can be estimated well below 1. We consider an example of this in Figure 11. Here, we simulate panel data according to $Y_{i,t} = \alpha_i + \beta_i Y^*_{i,t}$ for $i = 1, \ldots, 5$ countries with $t = 1, \ldots, 100$ observations for each. $Y_{i,t} \sim \mathcal{N}(0,1)$, $\alpha_i \sim \mathcal{U}(-3,3)$, and $\beta_i \in \{0.1, 0.3, 0.5, 0.7, 0.9\}$. The black line is the estimated (pooled) regression line for $Y_{i,t} = \alpha + \beta Y^*_{i,t} + \varepsilon_{i,t}$. Then, the average β is estimated correctly ($\hat{\beta} = 0.497$ versus average β of 0.5). However, R^2 is estimated as 0.069, even though the R^2 for a regression for each country is 1. The red lines are regression lines estimated individually for each country (which could equivalently be implemented with country dummies). Here, the country-specific R^2 is correctly estimated as 1. This motivates the inclusion of dummies when estimating the FEVD.

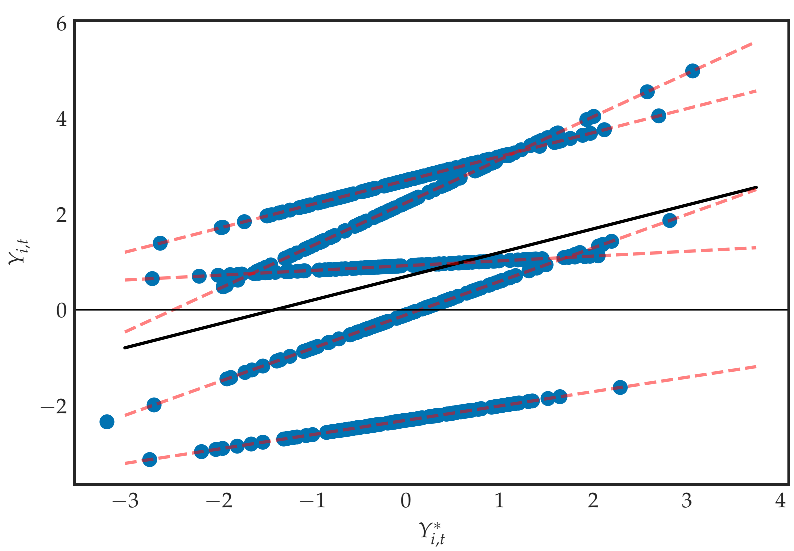


Figure 11: Example of bias in FEVD estimator

Note: The figure shows how despite there being no error term in the DGP and the DGP being linear, the regression fit is good in terms of estimating the average slope across countries without bias, but poor in terms of estimating R^2 due to heterogeneity in coefficients across countries. This motivates the use of dummies when estimating the FEVD, and shows why it is not necessary when estimating IRFs.

For this reason, we decompose the overall β in eq. (1) (and $\rho_{s,j}$ in eq. (57)) into the

27. This holds if β_i is unrelated to the other terms in the model, see the discussion in Sun and Shapiro (2022).

different countries. To be specific, we replace eq. (57) by

$$Z_{i,t+s} = \sum_{j=1}^{p} \gamma'_{s,j} Z_{i,t-j} + \sum_{j=1}^{p} \delta'_{s,j} Y^*_{i,t-j} + \sum_{j=0}^{s} \rho_{s,j} Y^*_{i,t+j} + \sum_{j=0}^{s} \sum_{i=2}^{N} \rho_{s,j,i} Y^*_{i,t+j} D_i + F'_{t,s} + f_{i,t,s}, \tag{58}$$

where D_i is a dummy for country i. We then estimate the FEVD as the partial R^2 of $(Y^*_{i,t}, \ldots, Y^*_{i,t+s})$. The estimator is implemented by saving the sum of squared residuals from eq. (57) ($\text{SSR}^f_s = \sum_{i,t} \hat{f}^2_{i,t,s}$), and then saving the SSR from the regression

$$Z_{i,t+s} = \sum_{j=1}^{p} \tilde{\gamma}'_{s,j} Z_{i,t-j} + \sum_{j=1}^{p} \tilde{\delta}'_{s,j} Y^*_{i,t-j} + X_{t,s} + r_{i,t,s},$$

as SSR^r_s. We then compute the estimated of the variance square as the partial R^2:

$$\text{FEVD}_s = 1 - \frac{\text{SSR}^f_s}{\text{SSR}^r_s}.$$

While the FEVD estimator is *downward* biased in the presence of measurement error, there might be some small-sample bias in the other direction in practice. This could be an issue when including country dummies in the regression, since the number of regressors then grows quickly in h. For this reason, we adjust the FEVD for small-sample bias using a VAR-based bootstrap, as suggested by Gorodnichenko and Lee (2020).

A.7 Empirical robustness checks

A.7.1 Structural vector autoregression We seek to corroborate our main results using a structural vector autoregression (SVAR) with sign restrictions. Specifically, we use the sign restrictions to identify foreign demand shocks from other shocks. To do this, we estimate a VAR model with variable vector $Z_{i,t} = (X_{i,t}, Y^*_{i,t}, \pi^*_{i,t}, r^*_{i,t})'$, where $X_{i,t}$ is a variable for the small open economy $i = 1, \ldots, N$. The four structural shocks are: A domestic shock, a foreign demand shock, a foreign supply shock, and a foreign monetary policy shock. The imposed sign restrictions are all standard, and are shown in Table 9.

	$X_{i,t}$	$Y^*_{i,t}$	$\pi^*_{i,t}$	$r^*_{i,t}$
Domestic shock	$*$	0	0	0
Foreign demand shock	$*$	$+$	$+$	$+$
Foreign supply shock	$*$	$+$	$-$	$-$
Foreign monetary policy shock	$*$	$+$	$+$	$-$

Table 9: SVAR sign restrictions

Note:"$*$" indicates no restriction.

We use the Bayesian approach and code from Arias, Rubio-Ramírez, and Waggoner (2018) to impose the sign restrictions. We report the IRFs for the same set of variables considered in Section 2, and use a panel data set as in our local projections. The IRFs are shown in Figure 12. As described in the main text, our main findings are generally confirmed.

For the same reason as in the local projections, we need to take into account heterogeneity across countries when computing the FEVD. Thus, we take the simplest approach of estimating the FEVD separately for each country. We then report the average FEVD across countries and their quantiles in Table 10.

h	Y	C	X	M	NX
4	0.13 (0.03,0.25)	0.09 (0.03,0.15)	0.18 (0.05,0.32)	0.20 (0.06,0.38)	0.09 (0.05,0.16)
8	0.14 (0.05,0.21)	0.13 (0.04,0.23)	0.21 (0.09,0.34)	0.21 (0.10,0.36)	0.13 (0.07,0.23)
∞	0.18 (0.11,0.26)	0.18 (0.08,0.29)	0.23 (0.12,0.35)	0.23 (0.14,0.38)	0.18 (0.10,0.29)

Table 10: FEVD of foreign demand shocks using SVAR

Note: $h \to \infty$ refers to $h = 39$. Parentheses indicate 95% quantiles across countries.

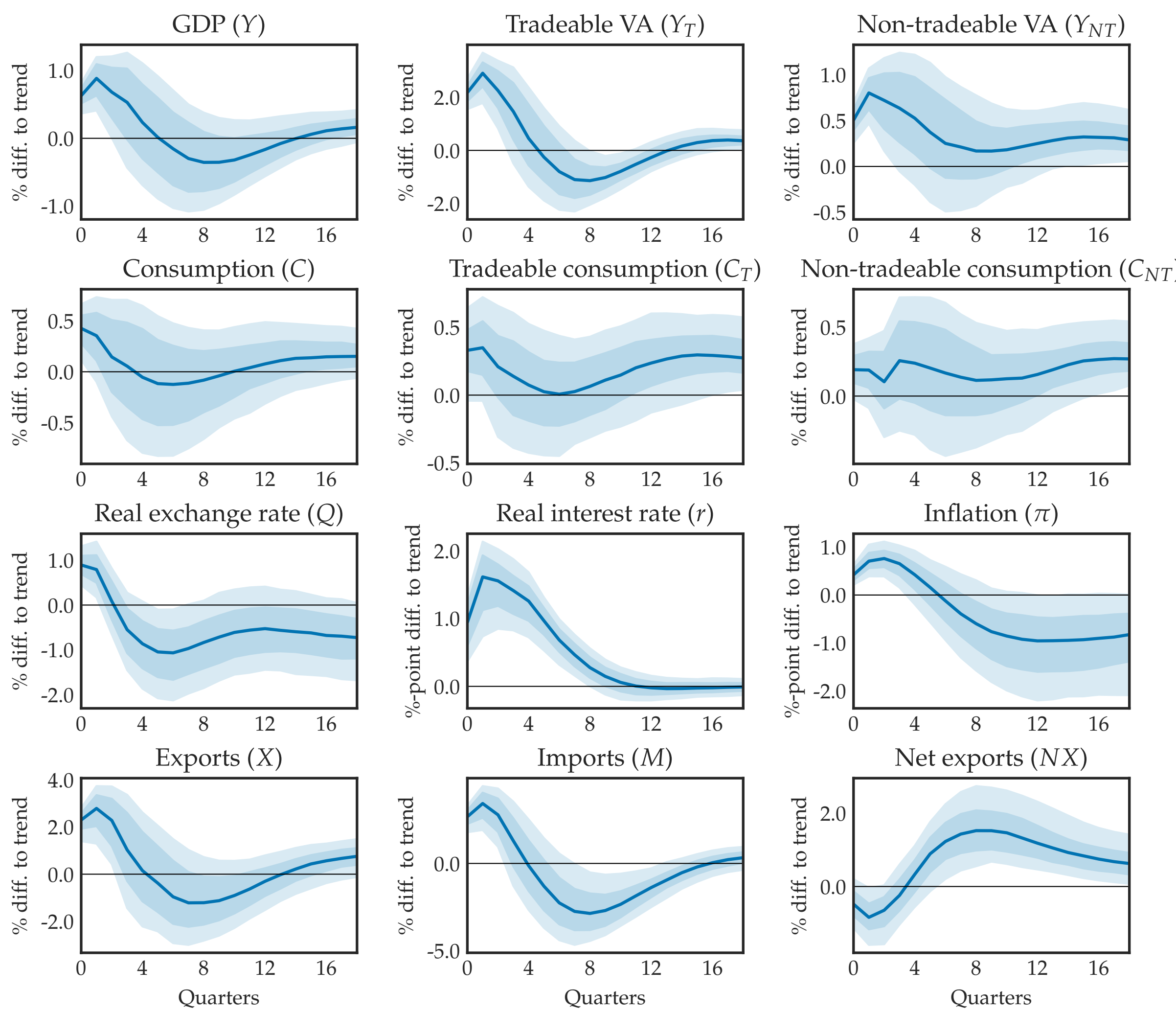


Figure 12: SVAR IRFs

Note: The figure plots SVAR-based IRFs. The shock is the foreign demand shock. The shaded areas indicate 95 and 68 pct. credible sets.

A.7.2 Changes to variables

HP filter. We filter the data using an HP filter (Hodrick and Prescott, 1997) instead of a regression on time trends. We use the standard quarterly smoothing parameter of $\lambda = 1600$. The IRFs are shown in Figure 13.

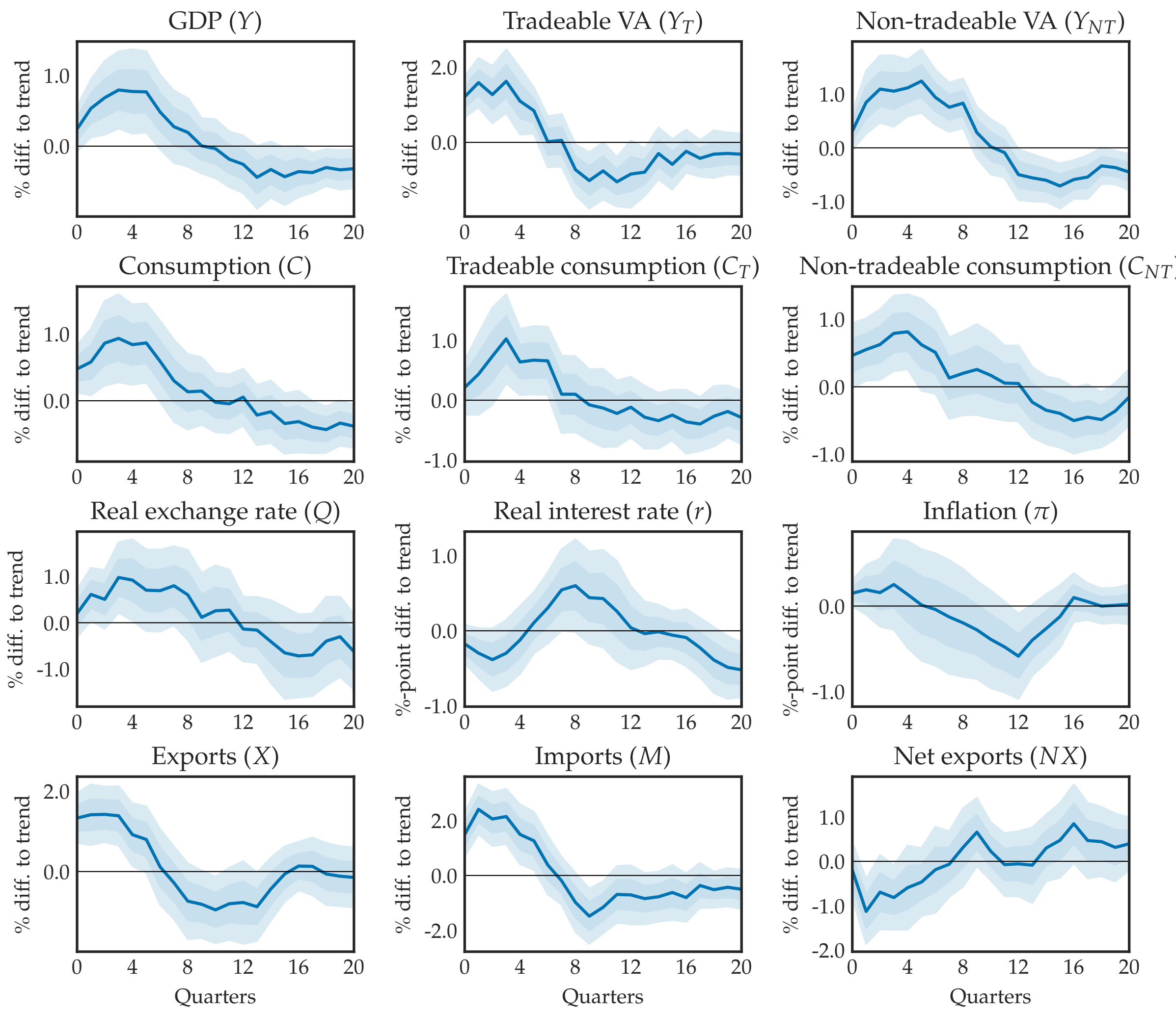


Figure 13: LP results with HP filter

Note: See Figure 2.

Hamilton filter. We filter the data using an Hamilton filter (Hamilton, 2018) instead of a regression on time trends. We use the suggested parameters of $h = 8$ and $p = 4$. The IRFs are shown in Figure 14.

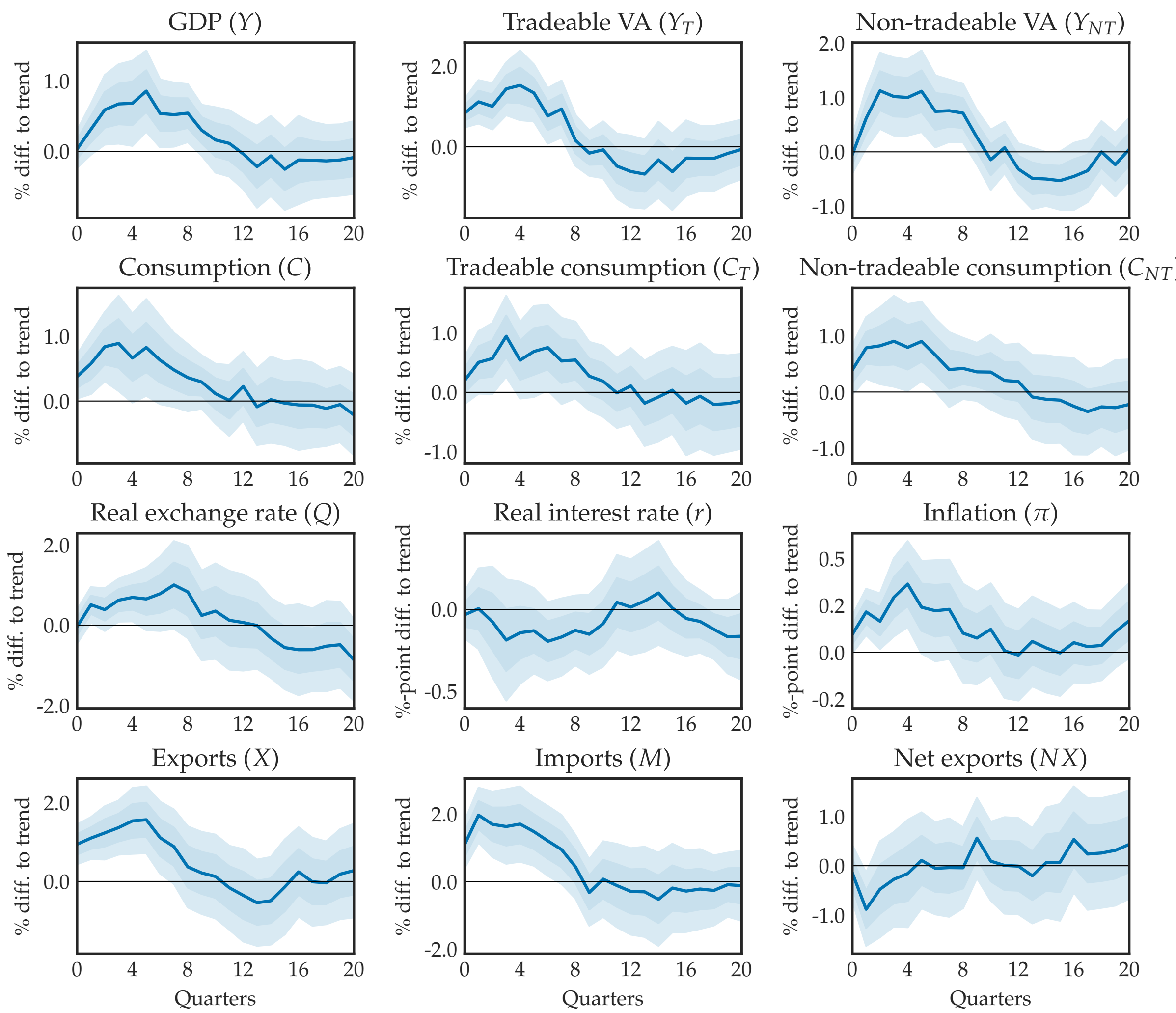


Figure 14: LP results with Hamilton filter

Note: See Figure 2.

Import shock. We consider a shock to $M^*_{i,t}$ instead of $Y^*_{i,t}$. The IRFs are shown in Figure 15.

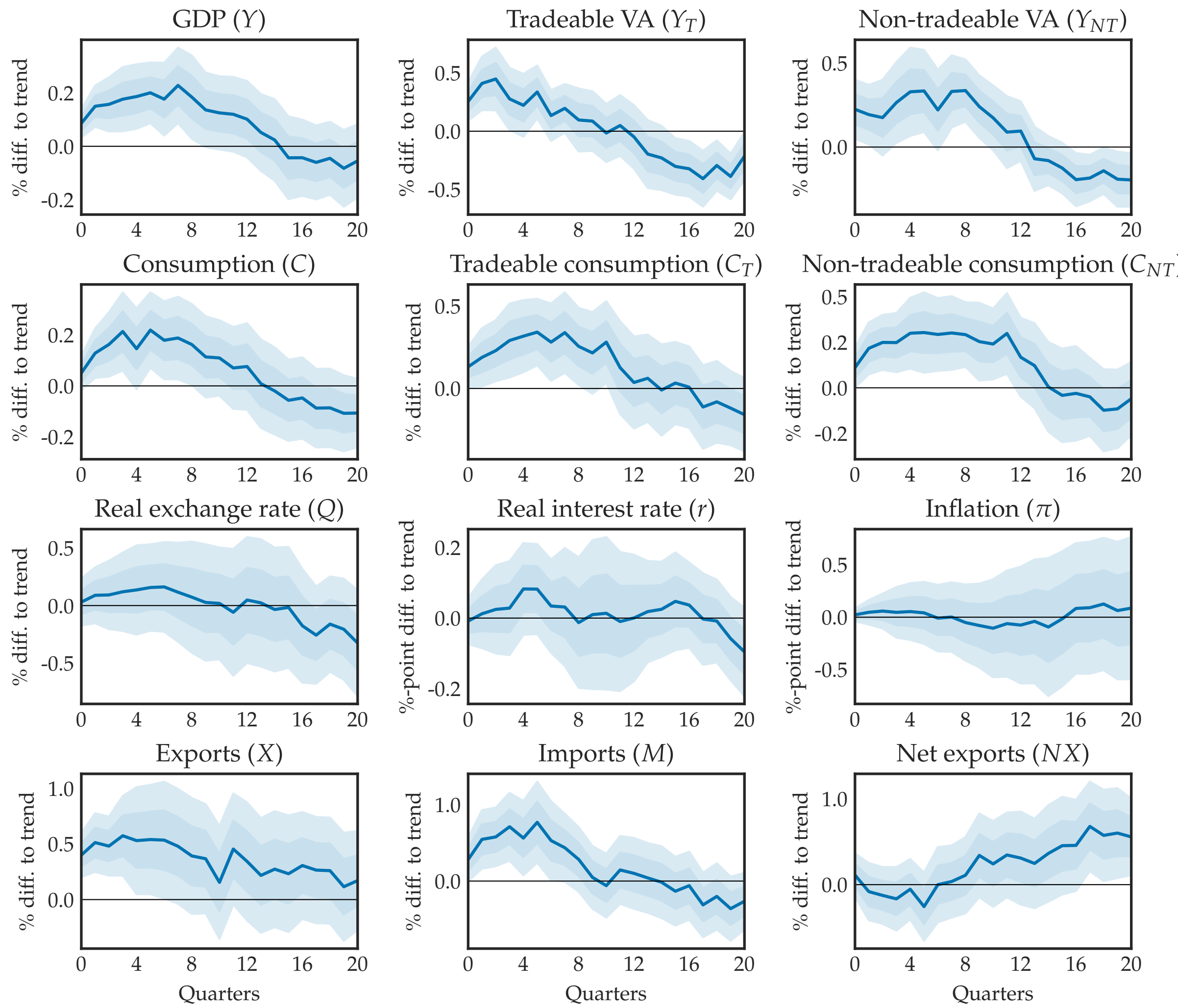


Figure 15: LP results with foreign import shock

Note: See Figure 2. The shock is to $M^*_{i,t}$.

Only large economies on right-hand side. We consider constructing $Y^*_{i,t}$ using only large economies. For the list of large economies, see Table 6. The IRFs are shown in Figure 16.

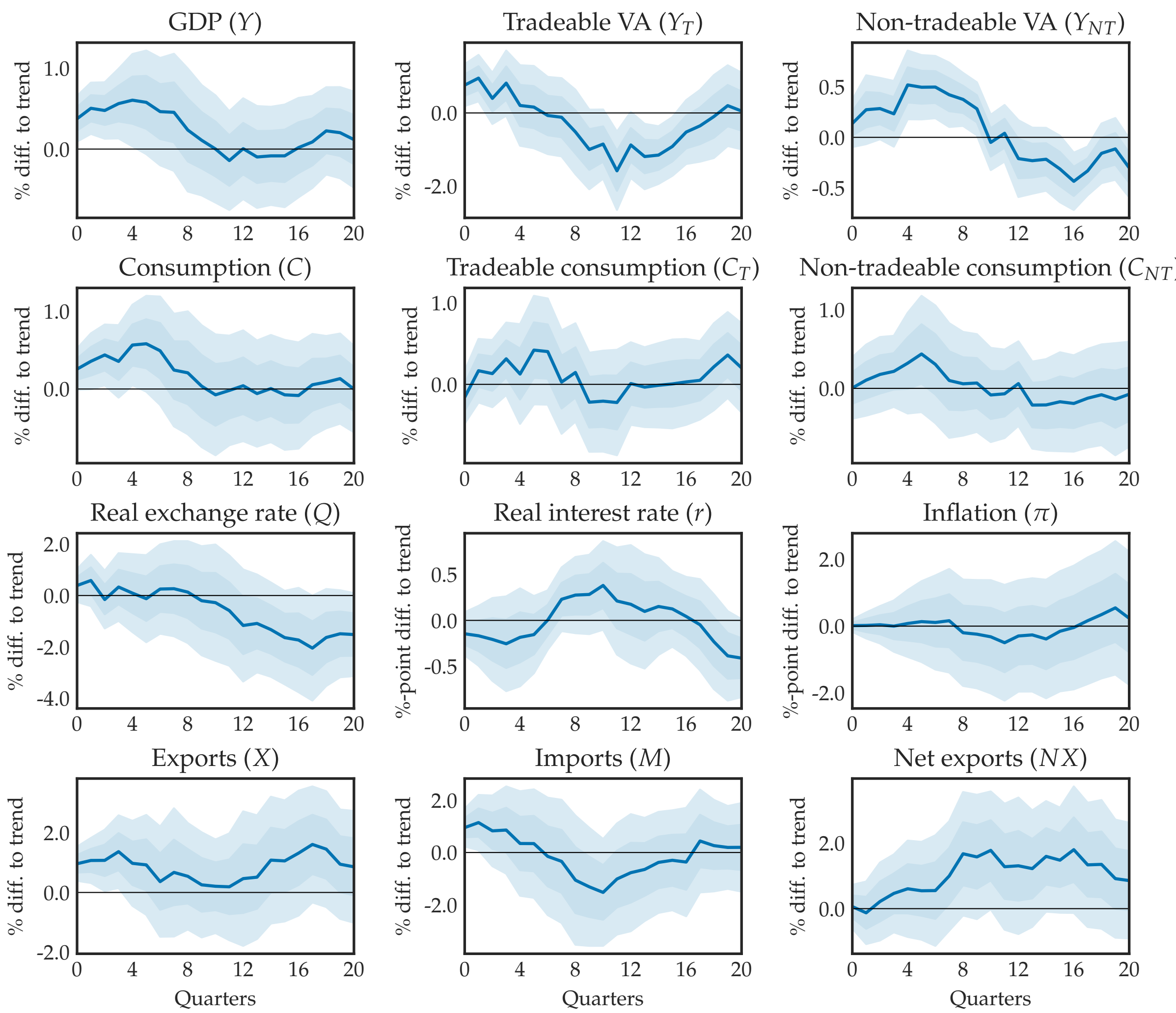


Figure 16: LP results with only large economies used in the construction of $Y^*_{i,t}$.

Note: See Figure 2.

Common large economy. We consider constructing $Y^*_{i,t}$ with a common weight matrix for all countries, such that $Y^*_{i,t} = Y^*_t$. In this case, we do not base the weights on trade data, but instead of the countries' fraction of total (world) GDP. The IRFs are shown in Figure 16.

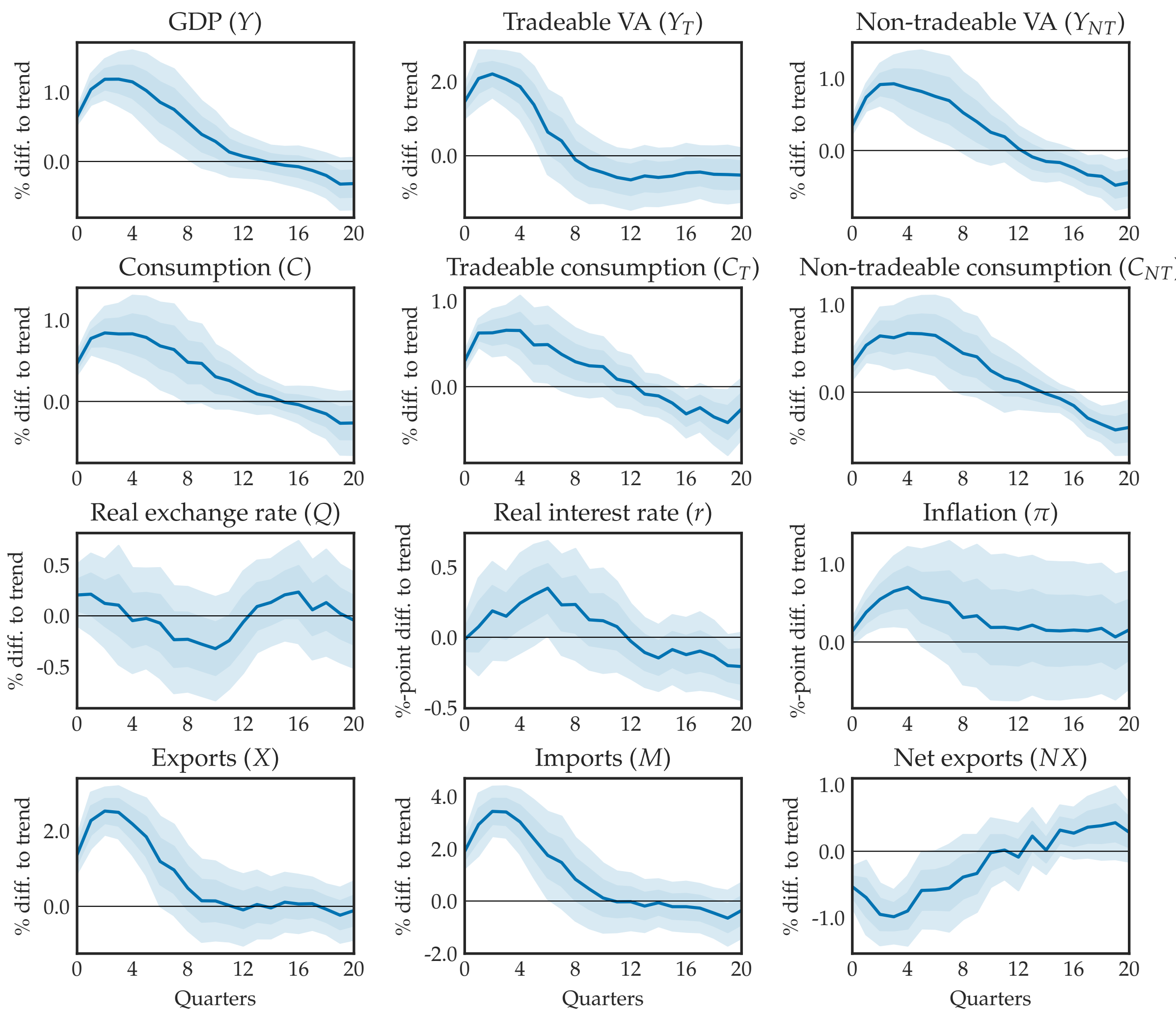


Figure 17: LP results with $Y^*_{i,t} = Y^*_t$ and no time fixed effects.

Note: See Figure 2.

A.7.3 Changes to LP specification

More lags. We use $p = 4$ lags instead of $p = 2$. The IRFs are shown in Figure 18.

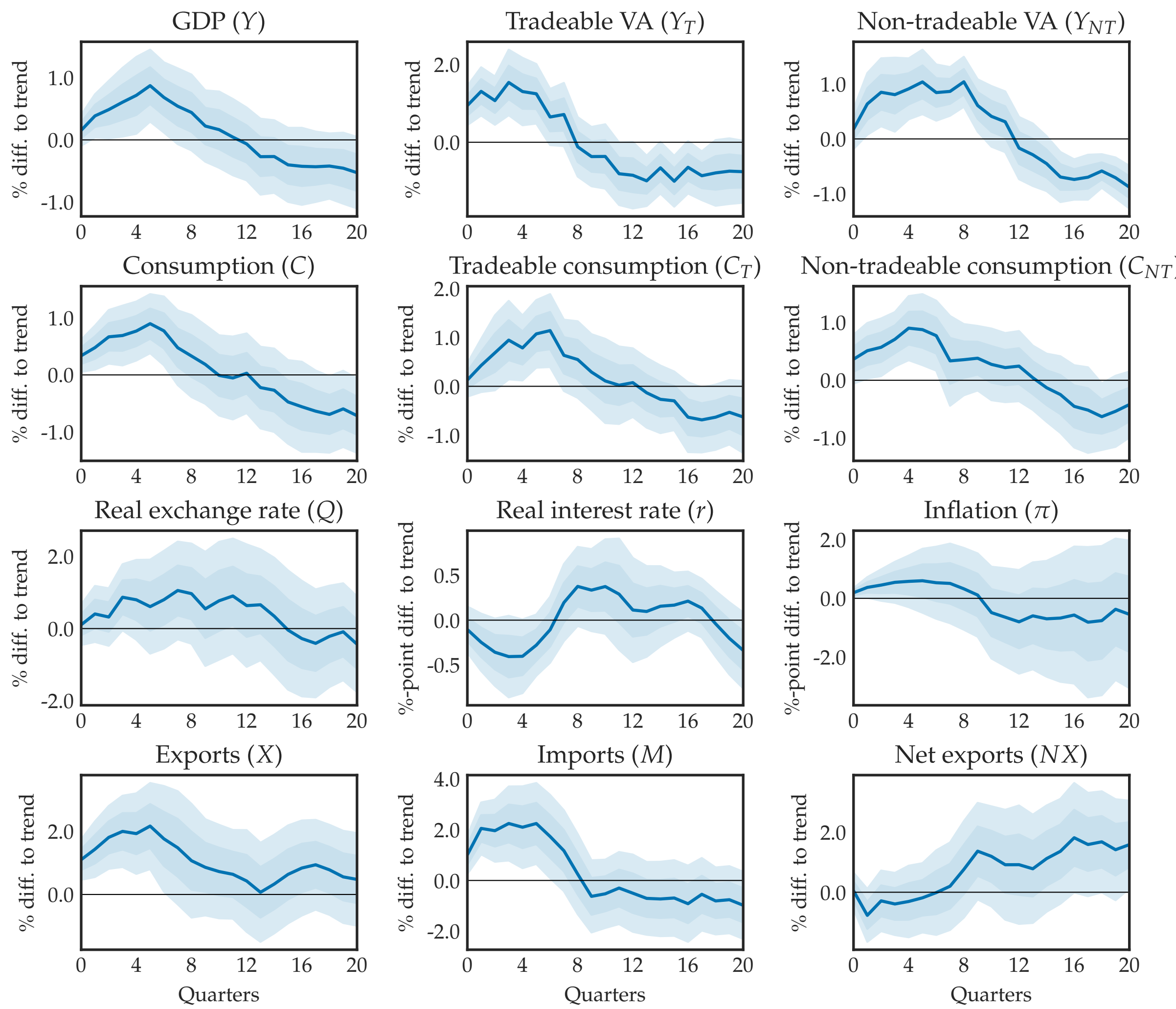


Figure 18: LP results with 4 lags

Note: See Figure 2.

Without time fixed effects. We remove time fixed effects from the model, i.e., we exclude $X_{t,h}$ from the regression. The IRFs are shown in Figure 19.

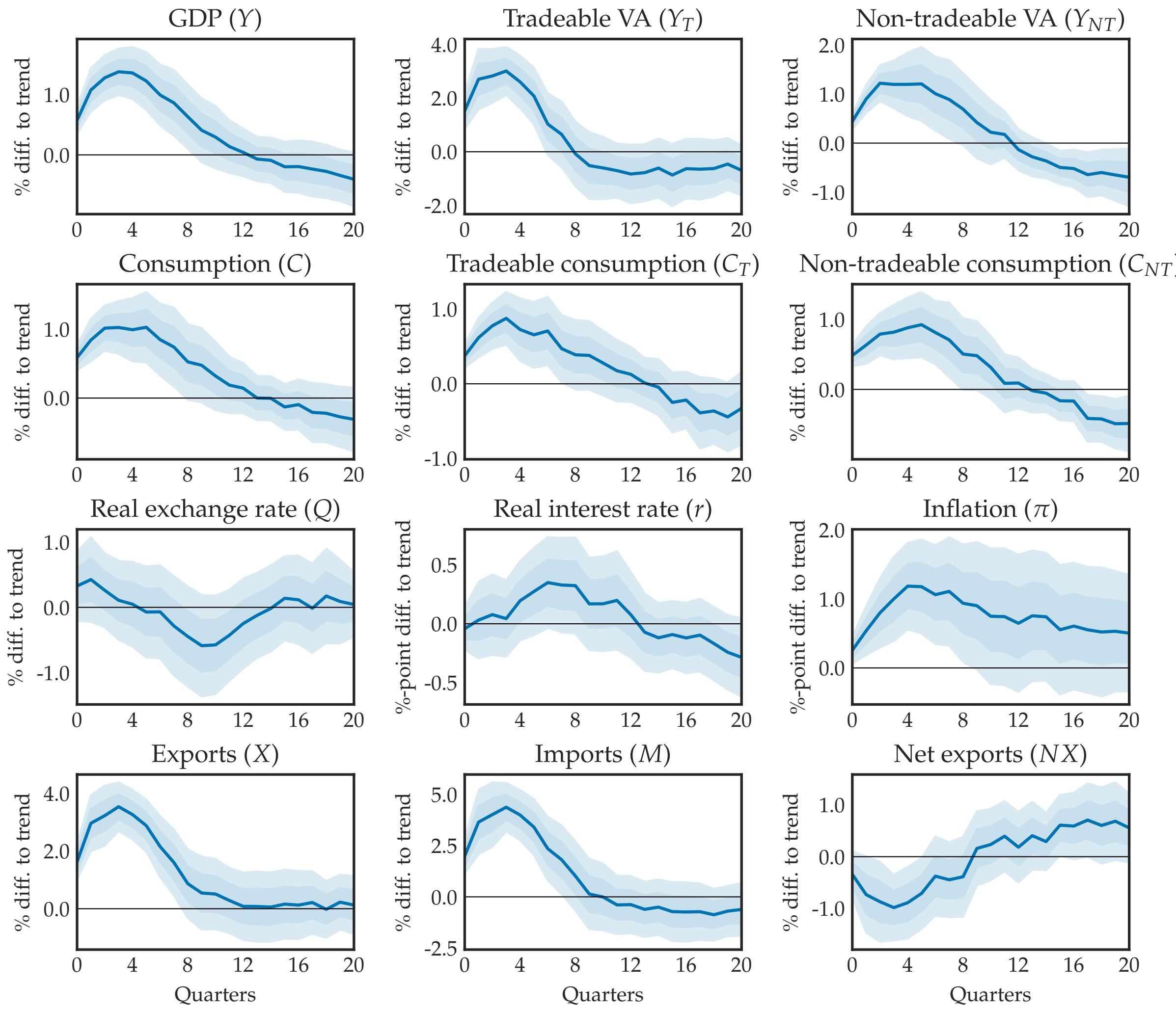


Figure 19: LP results without time fixed effects

Note: See Figure 2.

Time-region fixed effects. We add time-region fixed effects to the model. Specifically, we interact "region" dummies with the time period dummies. The "regions" are: Advanced economies, emerging markets, Euro Area, America, Asia, and Europe. Each country can be in multiple "regions". The IRFs are shown in Figure 20.

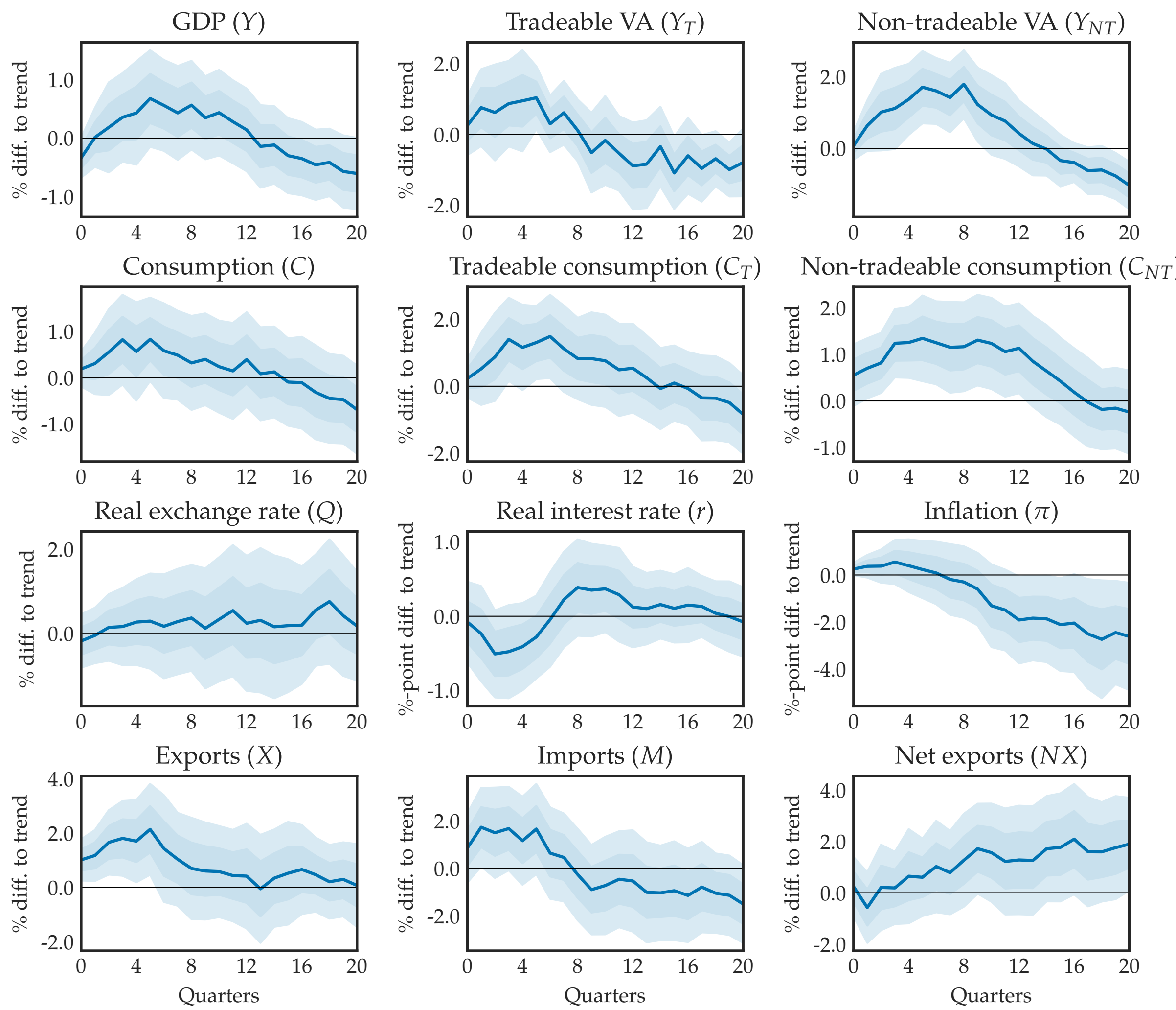


Figure 20: LP results with time-region fixed effects

Note: See Figure 2.

Fixed and floating exchange rates. We estimate the IRFs separately for fixed and floating exchange rate countries. We use the distinction of episodes of countries having a fixed and floating exchange rate from Ilzetzki, Mendoza, and Végh (2013) and update it to the end of our sample in 2019. The results for each sample are shown in Figures 21 and 22.

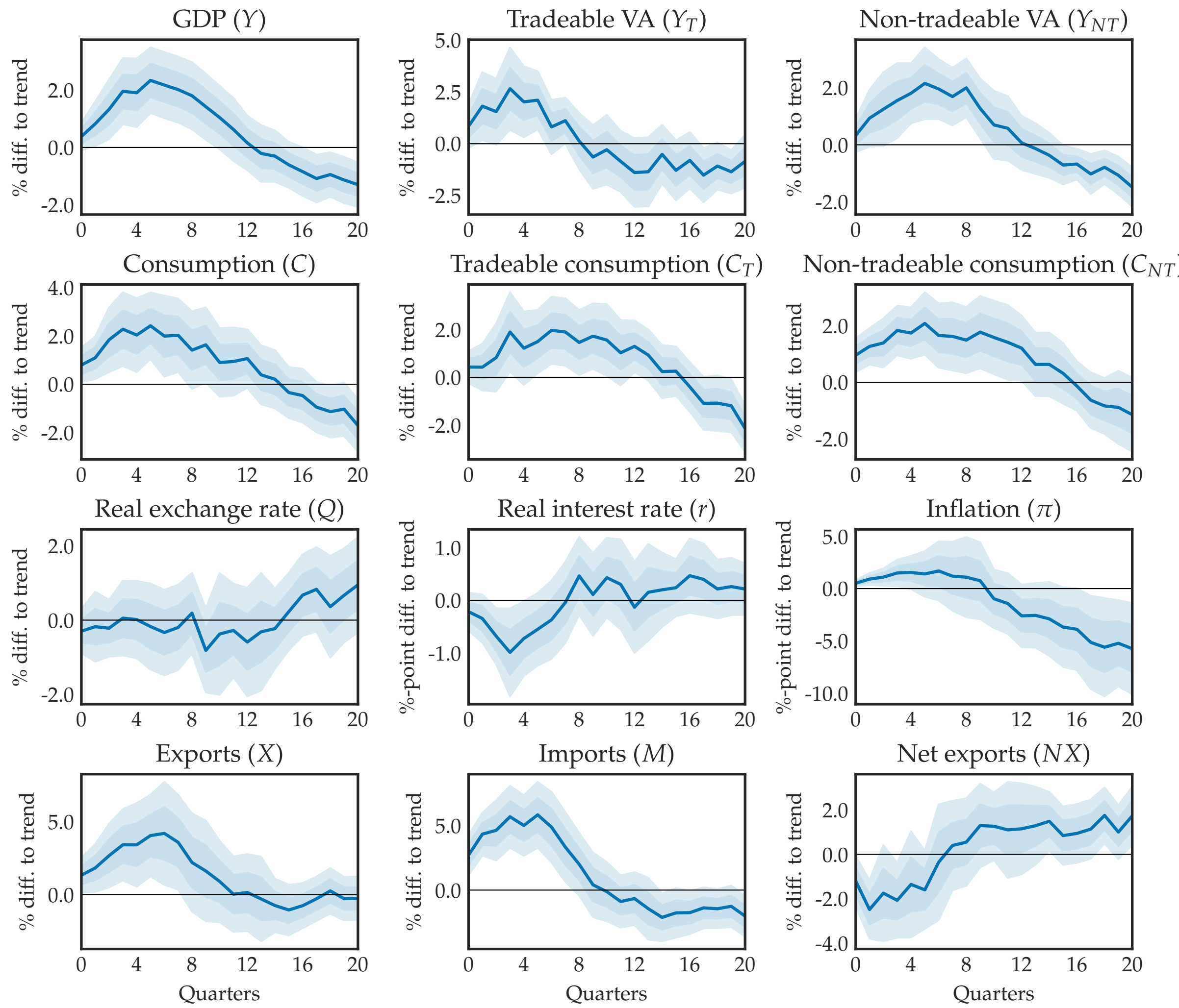


Figure 21: LP results with fixed exchange rate countries only

Note: See Figure 2.

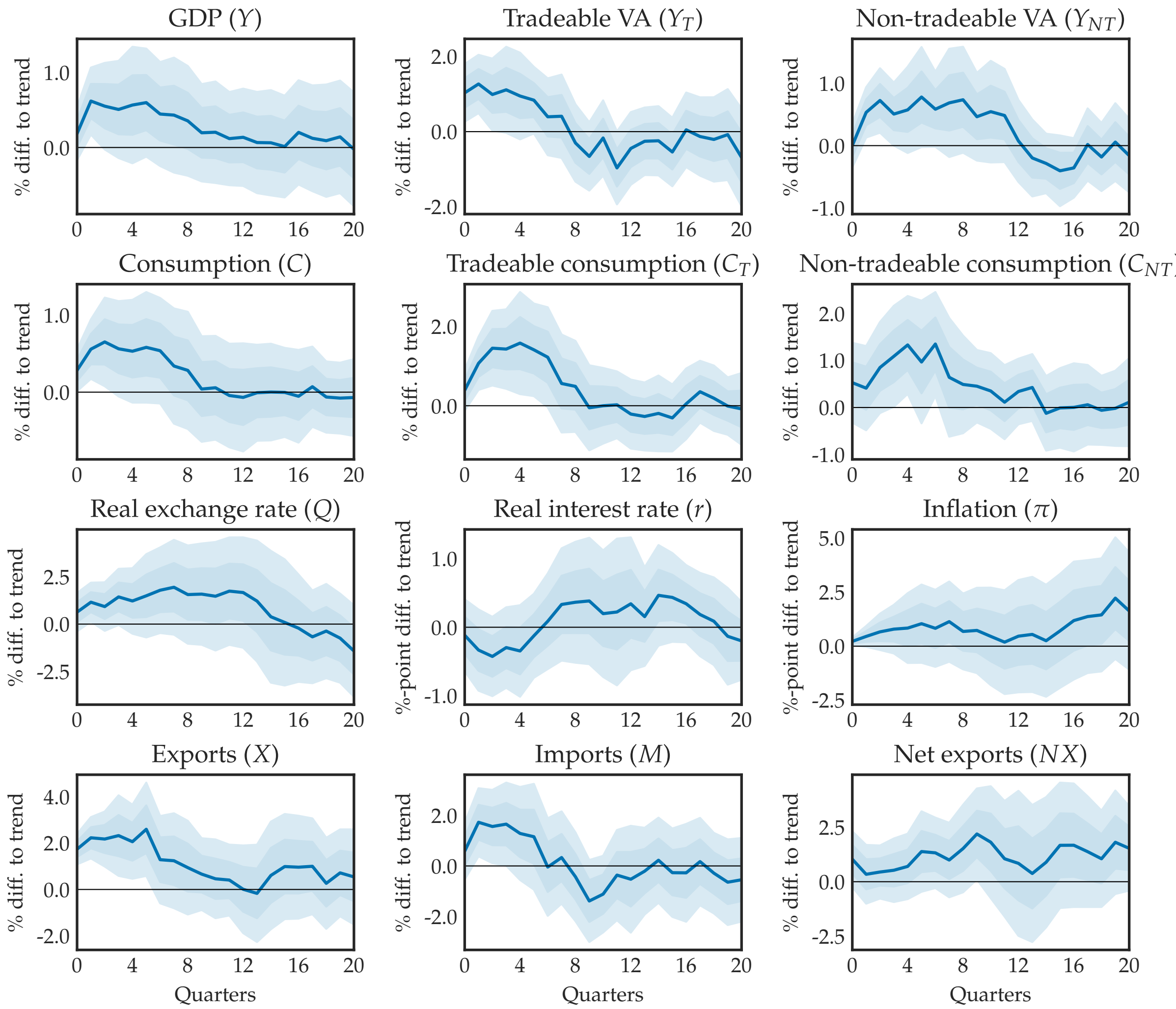


Figure 22: LP results with floating exchange rate countries only

Note: See Figure 2.

Balanced sample We restrict the sample to a balanced panel starting in 1996. The IRFs are shown in Figure 23.

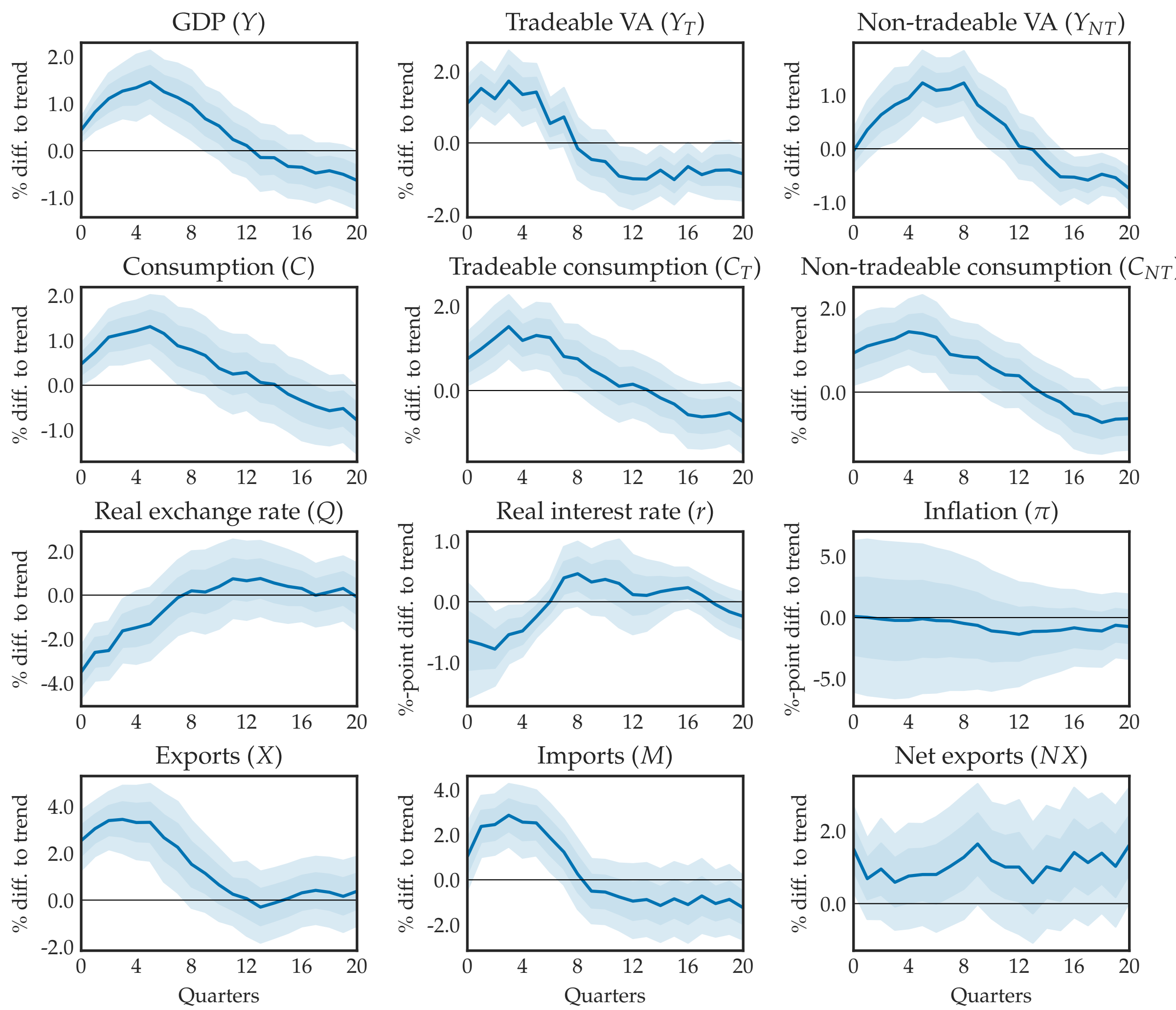


Figure 23: LP results with balanced panel starting in 1996

Note: See Figure 2.

A.8 Country-specific impact

We estimate the on-impact IRF heterogeneously across countries. To do this, we simply replace the term $\beta_0 Y^*_{i,t}$ in eq. (1) (for $h = 0$ and $Z_t = Y_t$) with $\sum_{i=1}^{N} \beta_{0,i} Y^*_{i,t} D_i$. Then, $\beta_{0,i}$ measures the on-impact IRF for country i, and confidence intervals are obtained as usual. The results are plotted in Figure 24. The figure shows that the on-impact IRF is positive—but somewhat different—for all countries, consistent with the main results. The fact that the response is insignificant in some cases highlights the advantage of our main specification: We gain statistical power by pooling the data across countries.

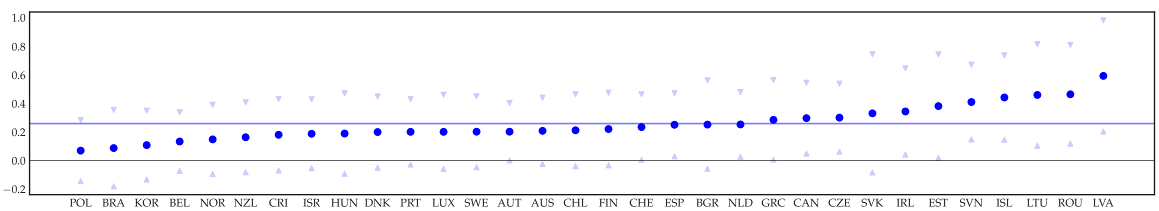


Figure 24: Heterogeneous on impact IRFs of $Y_{i,t}$

Note: Shows $\hat{\beta}_{0,i}$ for different countries. The blue horizontal line is $\hat{\beta}_0$ from the main specification. The arrows indicate 95 pct. confidence intervals. We use Driscoll-Kraay standard errors (see Driscoll and Kraay, 1998).

B Model Appendix

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.[28] The notation follows that in the main text.

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{59}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{60}$$

$$C^*_{H,t} = \alpha\left(\frac{P^*_{H,t}}{P^*}\right)^{-\gamma} C^*_t \tag{61}$$

$$C_t + A_t = \left(1 + r^a_t\right) A_{t-1} + N_t w_t \tag{62}$$

$$C_t = \mathcal{C}_t\left(\left\{r^a_s, r_s, Y^{hh}_s\right\}_{s=0}^{\infty}\right) \tag{63}$$

$$Y_t = Z_t N_t \tag{64}$$

$$W_t = \frac{1}{\mu} P_{H,t} Z_t \tag{65}$$

$$w_t = \frac{W_t}{P_t} \tag{66}$$

$$\pi_{w,t} = \kappa_w\left(\frac{\xi N_t^{\frac{1}{\varphi}}}{\frac{1}{\mu_w} w_t} - 1\right) + \beta\pi_{w,t+1} \tag{67}$$

$$Q_t = E_t\frac{P^*_t}{P_t} \tag{68}$$

$$P_t = \left[\alpha P_{F,t}^{1-\eta} + (1-\alpha) P_{H,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{69}$$

$$P_{F,t} = E_t P^*_t \tag{70}$$

$$P^*_{H,t} = \frac{P_{H,t}}{E_t} \tag{71}$$

28. In addition, we allow households to invest in firm equity, while in the model of Gali and Monacelli (2005) dividends are paid out to the representative household each period. This difference does not matter in a RANK context, but it does in the HANK model.

$$i_t = i_{ss} + \phi^{\pi} \pi_{H,t+1} \tag{72}$$

$$D_t = \frac{P_{H,t} Y_t - W_t N_t}{P_t} \tag{73}$$

$$Y_t = C^*_{H,t} + C_{H,t} \tag{74}$$

$$1 + r_t = (1 + r^*_t) \frac{Q_{t+1}}{Q_t} \tag{75}$$

- Equations (59) through (61) are domestic and foreign household CES-demand functions, respectively.
- Equations (62) and (63) are budget constraint and consumption function of domestic households and together make up the household block of the model.
- Equations (64) and (65) are the production function and associated first-order condition for labor demand of domestic firms. Equation (67) is the New-Keynesian wage Philips-curve (NKWPC).
- Equation (66) defines the real wage.
- Equation (68) is the definition of the real exchange rate.
- Equation (69) is the domestic CPI which follows from the CES specification of consumer preferences over consumption bundles.
- Equations (70) and (71) reflect the law of one price of domestic and foreign goods, respectively.
- Equation (72) is the Taylor rule for the domestic central bank.
- Equation (73) is the definition of domestic firm dividends.
- Equation (74) is domestic goods market clearing.
- Equation (75) is the UIP condition in real terms.

B.2 Linearization

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

B.2.1 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 (69) around the steady state:

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

Use the sequence space version of the law of one price (70), $dP_{F,t} = dE_t + dP_t^*$, and the real exchange rate (68), $dQ_t = dE_t + dP_t^* - dP_t$, to rewrite the last term and arrive at:

$$dP_{H,t} = dP_t - \frac{\alpha}{1-\alpha} dQ_t \tag{76}$$

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

$$d\pi_{H,t} = d\pi_t - \frac{\alpha}{1-\alpha}\left(dQ_t - dQ_{t-1}\right) \tag{77}$$

B.2.2 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 (64) and (65) to substitute out W_t and Z_t:

$$\begin{aligned} Y_t^{hh} &= \frac{W_t N_t}{P_t} \\ &= \frac{1}{\mu}\frac{P_{H,t}}{P_t} Y_t \end{aligned}$$

Next, linearize and use (76):

$$dY_t^{hh} = \frac{1}{\mu} dY_t + \frac{1}{\mu}\left(dP_{H,t} - dP_t\right)$$
$$dY_t^{hh} = \frac{1}{\mu} dY_t - \frac{1}{\mu}\frac{\alpha}{1-\alpha} dQ_t \tag{78}$$

B.2.3 UIP and Taylor rule

Start with (77) forwarded one period:

$$d\pi_{H,t+1} = d\pi_{t+1} - \frac{\alpha}{1-\alpha}\left(dQ_{t+1} - dQ_t\right) \tag{79}$$

The Taylor rule (72) 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 (79) and rearrange:

$$d\pi_{H,t+1} = -dr_t + \phi^\pi \pi_{H,t+1} - \frac{\alpha}{1-\alpha}\left(dQ_{t+1} - dQ_t\right) \tag{80}$$

Use the UIP condition (75) to substitute dr_t out of (80):

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

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

$$\left(1-\phi^\pi\right) d\boldsymbol{\pi}_{\boldsymbol{H}} = \frac{1}{1-\alpha}\mathbf{G}^{r,Q} d\mathbf{Q}, \tag{81}$$

where

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

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

$$d\mathbf{r} = -\mathbf{G}^{r,Q} d\mathbf{Q} \tag{82}$$

B.2.4 NKWPC

Linearizing the NKWPC (67) around the zero-inflation steady state with $\frac{1}{\mu_w} w_{ss} = \xi$ and $w_{ss} = \frac{1}{\mu}$, we get:

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

where the first line uses labor market clearing $dN_t = dY_t$ and the second line uses $\pi_{w,t} = \pi_{H,t}$ from the firm FOC (65). We now write the NKPC in sequence space:

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

where

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

Finally, we can substitute out $d\boldsymbol{\pi}_{\boldsymbol{H}}$ using (81) to establish a link between the real exchange rate and output:

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

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

$$d\mathbf{Q} = -\mathbf{G}^{Q,Y} d\mathbf{Y} \tag{83}$$

where

$$\mathbf{G}^{Q,Y} \equiv \Xi\, (\phi^\pi - 1)\, \kappa_w \frac{1}{\varphi} \tag{84}$$

$$\Xi \equiv \left(\frac{1}{1-\alpha} \left((\phi^\pi - 1)\, \alpha \kappa_w \mathbf{I} + \mathbf{\Gamma} \mathbf{G}^{r,Q} \right) \right)^{-1} \tag{85}$$

B.2.5 Households

Linearizing the budget constraint (62) we have

$$d\mathbf{C} = \mathbf{M}^v \left(d\mathbf{r}^a - d\mathbf{r} \right) + \mathbf{M}^r d\mathbf{r} + \mathbf{M} d\mathbf{Y}^{hh}$$

where $\mathbf{M}^v, \mathbf{M}^r, \mathbf{M}$ are the Jacobians of $\mathbf{C}$ w.r.t the valuation effect, the real interest rate and household labor income $Y^{hh} = W_t N_t / P_t$, respectively. In most models where dividends are paid out through asset ownership, the revaluation effect is likely to be small. For simplicity, assume that it is zero, $\mathbf{M}^v = 0$. Then we have:

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

Using the expression for household income $d\mathbf{Y}^{hh}$ from (78) yields

$$d\mathbf{C} = \mathbf{M}^r d\mathbf{r} + \frac{1}{\mu}\mathbf{M} d\mathbf{Y} - \frac{1}{\mu}\frac{\alpha}{1-\alpha}\mathbf{M} d\mathbf{Q}, \tag{86}$$

We can now derive the response of consumption as a function of output. Starting from (86) and substituting out interest rates and the real exchange rate using (82) and (83) gives

$$\begin{aligned} d\mathbf{C} &= \mathbf{M}^r d\mathbf{r} + \frac{1}{\mu}\mathbf{M} d\mathbf{Y} - \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M} d\mathbf{Q} \\ &= \mathbf{M}^r d\mathbf{r} + \frac{1}{\mu}\mathbf{M} d\mathbf{Y} + \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M}\mathbf{G}^{Q,Y} d\mathbf{Y} \\ &= -\mathbf{M}^r \mathbf{G}^{r,Q} d\mathbf{Q} + \frac{1}{\mu}\mathbf{M} d\mathbf{Y} + \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M}\mathbf{G}^{Q,Y} d\mathbf{Y} \\ &= \left(\frac{1}{\mu}\mathbf{M} + \mathbf{M}^r \mathbf{G}^{r,Q}\mathbf{G}^{Q,Y} + \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M}\mathbf{G}^{Q,Y}\right) d\mathbf{Y} \\ &= \mathbf{G}^{C,Y} d\mathbf{Y} \end{aligned} \tag{87}$$

where

$$\mathbf{G}^{C,Y} \equiv \frac{1}{\mu}\mathbf{M} + \mathbf{M}^r \mathbf{G}^{r,Q}\mathbf{G}^{Q,Y} + \frac{1}{\mu}\frac{\alpha}{(1-\alpha)}\mathbf{M}\mathbf{G}^{Q,Y} \tag{88}$$

Equation (87) describes the partial equilibrium response of consumption as a function the response of domestic production to the foreign demand shock. Conditional on the response of production, the matrix $\mathbf{G}^{C,Y}$ determines the response of consumption, including its sign.

B.2.6 Goods market clearing Substitute the CES demand functions (59) through (61) into the goods market clearing condition (62) 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 $\chi = \eta\,(1-\alpha) + \gamma$ is the composite trade elasticity.

Writing this in sequence space and substituting in for $d\mathbf{Q}$ from (83) yields

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

Finally, use (87) to derive the general equilibrium solution for output in response to a foreign demand shock as

$$\begin{aligned} d\mathbf{Y} &= (1-\alpha)\, \mathbf{G}^{C,Y} d\mathbf{Y} - \frac{\alpha}{(1-\alpha)} \chi \mathbf{G}^{Q,Y} d\mathbf{Y} + \alpha d\mathbf{C}^{*} \\ &= \left\{ \mathbf{I} - (1-\alpha)\mathbf{G}^{C,Y} + \frac{\alpha}{1-\alpha} \chi \mathbf{G}^{Q,Y} \right\}^{-1} \alpha d\mathbf{C}^{*} \\ &= \mathbf{G}^{Y,C^{*}} d\mathbf{C}^{*} \end{aligned} \tag{89}$$

where

$$\mathbf{G}^{Y,C^{*}} = \left\{ \mathbf{I} - (1-\alpha)\mathbf{G}^{C,Y} + \frac{\alpha}{1-\alpha} \chi \mathbf{G}^{Q,Y} \right\}^{-1} \alpha \tag{90}$$

B.2.7 Floating vs. fixed exchange rate regimes

We now consider the case of a fixed exchange rate, which replaces the Taylor rule (72) with $dE_t = 0$. 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 (69) 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:

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

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.2.7) and writing in sequence-space yields:

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

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

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

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

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

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 $\mathbf{Q}, \mathbf{Y}$ relation. In the absence of a domestic monetary policy response to increasing inflation, the sign of the movement in the domestic real interest rate flips over. If we set $d\boldsymbol{\pi}^* = 0$ we obtain the following expression for $\mathbf{G}^{Q,Y}$ under a peg:

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

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

C Numerical Appendix

C.1 Calibration details

C.1.1 Functional form for debt-finance rule We apply the following functional form for the lump-sum tax τ_t:

$$\tau_t = \begin{cases} \tau_{ss} & \text{if } t < t_B \\ (1-\omega(\tilde{t}))\tau_{SS} + \omega(\tilde{t})\tilde{\tau}_t & \text{if } t \in [t_B, t_B + \Delta_B]\,, \tilde{t} = (t - t_B)/\Delta_B\,, \\ \tilde{T}_t & \text{if } t > t_B + \Delta_B \end{cases} \tag{91}$$

where

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

We set $t_B = 50$ such that the tax is constant for 50 quarters after a shock, and the level of debt instead adjusts. We set $\Delta_B = 30$ such that the full effect of stabilizing taxes is phased in over another 30 quarters. Finally, we set $\epsilon_B = 0.5$ 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.

C.1.2 Jacobians

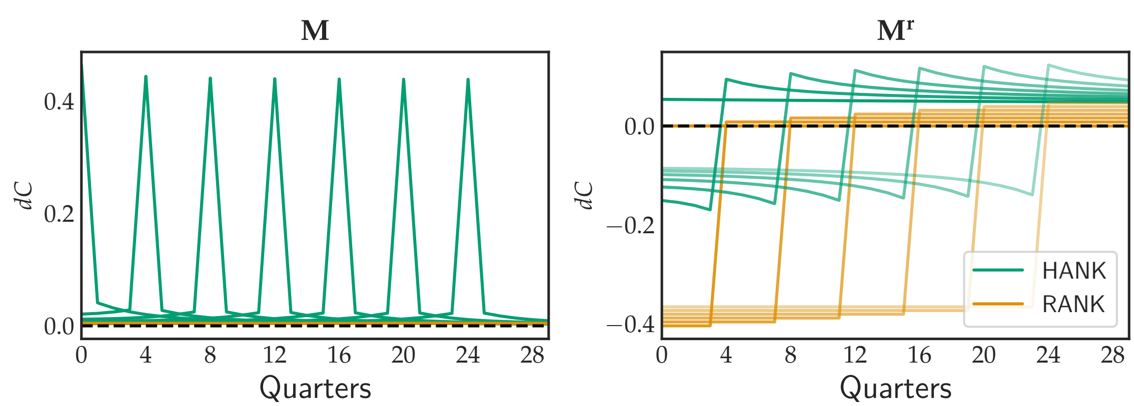
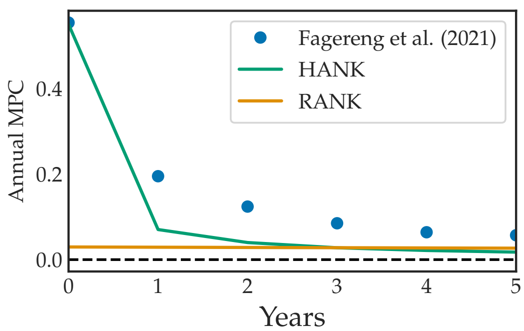


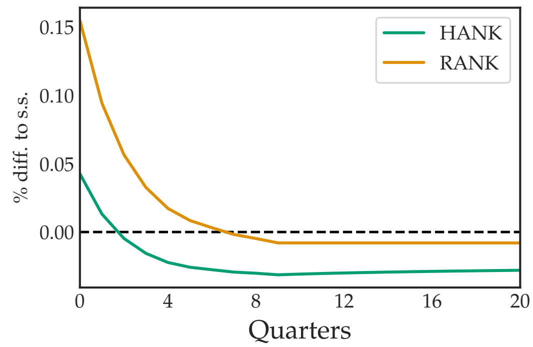
Figure 25: Columns of Jacobians in HANK and RANK

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

Figure 26: Household calibration moments



(a) Calibration of MPCs.



(b) Interest rate sensitivity.

Note: Panel (a): Annual model MPCs against estimates from Fagereng, Holm, and Natvik (2021). Panel (b): Consumption response to a persistent interest rate decrease in HANK, RANK, and Kaplan, Moll, and Violante (2018).

C.2 Other model IRFs

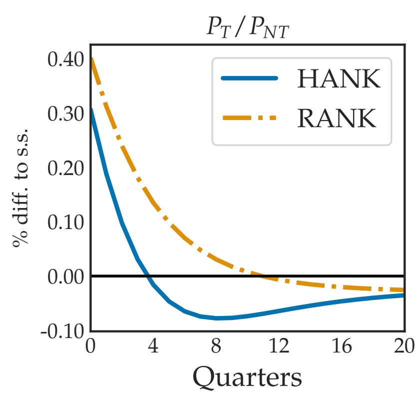


Figure 27: Response of relative prices P_T / P_{NT}

Note: Response of the relative price between tradeable and non-tradeable goods to a foreign demand shock under a floating exchange rate.

C.3 Sensitivity analysis

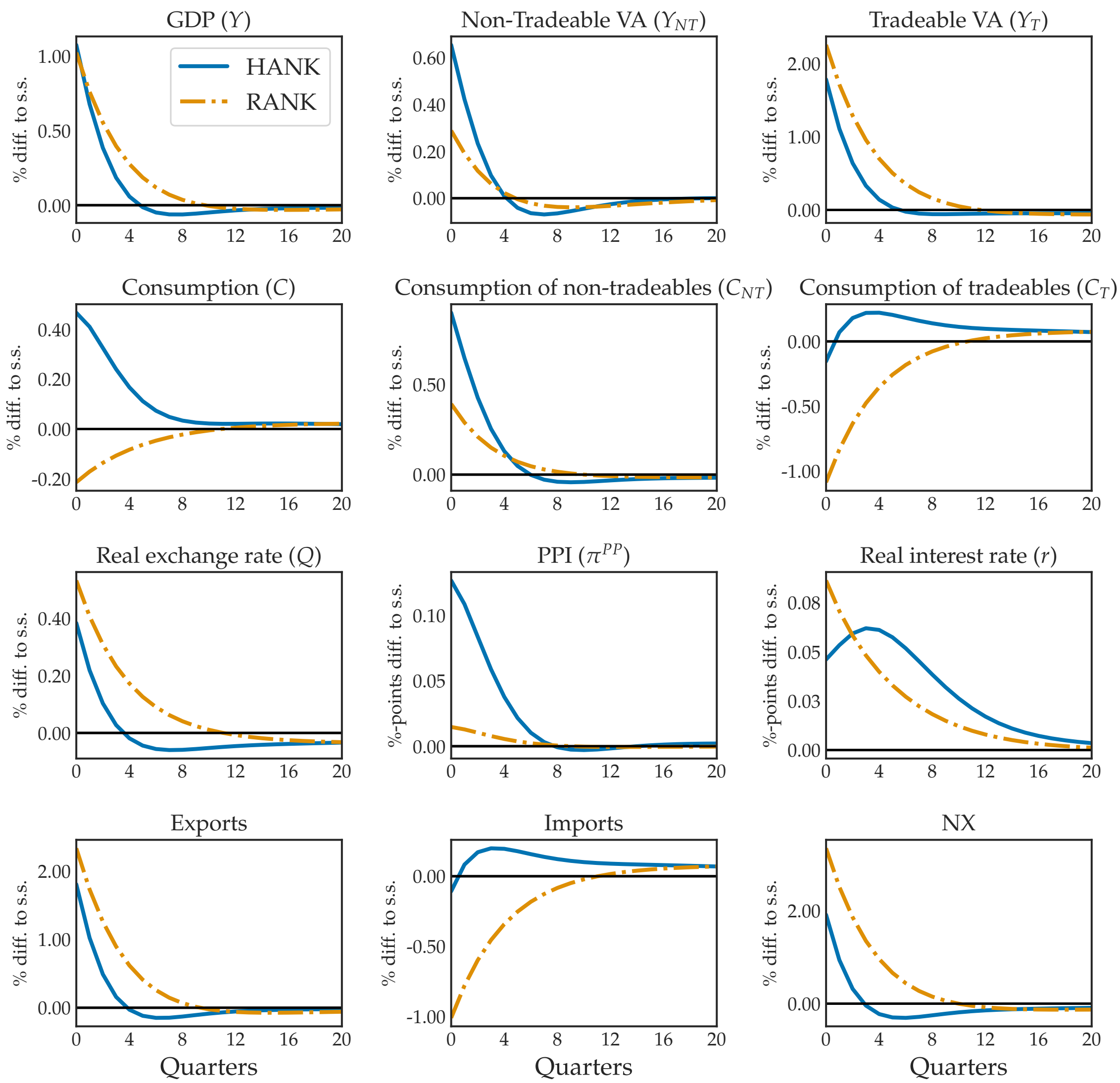


Figure 28: Response to foreign demand shock with no IO structure ($\alpha_{NT}^{X} = \alpha_{T}^{X} = 0$)

Note: Responses to a foreign demand shock under a floating exchange rate without intermediate goods in production and hence no input-output structure between sectors.

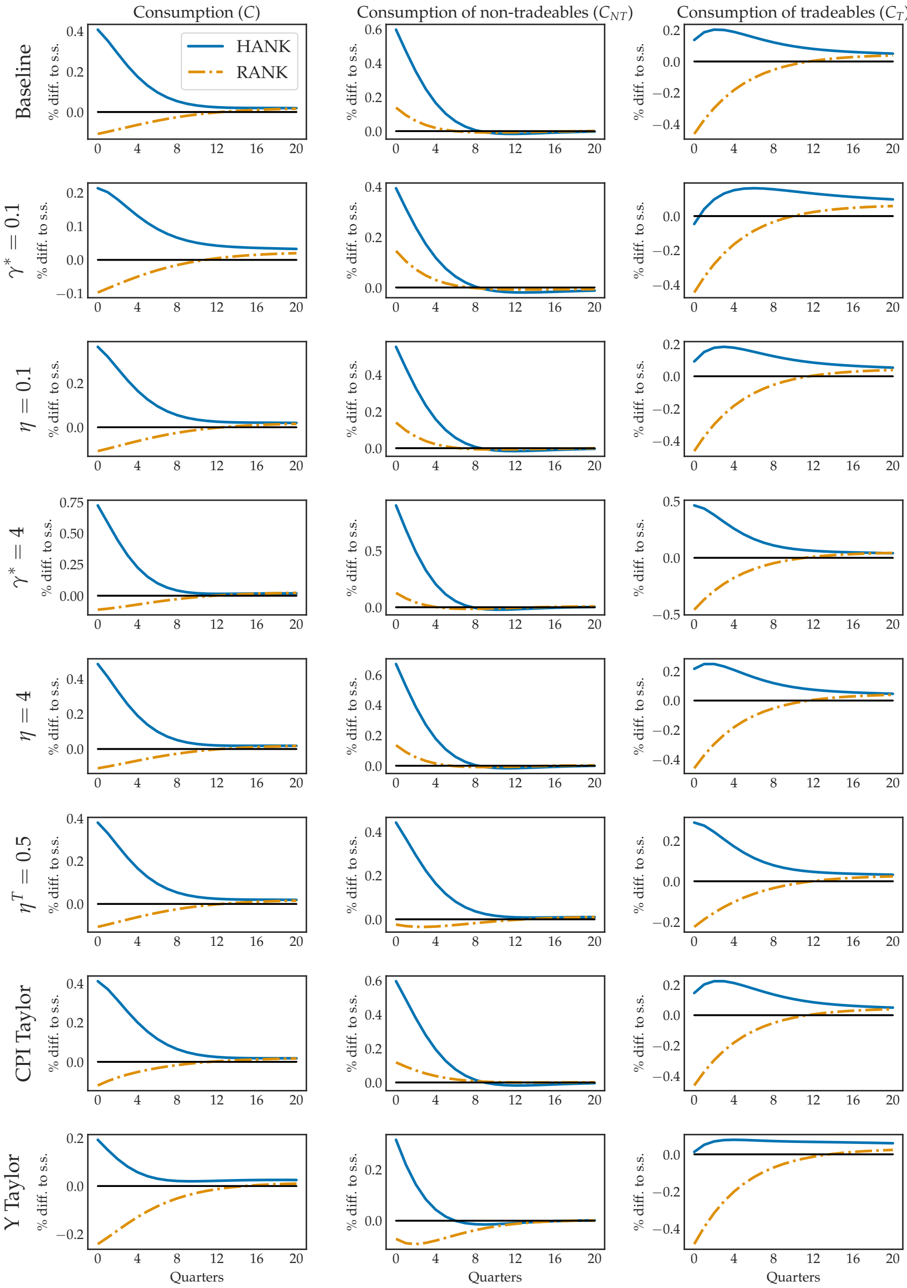


Figure 29: Foreign demand shock responses under various calibrations.

Note: The Figure shows the response to a foreign demand shock under various different parametric assumptions. Row 1) is the baseline model corresponding to the IRFs in Figure 4. Row 2) and 4) consider respectively a low and high foreign trade elasticity (i.e. a low domestic export elasticity). Row 3) and 5) consider respectively a low and high domestic import elasticity. Row 6) considers the cases with a low elasticity of substitution in demand between tradeables and non-tradeable goods. 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 $\phi^Y = 0.25$.

C.4 Correlated shocks

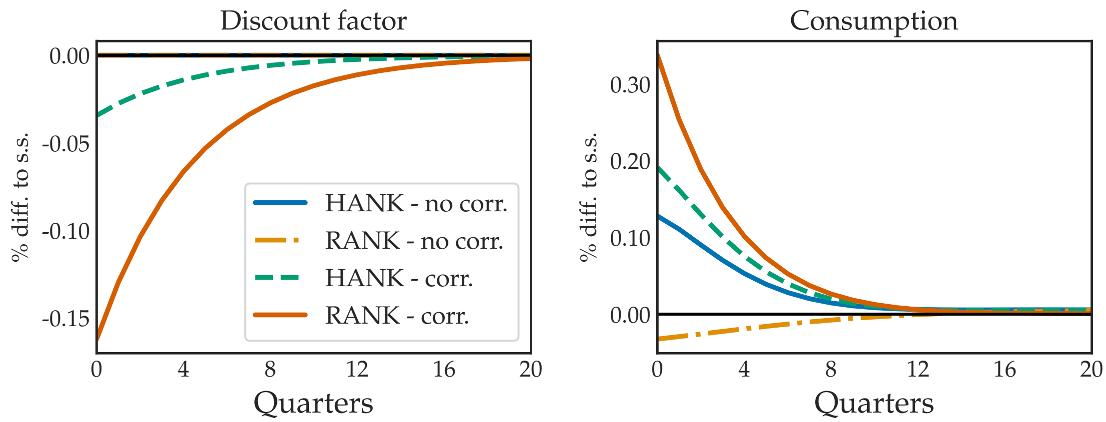


Figure 30: Correlated shocks

Note: The Figure shows the response of domestic variables to a foreign demand shock. The foreign demand shock is a drop in the foreign discount factor, β_t^*, as given by eq. (50), scaled such that foreign demand increases by 1 pct. on impact. The responses are shown for four models: HANK with correlated β-shocks ($\lambda = 0.19$), RANK with correlated β-shocks ($\lambda = 0.89$), and HANK and RANK without correlated β-shocks ($\lambda = 0$). The former two values are chosen such that the response of aggregate consumption (relative to output) matches the empirical results.

C.5 Details on fiscal devaluation

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

Since the VAT is reimbursed on exports and 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 the VAT is levied on producers, sectoral dividends become:

$$D_{s,t} = (1 - \tau_t^v) \frac{P_{s,t} Z_{s,t} - P_{s,t}^X X_{s,t}}{P_t} - (1 - \zeta^p) \frac{W_{s,t} N_{s,t}}{P_t} - \frac{\theta_s^P}{2} \left(\frac{P_{s,t}}{P_{s,t-1}} - 1 \right)^2 Z_{s,t}.$$

Since firms maximize the discounted value of dividends, the tax and the subsidy affect the first-order condition of the firms. Lastly, the government budget constraint changes to:

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

We construct a fiscal devaluation following Farhi, Gopinath, and Itskhoki (2014). We choose a sequence $\{\delta_t\}$ and impose the following paths for the tax and 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 0.8 to be consistent with the other shocks considered in the model. As shown in Farhi, Gopinath, and Itskhoki (2014) one can perfectly mimic a permanent, one-time unexpected nominal devaluation using the VAT and labor subsidy. Since we consider a temporary shock, it is generally not the case that the fiscal and nominal devaluation coincide perfectly. In practice we pick the mix of the VAT and the subsidy (determined by ω^v) to resemble the terms-of-trade movement occurring under a nominal devaluation as close as possible. In our case this happens when $\omega^v = 0.45$, which is close to the value of Farhi, Gopinath, and Itskhoki (2014) of $\omega^v = 0.5$.

C.6 Labor income responses

Table 11 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	-2.12	-1.69	1.26	-1.00	-1.50	-1.60	0.94
Domestic demand, β	-1.00	-0.32	-0.90	0.35	-1.00	-0.36	-0.90	0.40
Public transfers, T	1.00	0.02	0.78	0.02	1.00	0.21	0.86	0.25
Public spending, G	1.00	0.46	2.29	0.20	1.00	0.66	2.08	0.32
Monetary policy, i	1.00	1.40	1.49	0.94	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.52	1.42	1.07
Fiscal devaluation	-	-	-	-	1.00	1.72	1.67	1.03

Table 11: Cumulative labor income effects of demand shocks and policy instruments.

Note: See notes to Table 5. Y_T^{hh} and Y_{NT}^{hh} denote labor income of households employed in the tradeable and non-tradeable sectors, respectively.

C.7 Alternative specification for policy shocks

C.7.1 Varying shock persistence

	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	-1.70	-0.69	2.48	-1.00	-1.19	-0.92	1.29
Domestic demand, β	-1.00	-0.59	-1.18	0.50	-1.00	-0.65	-1.15	0.57
Public transfers, T	1.00	0.48	1.23	0.39	1.00	0.59	1.18	0.50
Public spending, G	1.00	-0.52	1.68	-0.31	1.00	0.06	1.42	0.04
Monetary policy, i	1.00	0.94	1.03	0.91	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	0.99	1.00	0.99
Fiscal devaluation	-	-	-	-	1.00	1.00	1.00	1.00

Table 12: Cumulative effects of demand shocks and policy instruments with high persistence ($\rho = 0.9$)

Note: The table considers the same set of responses as Table 5 in the main text but for a higher level of shock persistence ($\rho = 0.9$) across all shocks.

	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	-1.16	-0.93	1.26	-1.00	-0.94	-1.03	0.92
Domestic demand, β	-1.00	-0.74	-1.12	0.66	-1.00	-0.75	-1.11	0.68
Public transfers, T	1.00	0.61	1.17	0.52	1.00	0.66	1.15	0.58
Public spending, G	1.00	0.18	1.36	0.13	1.00	0.31	1.31	0.24
Monetary policy, i	1.00	0.96	1.02	0.94	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.12	0.95	1.18
Fiscal devaluation	-	-	-	-	1.00	1.06	0.97	1.09

Table 13: Cumulative effects of demand shocks and policy instruments with low persistence ($\rho = 0.7$)

Note: The table considers the same set of responses as Table 5 in the main text but for a lower level of shock persistence ($\rho = 0.7$) across all shocks.

C.7.2 Targeted fiscal policies

	Floating				Fixed			
	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$
G $(s_T^G) = 0.1$	1.00	-0.12	1.50	-0.08	1.00	0.13	1.39	0.09
G $(s_T^G) = 0.2$	1.00	0.01	1.44	0.01	1.00	0.23	1.34	0.17
G $(s_T^G) = 0.3$	1.00	0.15	1.38	0.11	1.00	0.33	1.30	0.26
T $(s_T^T) = 0.4$	1.00	0.45	1.25	0.36	1.00	0.53	1.21	0.44
T $(s_T^T) = 0.5$	1.00	0.57	1.19	0.48	1.00	0.64	1.16	0.55
T $(s_T^T) = 0.6$	1.00	0.70	1.13	0.62	1.00	0.74	1.11	0.67

Table 14: Cumulative effects of fiscal policy shocks for varying degree of targeting

Note: The table considers the effects of targeted fiscal policy (either through transfers T or public consumption G) on household consumption, as in table 5. For G we vary the share of public consumption going towards the tradeable sector (s_T^G) between 10% and 30%, with 20% being the baseline case. For transfers we vary the distribution of transfers across household working in the tradeable and non-tradeable sector (s_T^T) between 40% and 60%, with 50% being the baseline, uniform distribution case.