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Dollar Invoicing, Global Value Chains, and the Business Cycle Dynamics of International Trade [*]

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Abstract

Recent literature has highlighted that international trade is mostly priced in a few key vehicle currencies, and is increasingly dominated by intermediate goods and global value chains (GVCs). Taking these features into account, this paper reexamines the business cycle dynamics of international trade and its relationship with monetary policy and exchange rates. Using a three country dynamic stochastic general equilibrium (DSGE) framework, it finds key differences between the response of final goods and GVC trade to both internal and external shocks. In particular, the model shows that in response to a dollar appreciation triggered by a US interest rate increase, direct bilateral trade between non-US countries contracts more than global value chain oriented trade which feeds US final demand. We use granular data on GVC at the sector level to document empirical evidence in favor of this prediction.

Keywords: Dollar invoicing, exchange rates, monetary policy, global value chains.

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1 Introduction

The impact of monetary policy and exchange rates on international trade has been one of the most intensively studied areas in international macroeconomics for decades. This paper provides a modern reexamination of this classical debate. The reexamination is warranted given the increasing empirical evidence documenting two key features of the evolving international trade system that could potentially alter the way we think about the business cycle dynamics of trade.

The first feature pertains to the currency of invoicing of international trade.[1] Exports around the world are priced in a handful of key global "vehicle" currencies, with the dollar being the most prominent one (see for instance Goldberg and Tille, 2008 and Gopinath (2016), Kamps (2006) and Ito and Chinn, 2013). Boz et al (2019 and 2020) have termed this the "dominant currency paradigm (DCP)". The prevalence of DCP in the data is in contrast to most models which are based on the Mundell-Fleming assumption of exports being priced in the currency of the exporter (producer currency pricing or PCP), as well as a subsequent literature that considered local currency pricing (LCP).[2] Under DCP, the passthrough of exchange rates to export prices is significantly reduced, and competitiveness effects from exchange rate devaluations via a boost in exports are muted. Instead, adjustment occur primarily through imports, where passthrough is close to complete.[3] Moreover, a uniform appreciation of the dollar leads to a decline in global trade.

Second, international trade is increasingly dominated by intermediate goods and global value chains.[4] This presents a challenge to the existing literature on both theoretical and empirical grounds. On the theoretical front, most macro models that are used to study business cycle dynamics, including those at central banks, ignore the distinction between gross and value added trade. Even the models that do allow for intermediate goods trade such as Boz et al (2020), do not allow for global value chain structures where goods cross border multiple times.

[1] While in this paper we take the currency of trade invoicing as given, a number of papers have identified factors determining this choice. These including nominal and real volatility (see Devereux et al. 2004 and Engel, 2006), price elasticities (Friberg, 1998), currency hedging (Golberg and Tille, 2008) and imported inputs (Novy, 2006). Bacchetta and van Wincoop (2004) and Mukhin (2019) emphasize the role of country market size as a determinant of currency of invoicing. Portes and Rey (1998) and Devereux and Shi (2013) identify externalities and transactions costs.

[2] See for instance Obstfeld and Rogoff (1995) for a fully articulated open economy model with PCP, and Betts and Devereux (1996) and Engel and Devereux (2003 and 2003) for arguments in favor of LCP.

[3] See Cook and Devereux (2006), Goldberg and Tille (2006), and Casas, Díez, Gopinath, and Gourinchas (2016)

[4] See for instance Johnson and Noguera (2012), Hummels, Ishii and Yi, 2001 and Koopman, Wang and Wei (2014),

On the empirical front, most databases for international trade only record gross trade flows, and do not distinguish between intermediate and final goods, and whether an import is used for domestic consumption or reexport.[5] Some databases do offer a coarse categorization of imports into intermediate and final goods, but they do not capture the subsequent journey of intermediate imports, i.e whether they are consumed within the importing country or cross international borders subsequently, and how many times if they do so. As we show in this paper, this subsequent journey and the final destination is critical for understanding the impact of trade to business cycle shocks.

In this paper we attempt to address both the theoretical and the empirical shortcomings identified above, to obtain a sharper understanding of the relationship between monetary policy, exchange rates and international trade. On the theoretical side, we set up a three country New Keynesian DSGE model where two small open "regional" economies trade with each other, as well as trade outside the region with a large global economy. Regional economies trade in goods meant for final consumption. In addition, we model a simple international value chain operating from within the region. Each economy operates an export platform producing goods to satisfy final demand from the broader global economy. Each export platform uses both domestic value added and imported inputs from the region. Following the DCP paradigm, regional currencies are used only in domestic transactions. Trade with the the rest of the world as well as trade within the region is denominated in the hard currency of the global market (dollar invoicing). Due to sticky prices in the global currency, fluctuations in the exchange rate relative to the external currency affect the price competitiveness of imports even if domestic fundamentals in the two small open economies remain unchanged.

In this scenario, the implication for exports of final goods within the region is fairly straightforward. Regional trade in final goods depends on aggregate spending in the importing country and the exchange rate of the importing country with the international currency, as opposed to the trade partner. However, the determinants of trade within the global value chain are more complicated. Intra-regional trade in inputs is less dependent on final demand within the immediate importing economy and more dependent on global demand, which in turn is endogenously related to the value of the international currency in general equilibrium.

We examine the equilibrium effects of internal and external shocks that causes shifts in exchange rates, focusing on a contractionary external interest rate shock that affects both economies and a monetary expansion in the regional trading partners.[6] Each shock leads to

[5] Custom regulations in certain sectors of countries like China that require processing imports to be recorded separately are an exception to this trend.

[6] While the main focus of our analysis is to study the relationship between exchange rates and international trade, we use a specific shock to the interest rate (either domestic or foreign) to condition the movements in

an exchange rate depreciation relative to international currency and each leads to a decline in intraregional trade. However, the intensity of the contraction depends on the type of shock, with final goods contracting less in the face of local monetary expansions, while intermediate goods exports contract less in the face of external interest rate shocks. Interpreted in terms of value added exports, the model predicts that in response to an external interest rate rise, value added exports to the regional economy contract by more than value added exports to the US.[7]

The predictions of the model cannot be appropriately tested using standard international trade databases that do not capture global value chains activity. In the empirical part, we therefore rely on a granular decomposition of international trade flows at the sector level developed by Wang, Wei and Zhu (2017 a and b). We show that while the evidence in favor of the main predictions of the model is ambiguous when we consider only a coarse classification between final and intermediate goods trade, we find much stronger evidence in favor of the model once we use input-output data to generate measures of global value chain trade that can be mapped more closely to the model.

The remainder of this paper is organized as follows. This section concludes with an overview of the related literature. We lay out the benchmark model in section 2. Section 3 discusses the calibration and illustrates the main dynamics of the model in response to shocks. Section 4 discusses the data and presents empirical results motivated by the model. Section 5 concludes with a summary of the main messages and policy implications that arise from the analysis.

Literature review

This paper lies at the intersection of three strands of literature in international macroeconomics-namely currency of trade invoicing, GVCs, and open economy new keynesian DSGE models.

On the determinants of currency of invoicing, a number of papers have identified factors influencing the currency of denomination. These include nominal and real volatility (Devereux et al. 2004 and Engel, 2006), price elasticities (Friberg, 1998), currency hedging (Golberg and Tille, 2008), imported inputs (Novy, 2006), financial market development and openness (Ito and Chinn, 2013 and Ito and Kawai, 2016), market size (Bacchetta and van

the exchange rate. Since the exchange rate is an endogenous variable, the literature has recently emphasized the importance of such conditioning on the nature of the shock-see for instance Forbes et al (2018) and García-Schmidt and Garcia-Cicco (2018).

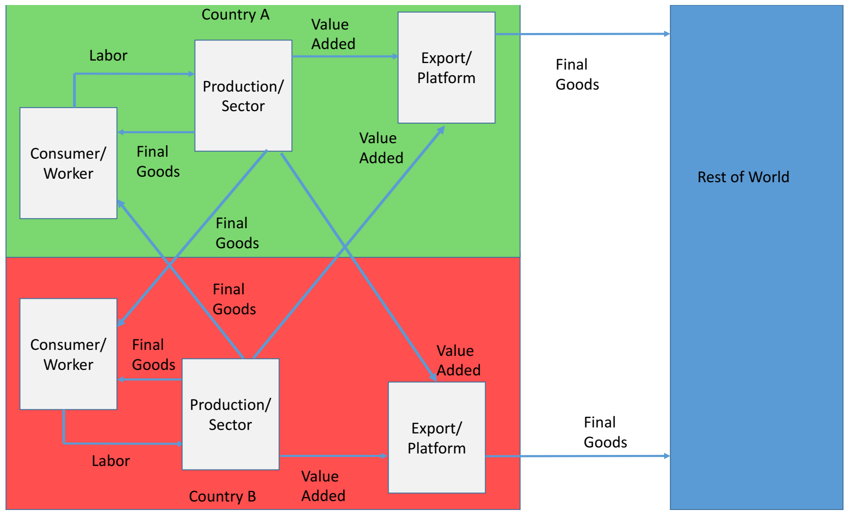
[7] Value added exports from country A to B denote the value added generated in country A that is eventually absorbed as final demand in country B. This may include direct exports of final goods, direct exports of intermediate goods that are used to produce and consume final goods within B, or indirect exports via third countries in GVCs. See for instance Johnson and Noguera (2012) and Wang, Wei and Zhu (2013).

Wincoop (2004)), and externalities and transactions costs (Portes and Rey (1998) and Devereux and Shi (2013)). Mukhin (2018) considers a model of endogenous currency choice, emphasizing how the role of strategic complementaries and country size have led to the emergence of the dollar as the dominant currency. Gopinath and Stein (2018) study how complementarity between a currency's role in the denomination of trade and financial contracts leads to the emergence of dominance currencies. Goldberg and Tille (2008) and Kamps (2006) constructed data on invoicing currencies for a broad set of countries, finding a heavy role for the US and Europe. This data is extended in Ito and Chinn (2013) and Gopinath (2016). Devereux, Hinton, and Dong (2016) identify the currency invoicing choice of Canadian importers.

With regard to the implications of currency of invoicing, Cook and Devereux (2006) show that emerging markets crises may be exacerbated by the effect of a region wide devaluation against the dollar on intra-regional trade. Goldberg and Tille (2008) show that trade between countries is sensitive to the monetary policy of the currency of invoice even when neither country issues that currency. Casas, Díez, Gopinath, and Gourinchas (2017) identify the optimal monetary policy in a small open economy facing exports priced in external currencies. Egorov and Mukhin (2019) and Goldberg and Tille (2009) also study optimal policy under dollar invoicing, documenting how it differs from traditional inflation targeting and puts more weight on the exchange rate. Zhang (2019) and Goldberg and Tille (2009) study how spillovers of US monetary policies are affected by currency of invoicing, and show how higher shares of foreign currency invoicing makes domestic monetary policy less potent.

The phenomena of global value chains has been one of the defining and most celebrated facets of globalisation over the last few decades (Baldwin and Lopez Gonzales (2015)). Hummels, Ishii and Yi (2001) and Hummels Rappoport and Yi (1998) were among the first to quantify the prevalence of vertical specialization in international trade, documenting a 20% growth in vertical specialization between 1970 and 1990. Recent advances in both data and methodology over the last 10 years has led to a resurgence in the literature studying GVCs. Johnson and Noguera (2012) propose a framework to decompose gross trade flows into value added to components. Koopman Wang and Wel (2014) provide a framework to decompose gross exports into a more granular eight-term decomposition, including measures such as reexports to third countries and reexports back to the original export country, and double counted value added terms. Wang, Wei and Zhu (2013, 2017a, 2017b) have extended the framework of Koopman, Wang and Wei (2014) to allow for a similar decomposition of trade flows at the bilateral and sector levels. Such data has led to a reexamination of several classical questions in international economics. For example, Patel, Wang and Wei (2019) study how real effective exchange rates should be interpreted in a world with global value

Figure 2.1 – *Schematic representation of the model*



chains.

On the modeling front, this paper borrows from the the extensive literature studying international business cycles through the lens of open economy new keynesian DSGE models, which in turn belong to the New Open Economy Macroeconomics (NOEM) paradigm of Obstfeld et al. (1996). Lane (2001) provides a survey of the NOEM literature.

2 Model

Figure 2.1 provides a schematic illustration of the model. It consists of two regional economies, $j = A$ and B, each with their own currency; along with a global economy ("Rest of the world") W, that issues dollars as a currency. All cross-country transactions, even within the region, are priced in dollars. Local currencies are only used within the domestic economy. Each of these countries import goods for final use. In addition, A and B operate platform export sectors which combine an array of value added from regional producers for ultimate final export to the global economy. The exchange rate between regional currencies and international dollars is S_t^j.

2.1 Household

The preferences of the household are:

$$\sum_{t=0}^{\infty} \beta^t u(C_t^j, L_t^j) = \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\zeta}{\zeta - 1} C_t^{j\,\frac{\zeta-1}{\zeta}} - \frac{\theta \cdot \Gamma}{1+\theta} L_t^{j\,\frac{\theta+1}{\theta}} \right\} \tag{2.1}$$

where L_t^j is aggregate labor; and C_t^j is the consumption basket which is a CES aggregate of regional goods, CR_t^j, and imported global goods, CW_t^j:

$$C_t^j = \left(a^{\frac{1}{\varsigma}} \cdot \left\{ CR_t^j \right\}^{\frac{\varsigma-1}{\varsigma}} + (1-a)^{\frac{1}{\varsigma}} \cdot \left\{ CW_t^j \right\}^{\frac{\varsigma-1}{\varsigma}} \right)^{\frac{\varsigma}{\varsigma-1}} \tag{2.2}$$

Regional goods are a combination of goods produced domestically and goods imported from the regional trading partner.

$$CR_t^j = \left(b^{\frac{1}{\psi}} \cdot \left\{ CH_t^j \right\}^{\frac{\psi-1}{\psi}} + (1-b)^{\frac{1}{\psi}} \cdot \left\{ CM_t^j \right\}^{\frac{\psi-1}{\psi}} \right)^{\frac{\psi}{\psi-1}} \tag{2.3}$$

where CH_t^j is domestically produced goods and CM_t^j is imported regionally produced goods.

Relative demand for global goods are based on the relative price of importing at global prices.

$$CW_t^j = (1-a) \cdot \left(\frac{S_t^j P_t^W}{CPI_t^j} \right)^{-\xi} \cdot C_t^j \tag{2.4}$$

where CPI_t^j is the domestic country consumer price index and, P_t^W, is the price of goods from the global economy denominated in international dollars.

The demand for regional goods is given by

$$CR_t^j = a \cdot \left(\frac{RPI_t^j}{CPI_t^j} \right)^{-\xi} \cdot C_t^j \tag{2.5}$$

where RPI_t^j is the cost-minimizing marginal cost of consuming regional goods. Domestic producer prices are priced at PPI_t^j in domestic currency. Goods can be imported from the regional trading partner at price $IPI_t^{\neq j}$ invoiced in global dollars. The cost minimizing combination of regional goods is characterized.

$$\begin{aligned} \frac{CM_t^j}{CR_t^j} &= (1-b) \cdot \left(\frac{S_t^j IPI_t^{\neq j}}{RPI_t^j} \right)^{-\psi} \quad \frac{CH_t^j}{CR_t^j} = b \cdot \left(\frac{PPI_t^j}{RPI_t^j} \right)^{-\psi} \rightarrow \\ RPI_t^j &= \left(b \cdot \left\{ PPI_t^j \right\}^{1-\psi} + (1-b) \cdot \left\{ IPI_t^{\neq j} \right\}^{1-\psi} \right)^{\frac{1}{1-\psi}} \end{aligned} \tag{2.6}$$

The demand for regional goods can be written[8]

$$\begin{aligned} CM_t^j &= (1-b)\cdot a\cdot\left(\frac{S_t^j IPI_t^{\neq j}}{RPI_t^j}\right)^{-\psi}\cdot\left(\frac{RPI_t^j}{CPI_t^j}\right)^{-\xi}\cdot C_t^j \\ CH_t^j &= a\cdot b\cdot\left(\frac{PPI_t^j}{RPI_t^j}\right)^{-\psi}\cdot\left(\frac{RPI_t^j}{CPI_t^j}\right)^{-\xi}\cdot C_t^j \end{aligned}$$

Households save by holding international bonds, B_t^j:

$$S_t^j B_{t+1}^j = (1+r_t)S_t^j B_t^j + W_t^j H_t^j - CPI_t^j C_t^j + \Pi_t^j \tag{2.7}$$

where W_t^j are nominal wages and interest rate, $1+r_t$. is an external interest rate in international dollars. The first order conditions are.

$$\begin{aligned} \Omega_t^j W_t^j &= -MU_t^H \;= \Gamma L_t^{j\,\frac{1}{\theta}} && (2.8)\\ \Omega_t^j CPI_t^j &= MU_t^C = C_t^{j\,\frac{-1}{\varsigma}} && (2.9)\\ 1 &= E_t[\beta\frac{\Omega_{t+1}^j}{\Omega_t^j}(1+r_t^j)\frac{S_{t+1}^j}{S_t^j}] = E_t[\beta\frac{\Omega_{t+1}^j}{\Omega_t^j}(1+i_t^j)] \end{aligned}$$

where Ω_t^j is the shadow value of domestic currency and i_t^j is the implicitly defined domestic currency nominal interest rate.

2.2 Production Firms

2.2.1 Domestic Value Added

Production firms hire labor and sell goods in competitive wholesale markets

$$Y_t^j = Z_t^j L_t^j \;\rightarrow MCY_t^j = \frac{W_t^j}{Z_t^j} \tag{2.10}$$

where Y_t^j is output and Z_t^j is technology. The competitive price of production goods is MCY_t^j.

[8] Implicitly, the consumer price index is $CPI_t^j = \left(a\cdot\left\{RPI_t^j\right\}^{1-\xi} + (1-a)\cdot\left\{S_t^j P_t^W\right\}^{1-\xi}\right)^{\frac{1}{1-\xi}}$.

2.2.2 Export Platforms

Each country also hosts a platform that generates value for export to the global economy, V_t^j.

$$V_t^j = \left(d^{\frac{1}{\nu}} \cdot \left\{ VH_t^j \right\}^{\frac{\nu-1}{\nu}} + (1-d)^{\frac{1}{\nu}} \cdot \left\{ VM_t^j \right\}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}} \tag{2.11}$$

where VH_t^j is domestically produced value and VM_t^j are semi-processed materials imported from the regional trading partner. The cost minimizing marginal cost MCV_t^j of the export platform is characterized by

$$\begin{aligned} \frac{VM_t^j}{V_t^j} &= (1-d) \cdot \left(\frac{S_t^j IPI_t^{\neq j}}{MCV_t^j} \right)^{-\nu} \qquad \frac{VH_t^j}{V_t^j} = d \cdot \left(\frac{PPI_t^j}{MCV_t^j} \right)^{-\nu} \\ MCV_t^j &= \left(d \cdot \left\{ PPI_t^j \right\}^{1-\nu} + (1-b) \cdot \left\{ S_t^j IPI_t^{\neq j} \right\}^{1-\nu} \right)^{\frac{1}{1-\nu}} \end{aligned} \tag{2.12}$$

2.3 Distribution Firms

There is an industry that distributes domestic value added for domestic processing. Each distribution sector is made up of a unit range of monopolistically competitive firms.

$$CH_t^j + VH_t^j = H_t^j = \left[\int h_{l,t}^{\frac{\phi-1}{\phi}} dl \right]^{\frac{1}{1-\phi}} \tag{2.13}$$

Define the price of each domestic good as ppi_t^l where the price index is defined $PPI_t^j \cdot H_t^j \equiv \int \left\{ ppi_{l,t} h_{l,t} \right\} dl$.

Another sector produces for regional export purposes.

$$CM_t^{\neq j} + VM_t^{\neq j} = EX_t^j = \left[\int ex_{l,t}^{\frac{\phi-1}{\phi}} dl \right]^{\frac{1}{1-\phi}} \tag{2.14}$$

Define the price of each regional export as $ipi_{l,t}$ where the price index is defined $IPI_t^{\neq j} \cdot EX_t^j \equiv \int \left\{ ipi_{l,t} ex_{l,t} \right\} dl$. Note that this price is denominated in global dollars.

Finally, exports to the global economy are also constructed by distribution.

$$WM_t^j = \left[\int wim_{l,t}^{\frac{\phi-1}{\phi}} dl \right]^{\frac{1}{1-\phi}} \tag{2.15}$$

The price of exports to the global economy, $xpi_{l,t}$, is also priced in global dollars where the price index is defined $XPI_t^j \cdot WM_t^j \equiv \int \left\{xpi_{l,t} wim_{l,t}\right\} dl$.

Any of the firms in the distribution sector faces cost minimizing demand for $x_{l,t} \in \{h_{l,t}, ex_{l,t}, wim_{l,t}\}$ relative to total demand $X_t^j \in \{H_{l,t}, EX_{l,t}, WM_{l,t}\}$

$$x_{l,t} = \left(\frac{p_{l,t}}{P_t^j}\right)^{-\phi} \cdot X_t^j \rightarrow \tag{2.16}$$

where $p_{l,t} \in \{ppi_{l,t}, ipi_{l,t}^{\neq j}, xpi_{l,t}\}$ and $P_t^j \in \{PPI_t^j, IPI_t^{\neq j}, XPI_t^j\}$.

2.3.1 Sticky price firms

Distribution firms are given a chance to change prices with exogenous probability, $1-\kappa$. Distribution firms set an optimal price as a markup over a weighted average of future prices. Consider the distribution firms targeting the domestic sector.

$$\overline{ppi}_t^j = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j H_{t+n}^j PPI_{t+n}^{j\phi}\right] \cdot MCY_{t+n}}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j H_{t+n}^j PPI_{t+n}^{j\phi}\right]} \tag{2.17}$$

where τ is defined as a subsidy on production provided to potentially offset monopoly power. The dynamics of producer prices follows

$$PPI_t^{j(1-\phi)} = (1-\kappa)\overline{ppi}_t^{j(1-\phi)} + \kappa PPI_{t-1}^{j(1-\phi)} \tag{2.18}$$

The regional export distribution sector prices in international dollars. The optimal price is

$$\overline{ipi}_t^j = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi}\right] \cdot \frac{MCY_{t+n}^j}{S_{t+n}^j}}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi}\right]} \tag{2.19}$$

$$IPI_t^{j(1-\phi)} = (1-\kappa)\overline{ipi}_t^{j(1-\phi)} + \kappa IPI_{t-1}^{j(1-\phi)} \tag{2.20}$$

The global export distribution sector also prices in international dollars. The optimal price is

$$\overline{xpi}_t^j = \tau \frac{\phi}{\phi - 1} \frac{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j WM_{t+n}^j XPI_{t+n}^{j\phi}\right] \cdot \frac{MCV_{t+n}^j}{S_{t+n}^j}}{\sum_{n=0}^{\infty} (\beta\kappa)^n \left[\Omega_{t+n}^j WM_{t+n}^j XPI_{t+n}^{j\phi}\right]} \tag{2.21}$$

$$XPI_t^{j(1-\phi)} = (1-\kappa)\overline{xpi}_t^{j(1-\phi)} + \kappa XPI_{t-1}^{j(1-\phi)} \tag{2.22}$$

2.4 Global Demand

The global demand for country j exports is an isoelastic function of relative costs:

$$WM_t^j = f \cdot \left(\frac{XPI_t^j}{P_t^W} \right)^{-\varsigma} \cdot Y_t^W \tag{2.23}$$

2.5 Market Equilibrium

Goods market equilibrium implies

$$\begin{aligned} \int \{ h_{l,t} + ex_{l,t} \} \, dl &= Y_t^j \\ DH_t^j \cdot H_t^j + DX_t^j \cdot EX_t^j &= Y_t^j \end{aligned} \tag{2.24}$$

$$DH_t^j \equiv \left[\int \left(\frac{ppi_{l,t}}{PPI_t^j} \right)^{-\phi} dl \right] \quad DX_t^j \equiv \left[\int \left(\frac{ipi_{l,t}}{IPI_t^{\neq j}} \right)^{-\phi} dl \right] \tag{2.25}$$

and

$$\begin{aligned} \int \{ wim_{l,t} \} \, dl &= V_t^j \\ DW_t^j \cdot WM_t^j &= V_t^j \end{aligned} \tag{2.26}$$

$$DW_t^j \equiv \left[\int \left(\frac{xpi_{l,t}}{XPI_t^j} \right)^{-\phi} dl \right] \tag{2.27}$$

External interest rates are set at a risk premium over the exogenous interest rate r_t. The risk premium is a decreasing function of wealth, B_t^j .

$$1 + r_t^j = \Lambda_t^R \cdot \{ 1 + (r \cdot e^{-\eta B_t^j}) \} \tag{2.28}$$

where Λ_t^R is an external interest rate. Domestic interest rates follow a modified Taylor Rule with persistence.

$$1 + i_t^j = (1+i)^{1-\chi_i} \left(1 + i_{t-1}^j \right)^{\chi_i} \left(\frac{P_t^j}{P_{t-1}^j} \right)^{\chi_\pi (1-\chi_i)} \left\{ \frac{S_t^j}{S_t^{\neq j}} \right\}^{\chi_S (1-\chi_i)} \lambda_t^j \tag{2.29}$$

where λ_t^j, is a monetary policy shock. The focus price for monetary policy $P_t^j \in \{ CPI_t^j, PPI_t^{\neq j}, S_t^j \}$

depends on the policy experiment. We also allow a competitive devaluations component, in which monetary policy adjusts according to the gap versus the regional trading partner, $\frac{S_t^j}{S_t^{\neq j}}$.

3 Calibration and shocks

To the extent possible, we calibrate the model with parameters within the range of standard business cycle studies. The inter temporal elasticity of substitution, $\zeta = 1$, is consistent with log preferences. The Frisch elasticity of labor supply, θ, is set equal to 1. The parameter Γ is normalized so steady state employment is $L = 1$. The subjective discount factor is set, $\beta = .99$, consistent with an annualized interest rate near 4%. We follow Backus , Kydland and Kehoe (1992) in setting the Armington elasticity including: the elasticity of substitution between regional and global goods, $\xi = 1.5$; the substitutability between domestic and imported goods in regional consumption, $\psi = 1.5$; and the substitutability of domestic and regional goods in the export platform's production is $\nu = 1.5$. The elasticity of substitution between differentiated goods, $\phi = 11$, consistent with an markup of 10% gross of subsidy. We assume a subsidy, $\tau\frac{\phi}{\phi-1} = 1$, so net steady state markup is zero. We set price stickiness so that prices adjust on an annual average basis, $\kappa = .75$. We calibrate around a zero inflation, zero current account steady state with the risk premium parameter set just large enough to ensure long-term convergence, $\eta = -.0001$. We calibrate the shares of the model so that total exports are 50% of GDP and exports to the regional trading partner are 50% of exports. This implies $a = b = d = .75$. We normalize the foreign price level to unity, $P^W = 1$; the size of demand from the global economy, $f \cdot Y^W$ is set so that the bilateral trade balance is zero at a real exchange rate of 1.

The policy parameter $\{\chi_i, \chi_\pi, \chi_S\}$ will be set according to the policy experiment. Our benchmark interest rate smoothing parameter is $\chi_i = .75$ corresponding to the degree of price stickiness.

3.1 Global Interest Rate Shocks

We consider the response of the economy to an external interest rate shock that affects both economies. The external shock follows an AR(1) process:

$$\ln \Lambda_t^R = \rho^R \cdot \ln \Lambda_{t-1}^R + \varepsilon_t^R \tag{3.1}$$

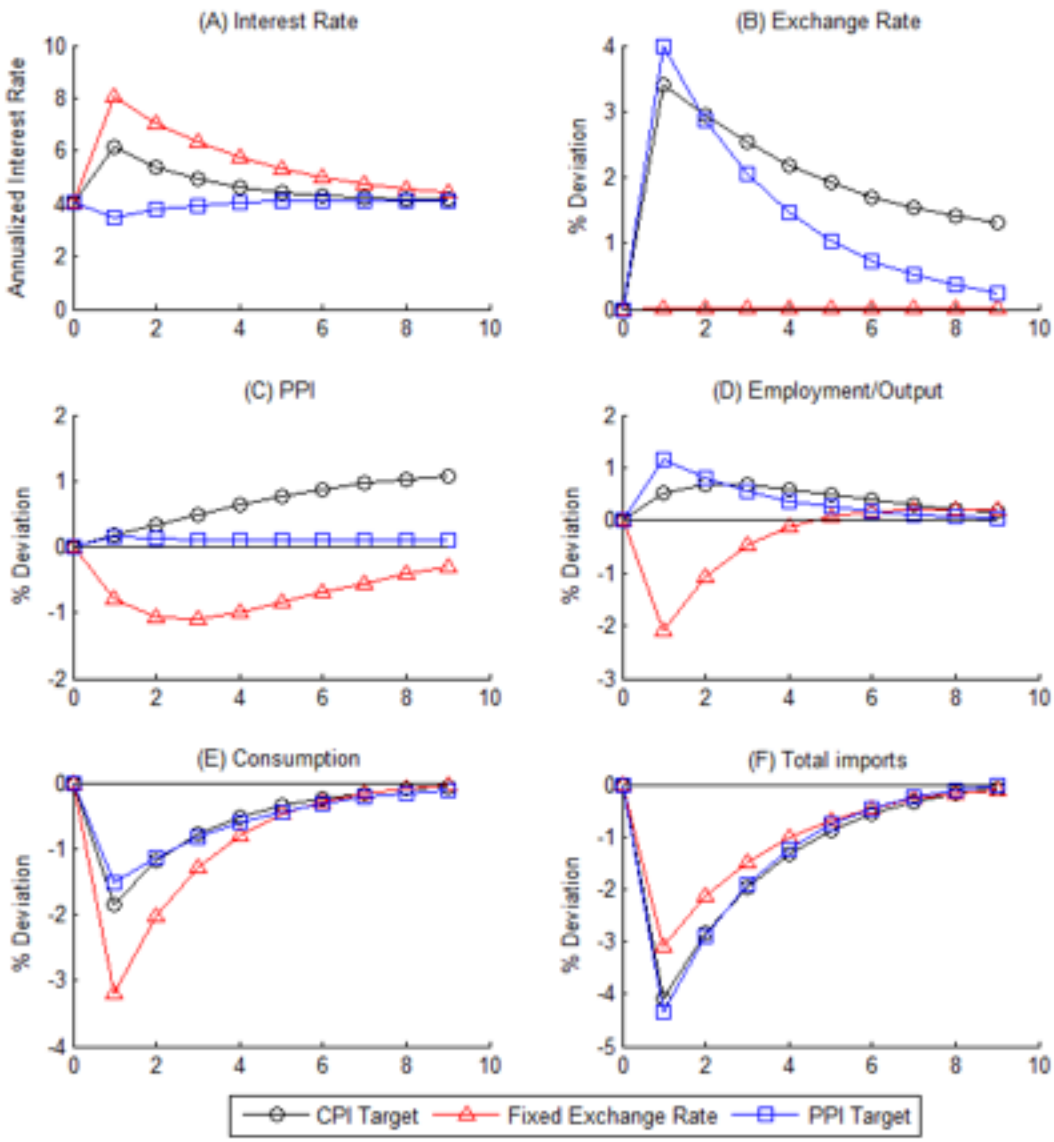
We calibrate the auto-correlation, $\rho^R = .75$, to the degree of domestic interest rate persistence and examine the case of a shock, $\varepsilon_t^R = .01$, that raises the real interest rate (ceteris parabis) by 100 basis points or annualized 4%. We consider three possible policy responses. The Inflation Target case assumes a Taylor rule type focus on the CPI inflation rate, $P_t^j = CPI_t^j$, and $\chi_\pi = 1.5$. In a second case, we model a fixed exchange rate with $P_t^j = S_t^j$, and $\chi_\pi = 5000$. In a third case, we model a Producer Price target which sets $P_t^j = PPI_t^j$, and $\chi_\pi = 5000$ which focuses directly on the sticky price. We set $\chi_S = .00001$ to allow for long-term stationarity in the relative exchange rate between regional trading partners. Note that we model the shock as affecting both countries symmetrically and each country responding with identical policy rules. Therefore, each economy will have identical responses to the external shock.

A persistent increase in the external interest rate will require a real depreciation for both small economies. The real depreciation can occur through some combination of exchange rate depreciation or nominal deflation. Figure 3.1, Panel A shows the adjustment of the nominal interest rate (reported in annualized terms). The required policy response under a Fixed Exchange Rate will be to match the rise in external interest rates on a one-for-one basis. Maintaining a soft CPI inflation target will allow for a milder increase in interest rates. To maintain a level for the Producer Price Index, the central bank must cut interest rates.

As shown in Figure 3.1, Panel B, the spot exchange rate depreciates in the absence of central bank commitment to an exchange rate peg. Either type of domestic inflation target will allow for an exchange rate depreciation. The CPI Inflation Target somewhat smoothes the exchange rate in the short-run but allows for a long run nominal expansion so the exchange rate adjusts more persistently. Panel C shows the response of the producer price index, PPI. Under a fixed exchange rate, real depreciation requires a persistent fall in the price level. Under the CPI Inflation Target, the smoothing of the CPI allows the PPI to remain stable initially, though over time there is some inflation.

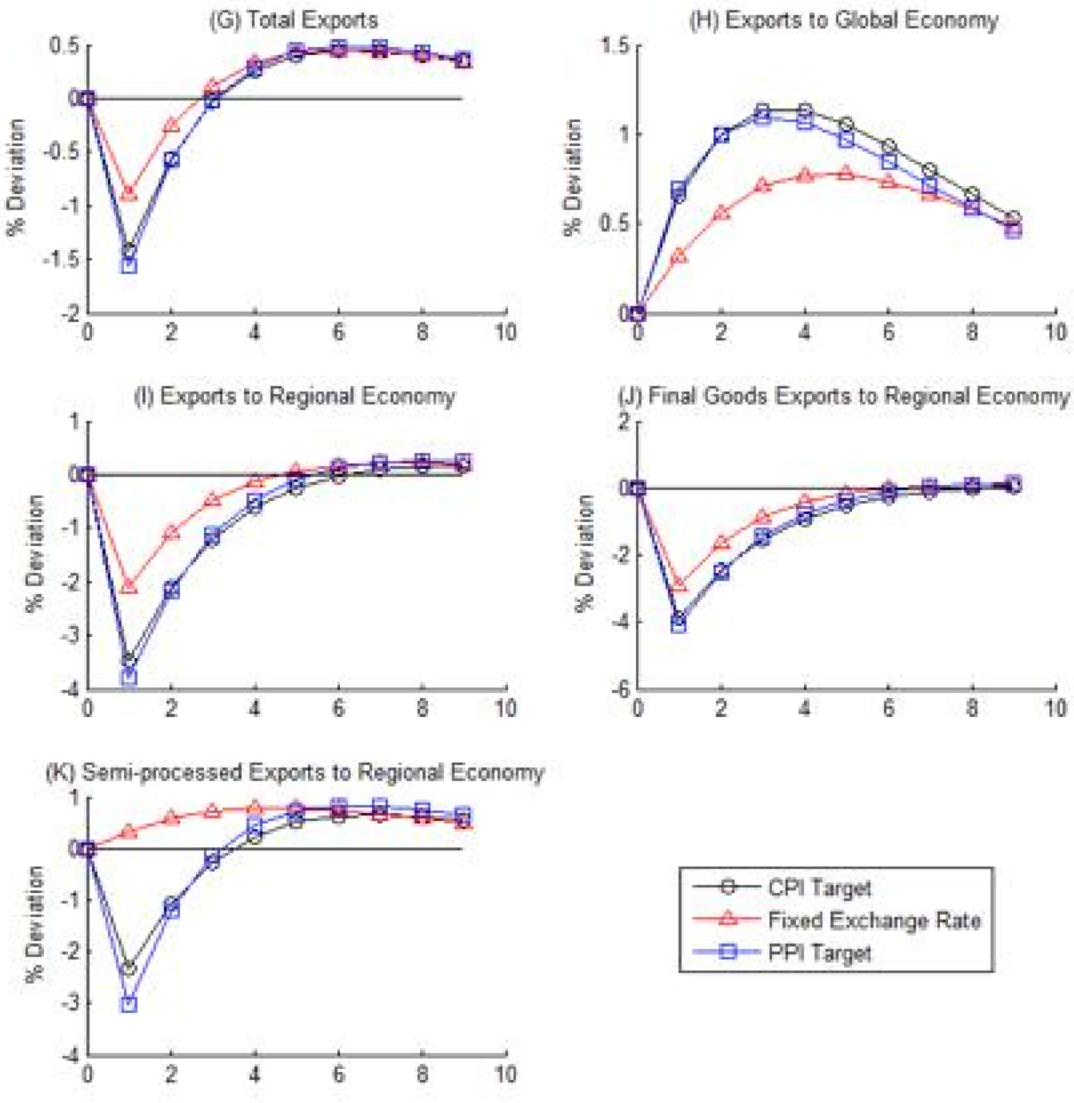
The implications for the real side of the economy can be seen in Panel D, which shows the response of employment, L_t, or equivalently output, Y_t. Flexible exchange rates avoids deflation entirely. As a result, the effect of the shock is expansionary on domestic output (partially due to the income effect on labor supply). By contrast, the Fixed Exchange rate regime requires the contraction to occur entirely through internal deflation. The deflationary environment leads to a persistent contraction in output. The soft CPI Inflation Target allows for a smoother nominal expansion and, therefore, a smoother real expansion. Panel E shows the response of aggregate consumption. The nominal contraction and sharper rise in real interest rates required under the Fixed exchange rate leads to the largest contraction in domestic consumption expenditure. CPI inflation targeting and the Producer Price target lead to roughly similar contractions in consumption.

Figure 3.1



Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three monetary policy rules: a) a standard CPI targeting interest rate rule; b) a fixed exchange rate with the global currency; c) a rule that stabilizes the domestic PPI. This part shows the response of domestic interest rates and exchange rate, producer prices, domestic output, consumption and imports.

Figure 3.1 *– cont.*



Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three monetary policy rules: a) a standard CPI targeting interest rate rule; b) a fixed exchange rate with the global currency; c) a rule that stabilizes the domestic PPI. This part shows the response of aggregate exports, exports to the global and regional economies, and exports by use

As shown in Panel F, there is a large decline in imports under all monetary policies for two potential reasons. First, aggregate consumption demand falls due to the contraction. Second, all imports are priced in international dollars; a depreciation against the global economy will pass through into import prices immediately, inducing a switch away from imports. Note that the second factor seems more important. The decline in imports is less severe under fixed exchange rates, though domestic demand contracts more sharply under that policy response. The exchange rate depreciation under the flexible exchange rate regimes such as the CPI Inflation and PPI Target tilt the consumption basket away from imports.More surprisingly, exchange rate depreciation also leads to a contraction in exports. Figure 3.1, Panel G shows the response of exports. Note that under all the policy regimes

there is a temporary decline in exports for three periods followed by a mild expansion. An explanation for this surprising result can be seen by examining the response of different types of exports. Panel H shows the response of exports to the global economy and Panel I shows the response of exports to the regional trading partner (which are also, symmetrically, imports from the regional trading partner). Under each monetary policy, exports to the global economy, WM, expand persistently. The real exchange rate depreciation reduces the relative price of domestic goods, increasing demand for domestic exports. Because exports are priced in global dollars, reduced costs pass through into prices only slowly. Under flexible exchange rates, the rapid exchange rate depreciation passes through very quickly into export prices and the exports to the global economy respond more sharply. Deflation of domestic prices under fixed exchange rates is slower due to sticky domestic prices, so the increase in exports to the global economy are milder under the Fixed Exchange Rate rule.

At the same time, exports to the regional economy decline under all monetary policies for two reasons. First, there is a decline in aggregate demand for all final goods in the region. Second, the exchange rate depreciation perversely makes importing goods within the regional economy more expensive as they are priced in international dollars. This causes demand to shift away from regional goods. Note that the latter substitution effect appears to be more important. Regional exports decline most sharply under the flexible exchange rate rule which features a smaller decline in demand but a significantly more dramatic exchange rate depreciation. A stable exchange rate response also stabilizes intraregional trade.

Regional exports are either used as final goods or for materials for the export platform. Regional exports for final use unambiguously contract following the rise in external rates (see Panel J). This occurs due to a combination of the decline in consumption, exacerbated by potential exchange rate depreciation. The response of regional exports for processing is more policy dependent (see Panel K). There are two different effects. First, the overall level of final products exported to the global economy increases which, in turn, increases demand for inputs from the regional trading partner. However, an exchange rate depreciation instantly makes imports priced in global dollars more expensive. Under fixed exchange rates, the first channel alone applies and the exports for regional processing increase. Under the flexible exchange rate regimes, the sharp exchange rate depreciation leads to the second channel dominating and exports for regional processing decrease.

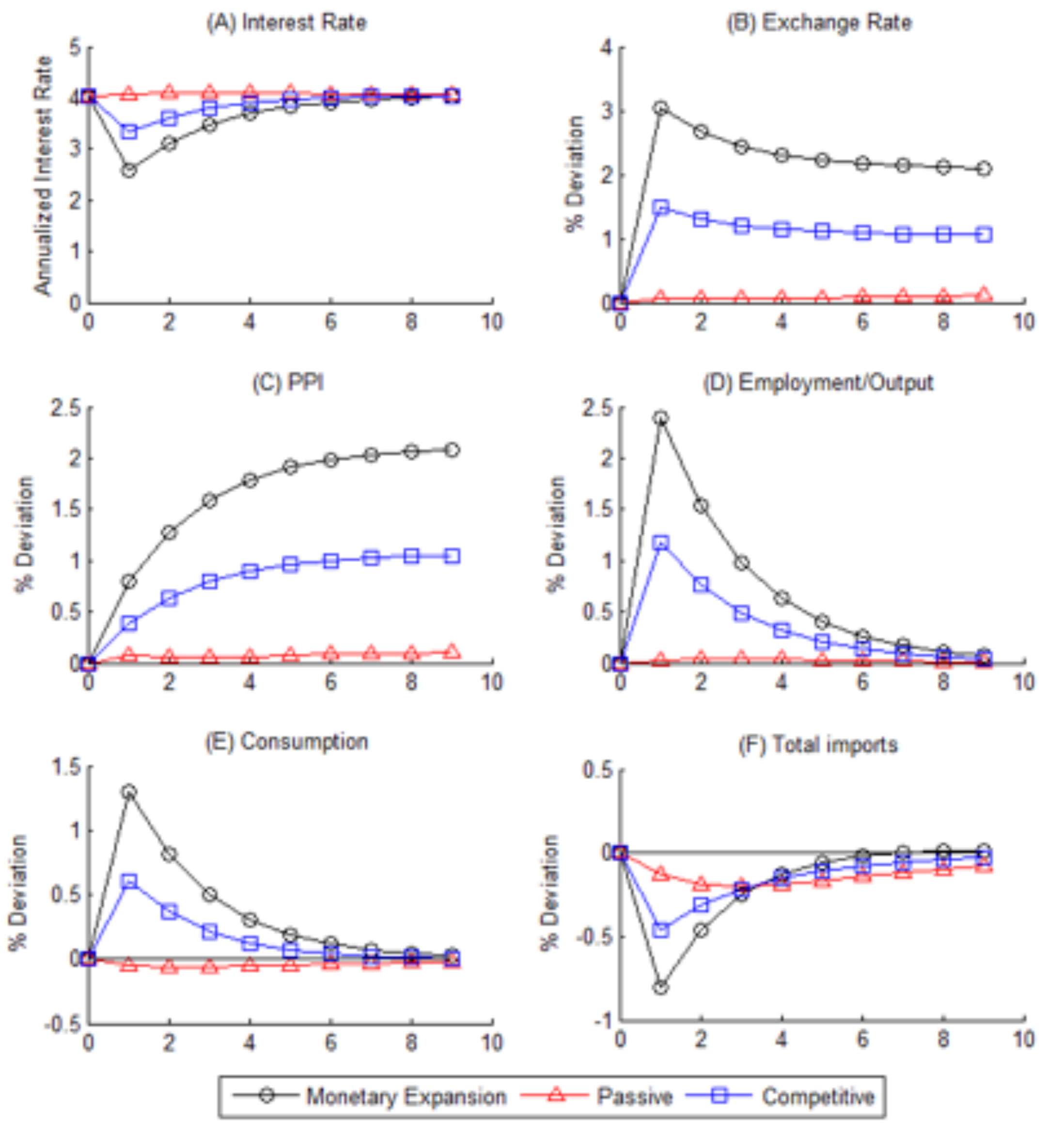
3.2 Domestic Monetary Policy Shocks

In this section, we consider the effect of an exogenous monetary policy expansion in Country A. We examine the effect of a one time shock to the interest rate rule at period 1, such that $\lambda^A_{t=1} = .99$, equivalent to a (ceteris parabis) 4% decline in annualized interest rates. Due to persistence in the interest rate rule, this leads to a persistent decline in the nominal interest rate in Country A. Figure 3.2 shows the response of the economy to a monetary policy shock in one country under two possible assumptions about the monetary policy rule of country B. First, we assume country B implements a policy following a CPI inflation target with $P_t = CPI_t$, $\chi_i = .75$, $\chi_\pi = 1.5$, and $\chi_S = .00001$. Beyond responding to any changes in the domestic CPI, the *Passive* central bank will not respond to monetary expansion from its trading partner. We also examine the case when the country B engages in a competitive devaluation with $\chi_S = 50000$. This implies that the interest rates of country B tracks the interest rates of country A exactly. When country B acts according to a *Competitive* rule, both countries have identical responses to the shock because both countries implement identical monetary policies.

Figure 3.2 shows the response of Country A and Country B when Country B has a passive policy; Country A is labeled *Monetary Expansion* and Country B is labeled *Passive*. For comparison, we show the symmetrical response of either Country A or Country B when Country B follows a competitive devaluation policy. Figure 3.2, Panel A shows the the extent of the interest rate cut for Country A. Because of the inflationary effects of the shock, the inflation targeting central bank will not fully implement the interest cut implied by the shock. This interest rate cut is persistent due to the interest smoothing parameter. The Passive trading partner's central banks interest rate remains essentially unchanged. Figure 3.2, Panel B shows that Country A experiences a persistent nominal exchange rate depreciation versus the global economy and its passive trading partner; depreciation generates nominal expansion in the PPI as shown in Panel C.

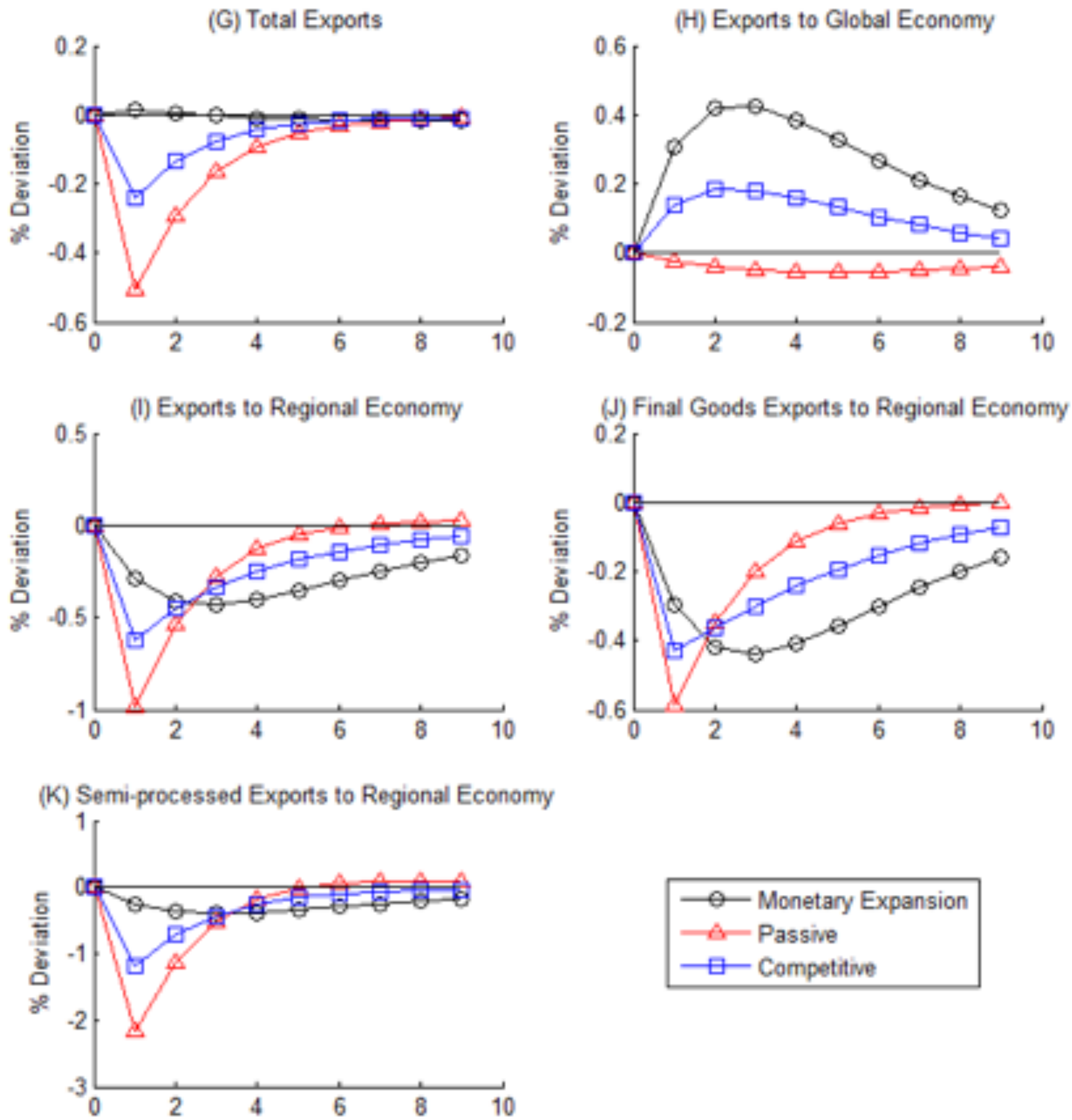
The nominal expansion leads to a real expansion in output and consumption in Country A (see Panel D and E). Note the expansion in output is proportionally stronger than the expansion in consumption. As a result, Country A experiences a sharp decline in imports.

Figure 3.2



Notes: Asymmetric impulse responses of both regional economies to an expansionary interest rate cut in one economy. The response is shown under two policy responses by the regional trading partner. The Monetary Expansion and Passive impulse responses show the response of the economy undertaking monetary expansion along with a passive regional trading partner operating a CPI targeting interest rate rule. The Competitive impulse response shows the outcome when the trading partner pegs its exchange rate to the regional trading partner. Under the Competitive scenario, both economies have the same monetary policy so the outcome is symmetric. This part shows the response of domestic interest rates and exchange rate, producer prices, domestic output, consumption and imports.

Figure 3.2 – *cont.*



Notes: Asymmetric impulse responses of both regional economies to an expansionary interest rate cut in one economy. The response is shown under two policy responses by the regional trading partner. The Monetary Expansion and Passive impulse responses show the response of the economy undertaking monetary expansion along with a passive regional trading partner operating a CPI targeting interest rate rule. The Competitive impulse response shows the outcome when the trading partner pegs its exchange rate to the regional trading partner. Under the Competitive scenario, both economies have the same monetary policy so the outcome is symmetric. This part shows the response of aggregate exports, exports to the global and regional economies, and exports by use.

The exchange rate devaluation versus the global economy increases the cost of imports which are priced in global dollars, so exchange rate pass through is immediate. The rising cost of imports causes the economy to shift to domestic value added. Panel F shows the Passive Country B also experiences a slow contraction in imports from regional trade. Country A experiences an increase in PPI which ultimately passes through to its export prices which reduces its exports to country B.

Panel G shows that the exchange rate depreciation in Country A results in very little net export response. The exchange rate depreciation versus the global dollar only slowly passes through to the price of exports. Thus, exports to the global economy increase only slowly. Likewise, the increased price of goods in Country A will slowly pass through into the price of exports to passive country B. These two effects offset. However, the exchange rate depreciation of country A immediately passes through into the price of imports from country B which are priced in global dollars; this reduces country B's exports relatively sharply despite the absence of a depreciation in its own exchange rate vs the global economy. Country B's exports of final goods fall by proportionally smaller amount than the exports for use in ultimate export as country A's overall final goods spending is expanding while their global exports adjust to only a small degree.

We compare the response of an asymmetric devaluation to one in which the trading partner matches the exchange rate devaluation. As shown, if both countries engage in nominal expansion, the exchange rate depreciation and domestic price expansion will pass through into import prices in both countries heightening the inflation response at any given interest rate path. As a result, the interest rate response is muted relative to the case when the trading partner is passive. Likewise, the exchange rate in each country depreciates, but the depreciation is milder than that seen in country A when the monetary policy is asymmetric. The nominal expansion leads to an increase in employment and output in both countries. Again, this is milder than the expansion observed in country A under asymmetric monetary policy. In both countries, the exchange rate depreciation leads to a contraction in both imports and exports. Each country experiences a mild expansion in exports to the global economy. However, this is dominated by the decline in regional trade.

3.3 Summary of main results and testable implications

Figure 3.3 and Table 1 summarize the main results from the simulation exercises discussed above in the form of testable implications in the data. Irrespective of whether the exchange rate depreciation is caused by a foreign interest rate rise or a domestic cut, total exports to the global economy increase (Figure 3.3, top right panel). In addition, both final

Table 1 – *Model implied impact of interest rate shocks leading to an exchange rate depreciation*

	External interest rise	Domestic interest cut
Domestic exchange rate	Depreciation	Depreciation
Total exports	↓	↓/↑
Exports to regional economy	↓	↓
Final goods exports to regional	↓	↓
Final exports to global economy	↑	↑
Intermediate exports to regional economy	↓/↑	↓
$\frac{\textbf{Value added exports to regional economy}}{\textbf{Value added exports to global economy}}$	↓	↑

and material goods exports to the regional economy decline. For an external interest rate increase, final goods exports decline much more sharply than intermediate ("material") exports that eventually serve final demand in the global economy(Figure 3.3, bottom panels). In conjunction, these results show that in terms of value added exports share of value added exports to the regional trade partner declined much more sharply than the share of value added exports to the global economy.[9] In the next section, we test this prediction in the data, taking US to be the global economy and the rest of the world (excluding Europe and the US) to be the counterpart to the regional economy.

4 Empirical evidence

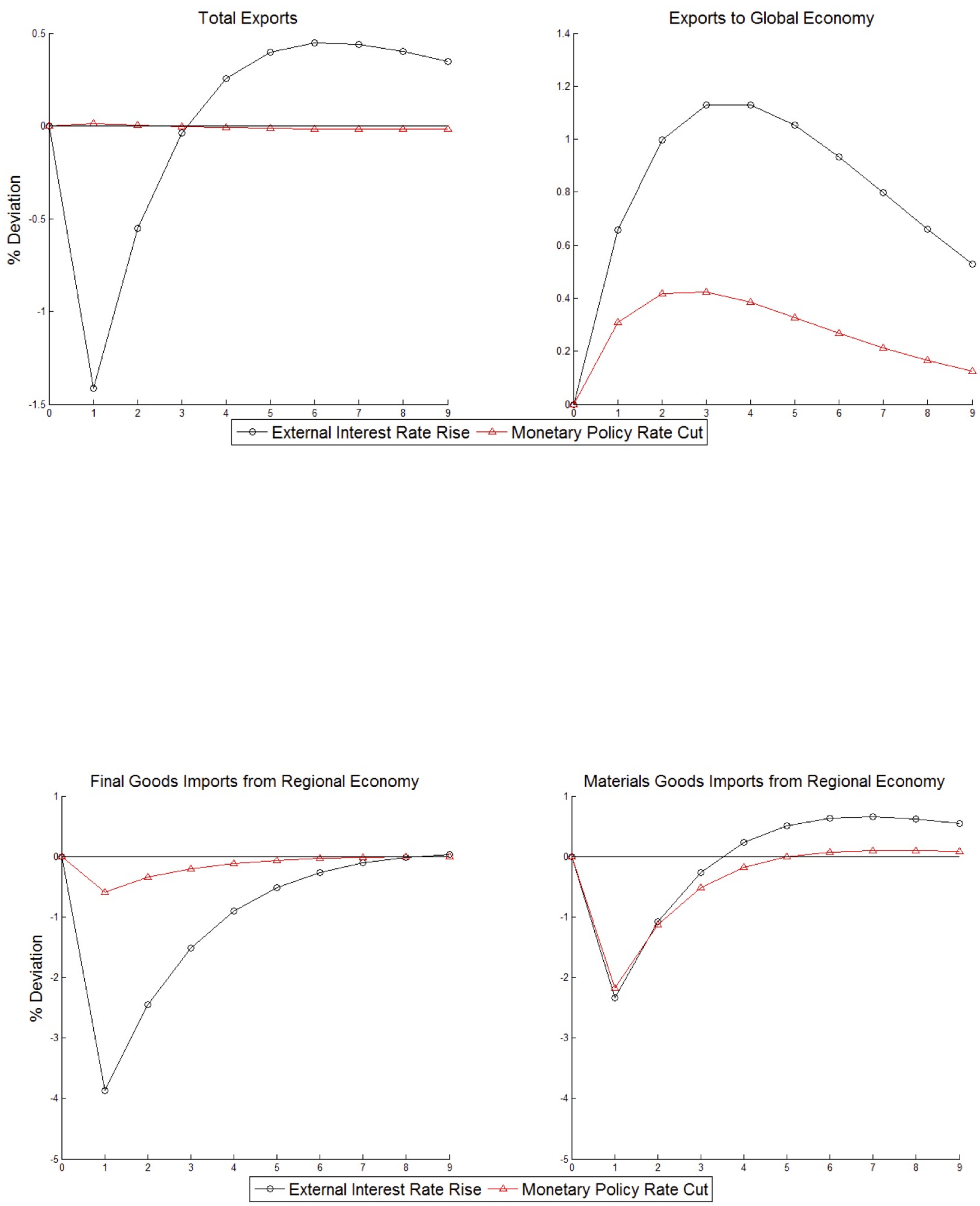
This section evaluates the key prediction of the model regarding the response to trade flows to an external interest rate shock.[10] The typical limitation of standard trade data sources on international trade (such as those available under national balance of payment statistics) is that they are in gross terms, and only capture direct trade between the importer and exporter. They do not capture the growing phenomenon of global value chains as modeled in this paper, where goods cross borders multiple times before being embodied in final goods.

Some data sources do provide a split between intermediate, final and capital goods exports. This is still not sufficient to test models of global value chains, since the classification

[9] As in Johnson and Noguera (2010) value added exports from country A to B is defined as the value added generated by country A that is eventually absorbed as final demand in country B. This may involve one or more border crossings.

[10] We choose to test the predictions of the model for external interest rate shocks as opposed to domestic monetary policy shocks because of complications associated with identifying the latter from time series macroeconomic data, particularly for a large set of emerging market economies.

Figure 3.3 *– Summary of response of trade to two shocks*



still only captures the nature of the trade flow up to the first border crossing, and not beyond. For example, all intermediate goods exports in our model end up in export platforms, and are eventually re-exported to the global economy. In the data however, majority of exports classified as "intermediate" are not re-exported, but end up being consumed by he direct importer. (see Appendix Table 3).[11]

To overcome this limitation, we use a granular decomposition of exports proposed by Wang, Wei and Zhu (2017 a and b). Their framework decomposes total bilateral exports into gross and value added components, and further categorizes the share that is absorbed in the immediate destination, the share that is reexported (either to third countries or back to the home country). The decomposition also keeps count of the number of border crossings involved. We focus in particular on the value added exports dimension of their decomposition. For each country pair, this decomposition provides the value added generated by one country that is absorbed in the other country as final demand, after single or potentially multiple border crossings and round tripping.

We define the following measures at the country-sector-destination level.

1. VAF: Value added exports (forward) of the country sector that are eventually consumed as final demand in a particular destination country. "Forward" means that this measure includes indirect exports of this sector via other sectors in the same country.

2. VAB: Value added exports (backward) of the country sector that are eventually consumed as final demand in a particular destination country. "Backward" means that this measure includes indirect exports of other sectors within the country via this sector.

3. IVAF: Indirect value added exports (forward) by the country sector to the destination country.

4. IVAB: Indirect value added exports (backward) by the country sector to the destination country.

Indirect value addded export measures the value added from country A that is consumed as final demand in country B, but is not directly exported by country A to country B.

For each of the above four variables (say x), our model predicts that in response to a US interest rate rise, the value of x destined for eventual final consumption in the US should fall by less than the corresponding value for other countries. In other words, if we define the ratio

[11] We further explore the implications of this limitation for our empirical results below.

$$r_x = \frac{x_{\text{sum across all non US countries}}}{x_{US}}; x \in \{VAF, VAB, IVAF, IVAB\} \qquad (4.1)$$

Our main prediction is that r_x should fall in response to US monetary contractions.

Estimation and results

We study the response of r_x changes in the external (US) interest rate using the following empirical specification, a local projection model in the spirit of Jorda (2005):

$$r_{x,t+h}^{i,j}(s) = \alpha^{i,j}(s) + \eta r_{xt-1}^{i,j}(s) + \beta i_{us,t} + \delta X_t + \epsilon_t^{i,j}(s) \qquad (4.2)$$

Here, $r_{x,t+h}^{i,j}(s)$ denotes a measure of trade as defined in equation 4.1 for source country i and sector s, and destination country j. $i_{us,t}$ is the US policy rate, which as is proxied by the shadow rate in Lombardi and Zhu (2014).[12] X_t is a vector of controls and includes contemporaneous and lagged values of changes in US GDP and inflation, the bilateral exchange rate between the importer and the exporter, change in real GDP and inflation of the importer and exporter, change in total imports by the importer, and change in total imports and exports by the importing country with the US, as well as the change in unit labor cost in the exporting country. A quadratic time trend is also included in the regressions. The impulse responses are computed using the local projection method developed in Jorda (2005).[13] To account for the endogeneity concerns emanating from the inclusion of the lagged dependent variable, the regressions are estimated using the GMM estimator based on Arellano and Bond (1992).

The main data source is the world input output database (WIOD).[14] The sample runs from 1995-2011 (annual) and covers 35 sectors in 40 countries (See Appendix D for the full list of countries and sectors). The available sample thus contains 54600 (=40*39*35) bilateral export observations at the sector level for each year. Of these, we exclude ones in which the exporting and the importing country is in Europe, since dollar invoicing in less likely in such cases. That said, the results are robust to including them in the sample.

Figure 4.1summarizes the main results from the estimation of equation 4.2. For both direct and indirect value added exports measures, the ratio r_x declines persistently in

[12] In robustness checks, we also considered a shock component of the us interest rate, compiled by taking the sum of all interest rate moves on around monetary policy announcements, as in Gertler and Karadi (2015).

[13] The large dimension of the dataset (where we have close to a million data points) makes the typical alternative of using vector autoregression less attractive.

[14] See Timmer et al (2015) for a detailed description of the database.

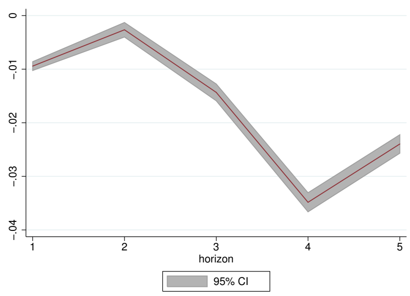
response to a US monetary contraction. This indicates, as predicted by the model, that trade that trade that serves final demand outside the US contracts by more than the global value chain oriented trade that eventually serves final demand in the US.

Boz et al (2018) argue that the role of invoicing may be substantially lower for commodities exports, since their prices are fairly flexible. Indeed, many commodities are traded on organized exchanges where prices fluctuate at a very high frequency. Motivated by this, we attempt to uncover differences across sectors by estimating our baseline empirical model (equation 4.2) by splitting the sample into three broad categories by export sector-primary, secondary and tertiary.[15] Figures 4.2 and 4.3 show the results. We do not find the dynamics for primary sectors, which are dominated by commodities, to be very different from the rest. One reason for this could be that the underlying input–output data used to estimate our value added export decomposition relies heavily on interpolations across sectors (see details on the interpolations, see Timmer el al, 2015), so the measurement of commodities trade in our database may not be as accurate as in direct customs trade data. A second reason for this could be that we can only control for the fact that one of the sectors in a particular bilateral value added trade flow is primary, but it could be the case that other sectors, including manufacturing and services, are involved in the value chain before it reaches the final consumer. In that case, the invoicing channel would still be present in the trade flow even if the value chain originates in a commodity sector.

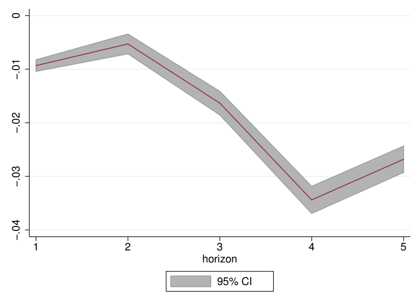
[15] see appendix D for the precise details of this classification.

Figure 4.1 *– Response of value added exports to non US countries and US to US monetary contractions*

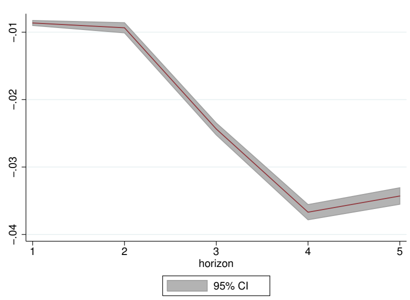
(a) VA_F



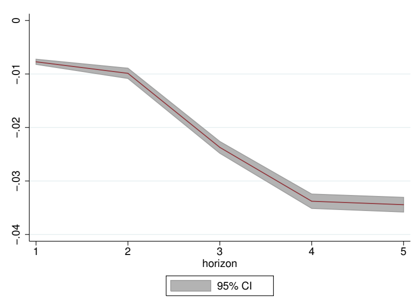
(b) VA_B



(c) IVAF



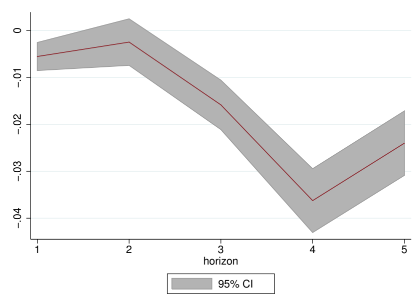
(d) IVAB



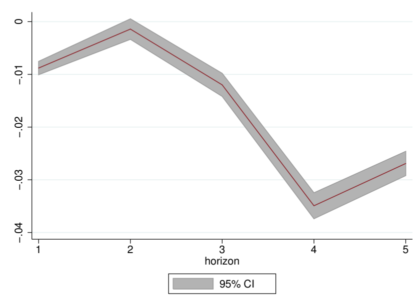
Notes: Each term represents the corresponding ratio as in equation 4.1. In particular, it is the value added exports to all non US countries, divided by value added exports to the US.

Figure 4.2 – *Response of value added exports to non US countries and US to US monetary contractions by sector*

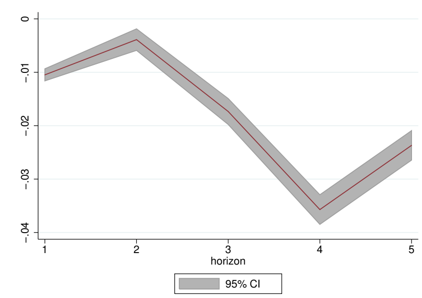
(a) VA_F (primary)



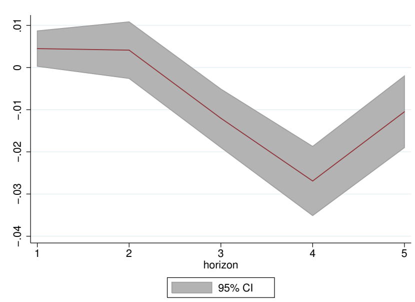
(b) VA_F (secondary)



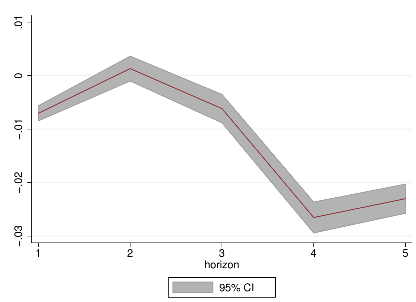
(c) VA_F (tertiary)



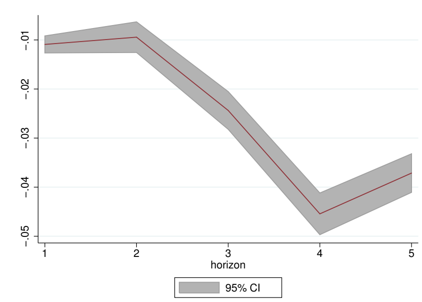
(d) VA_B (primary)



(e) VA_FB(secondary)

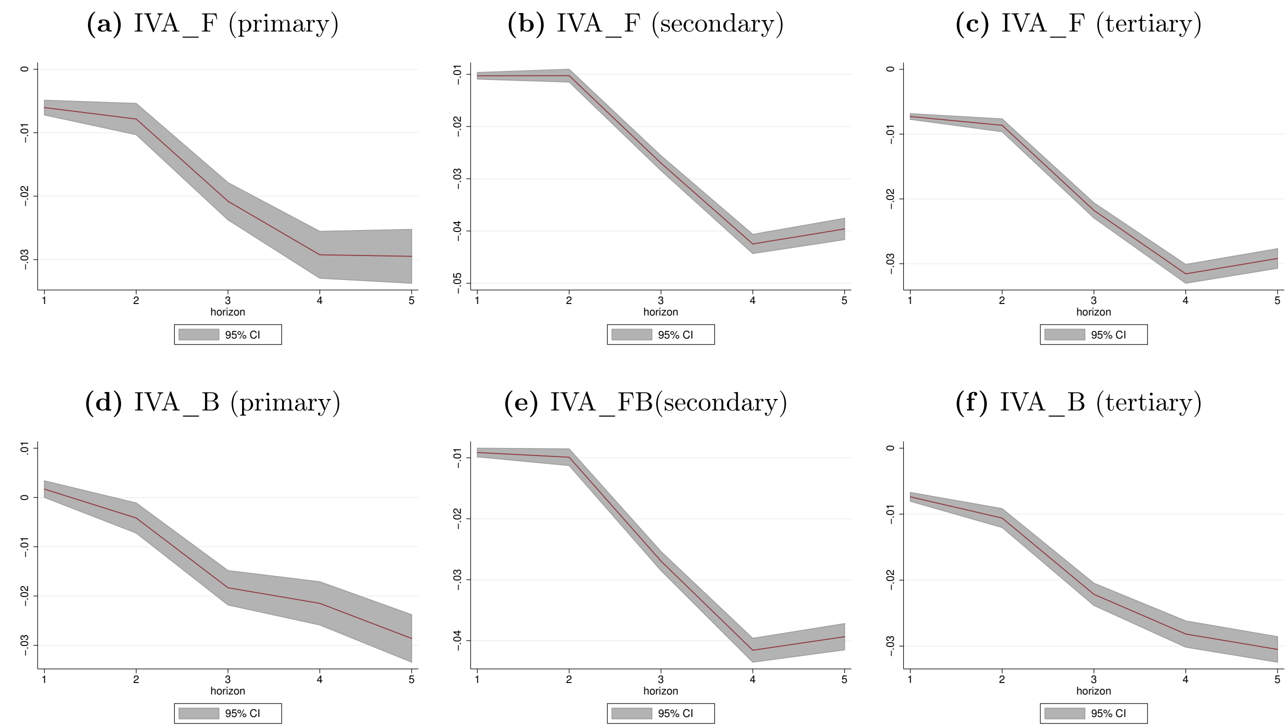


(f) VA_B (tertiary)



Notes: Each term represents the corresponding ratio as in equation 4.1. In particular, it is the value added exports to all non US countries, divided by value added exports to the US.

Figure 4.3 *– Response of indirect value added exports to non US countries and US to US monetary contractions by sector*



Notes: Each term represents the corresponding ratio as in equation 4.1. In particular, it is the value added exports to all non US countries, divided by value added exports to the US.

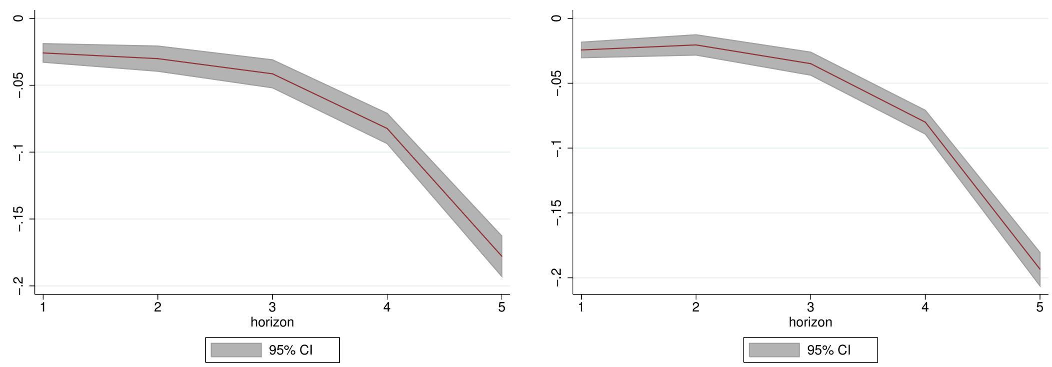
Appendix C conducts a similar exercise using an eight terms decomposition of bilateral intermediate exports from Wang, Wei and Zhu (2013) using an empirical set up similar to the one in this section. This decomposition focuses exclusively on intermediate goods exports,a and charactarises their subsequent journey after cthe first border crossing, where standard trade databases typically stop. The results are broadly in line with the model and with those discussed earlier in the section.

We end this section by highlighting the shortcoming of standard international trade data sources for studying global value chains. 4.4 displays the response of total (left panel) and intermediate (right panel) bilateral exports between non-US countries in response to a monetary contraction in the US obtained using the same specification and controls as in equation 4.2. While both measures of exports decline persistently, there is no discernible difference between the responses, in contrast to the predictions of the model. This indicates that due to the complex nature of global value chains in the data, a mere two way decomposition of trade data into intermediate and final goods trade is not rich enough to capture the dynamics of global value chain related trade.

Figure 4.4 – *Response of total and intermediate bilateral exports from non US exporters to non-US importers in response to a shock*

(a) Total bilateral exports (real)

(b) Total bilateral intermediate goods exports (real)



Notes: Percentage deviations from steady state. The shaded error band is the 95% confidence interval for the pooled sample. Since an export price index is not available in the database, sector level gross output price indices are used to convert nominal values to real ones.

5 Conclusion

Contrary to most mainstream open economy models and empirical investigations, international trade is primarily invoiced in a handful of global currencies, primarily the US dollar, and is dominated by trade in intermediate imports and global value chains. This paper explores the implications of these phenomena for the business cycle dynamics of different types of international trade flows in a general equilibrium setting. To this end, we set up a three-country model which comprises of two small open ("regional") economies which interact with each other and with a large "global" economy through international trade. All economies export final goods to each other which are consumed directly by consumers in the importing country. In addition, recognizing the rising role of trade in intermediate inputs and global value chains in international trade, we also allow the two small open economies to export intermediate goods to one another. These intermediate imports are used by the importer for subsequent processing, and the final product is exported to the global economy, thereby representing a stylized global value chain within the model.

In response to both internal and external shocks, the model has notably different implications for final goods trade on the one hand, and global value chain oriented trade on the other. For example, a monetary contraction in the global economy (US) leads to a depreciation of the currencies of both small open economies. Since all exports, irrespective of their country of origin, are priced in dollars, they become more expensive for the regional economies. Final consumers in these economies therefore substitute away from imports and towards the respective domestically produced goods, leading to a drop in final goods exports between the two small open economies. However, exports tied to global value chains are also affected by the implications of the shock on demand coming from the global economy, which rises in this case due to the appreciation of the global currency in real terms. These trade flows therefore decline by less, and under alternate monetary frameworks (for instance under fixed exchange rates) can even rise.

To test the implications of the model in the data, we exploit the most granular classification of exports available in a multi-country setting to decompose bilateral trade at the sector level for 35 sectors in 40 countries into different components based on the degree of involvement in supply chains and the number of international border crossings involved in the production process. Specifically, focussing on trade flows between two foreign countries in response to changes in US interest rates, we use the decomposition of gross bilateral exports in Wang, Wei and Zhu (2017 a and b) to show that components of international trade flows that are global value chain oriented and eventually service US consumers are less affected than final goods trade or trade flows that are more regional in nature.

Several notable policy implications emerge from these results. For instance, there is an extensive literature arguing in favor of structural benefits of global value chain participation in terms of increase in overall output and productivity.[16] Our paper is complementary to such studies since it explores the business cycle implications of global value chain participation, arguing that they can have a stabilizing effect on exports in the face of external interest rate shocks. This in turn can be an important rationale for countries to promote participation in global value chains through different policy levers like industrial policy and easing restrictions on foreign direct investment, which is typically of the "vertical" type in emerging markets.

Despite our attempts to use GVC data to ensure as close a correspondence between the model and the data as possible, a few qualifications are in order when interpreting the results. First, in the model, an external interest rate rise does not lead to a fall in aggregate demand in the global economy. If we interpret the US interest rate moves as purely exogenous shocks, then they would imply a contraction in aggregate demand in the US. This however would bias the empirical results against the model. The fact that we still find the empirical results to be in line with the model is therefore even more revealing.

Second, the model is kept stylized to highlight key features pertaining to the role of invoicing. We therefore only emphasize qualitative results, both in the model and in the data. A more quantitative assessment of the correspondence between the data and the model would warrant several features including financial frictions and various adjustment mechanisms that

[16] See for instance Kordalska et al (2016), Baldwin and Yan (2014) and Taglioni and Winkler (2016)

have been shown to be important the DSGE estimation literature-see for instance Smets and Wouters 2003, Lubik and Schorfeihde (2005) and Christiano Motto and Rostagno (2014). Relatedly, while we zero in and focus on the role of dollar invoicing in international trade, the dollar also happens to be the currency in which most international financial transactions, including debt contracts, are denominated. In fact, as shown in Gopinath and Stein(2019), the two roles of a dominant currency are complementary. Understanding this role of the dollar, particularly dollar denominated debt, in affecting ordinary and global value chain trades and how this interacts with the mechanisms in the paper that arise through currency invoicing would be a topic of interest for future investigation and of quantifying the effects of shocks on international trade more precisely.

Lastly, the paper focusses exclusively on positive aspects to highlight key mechanisms, the results naturally inspire an exploration of optimal monetary policy in a world with global value chains and currency invoicing frictions. While we do not do a formal welfare analysis, our results do suggest that flexible exchange rates (either through a PPI or CPI target) are likely to be a superior alternative to fixed exchange rates, even with the dominance of global value chains and dollar invoicing. While fixed exchange rates do help cushion the burden on sectors involved in global value chains, this comes at a much higher cost for the rest of the economy which manifests itself in sharper declines in output, consumption and employment.

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Appendix

A Robustness Checks

In this section we compare the response of the benchmark economy to an asymmetric monetary policy shock under a couple of alternate scenarios with regard to price setting and platform export specification.

A.1 Pricing Model

First, we assume the regional distribution firms price in the customer's country currency; only global exporters continue to price in global dollars. For exports to the global economy, prices are sticky in global dollars; for exports to the regional trading partner, the price is in the regional trading partners currency. Relative to the benchmark model, we re-write the price for domestic materials. This model replaces (2.6) and (2.12) with:

$$\frac{CM_t^j}{CR_t^j} = (1-b)\cdot\left(\frac{IPI_t^{\neq j}}{RPI_t^j}\right)^{-\psi} \qquad \frac{VM_t^j}{V_t^j} = (1-d)\cdot\left(\frac{IPI_t^{\neq j}}{MCV_t^j}\right)^{-\nu} \tag{A.1}$$

Replace pricing equation (2.19)

$$\overline{ipi}_t^j = \tau\frac{\phi}{\phi-1}\frac{\sum_{n=0}^{\infty}(\beta\kappa)^n\left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi}\right]\cdot MCY_{t+n}^j\cdot\frac{S_{t+n}^{\neq j}}{S_{t+n}^j}}{\sum_{n=0}^{\infty}(\beta\kappa)^n\left[\Omega_{t+n}^j EX_{t+n}^j IPI_{t+n}^{j\phi}\right]} \tag{A.2}$$

Optimal pricing is a weighted average of domestic marginal cost converted to the trading partner's currency. The principal difference in the pricing is the exchange rates in global dollars do not immediately pass through into inter-regional trade. We refer to this as the *Local Currency Pricing (LCP)* model.

An alternative pricing mechanism would be when every distribution firm prices in their own currency. This changes the demand curves, equilibrium and pricing. Replace the demand for imports (2.6) and (2.12) and import demand (2.23) with :

$$\frac{CM_t^j}{CR_t^j} = (1-b)\cdot\left(\frac{S_t PPI_t^{\neq j}}{S_t^{\neq j} RPI_t^j}\right)^{-\psi}$$

$$\frac{VM_t^j}{V_t^j} = (1-d)\cdot\left(\frac{S_t PPI_t^{\neq j}}{S_t^{\neq j} MCV_t^j}\right)^{-\nu}$$

$$WM_t^j = f\cdot\left(\frac{XPI_t^j}{S_t^j P_t^W}\right)^{-\varsigma}\cdot Y_t^W$$

Replace equilibrium (2.24) with:

$$CH_t^j + VH_t^j + CM_t^{\neq j} + VM_t^{\neq j} = H_t^j = \left[\int h_{l,t}^{\frac{\phi-1}{\phi}} dl\right]^{\frac{1}{1-\phi}} = \frac{Y_t^j}{DH_t^j} \tag{A.3}$$

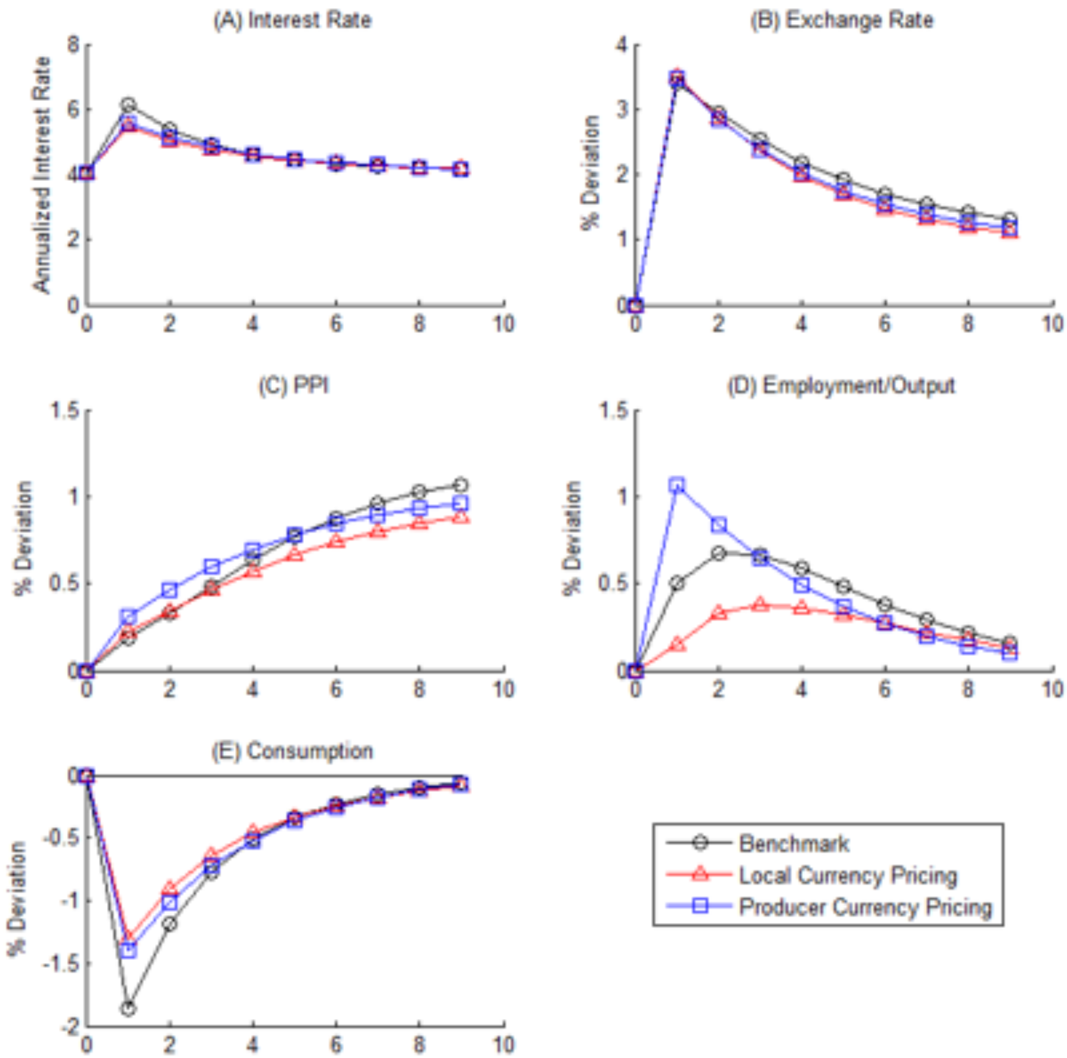
and replace pricing (2.21)

$$\overline{xpi}_t^j = \tau\frac{\phi}{\phi-1}\frac{\sum_{n=0}^{\infty}(\beta\kappa)^n\left[\Omega_{t+n}^j WIM_{t+n}^j XPI_{t+n}^{j\phi}\right]\cdot MCV_{t+n}^j}{\sum_{n=0}^{\infty}(\beta\kappa)^n\left[\Omega_{t+n}^j WIM_{t+n}^j XPI_{t+n}^{j\phi}\right]} \tag{A.4}$$

Optimal pricing of global exports are a weighted average of domestic currency marginal cost. All exchange rates passthrough into import prices immediately. We refer to this as the *Producer Currency Pricing (PCP)* model.

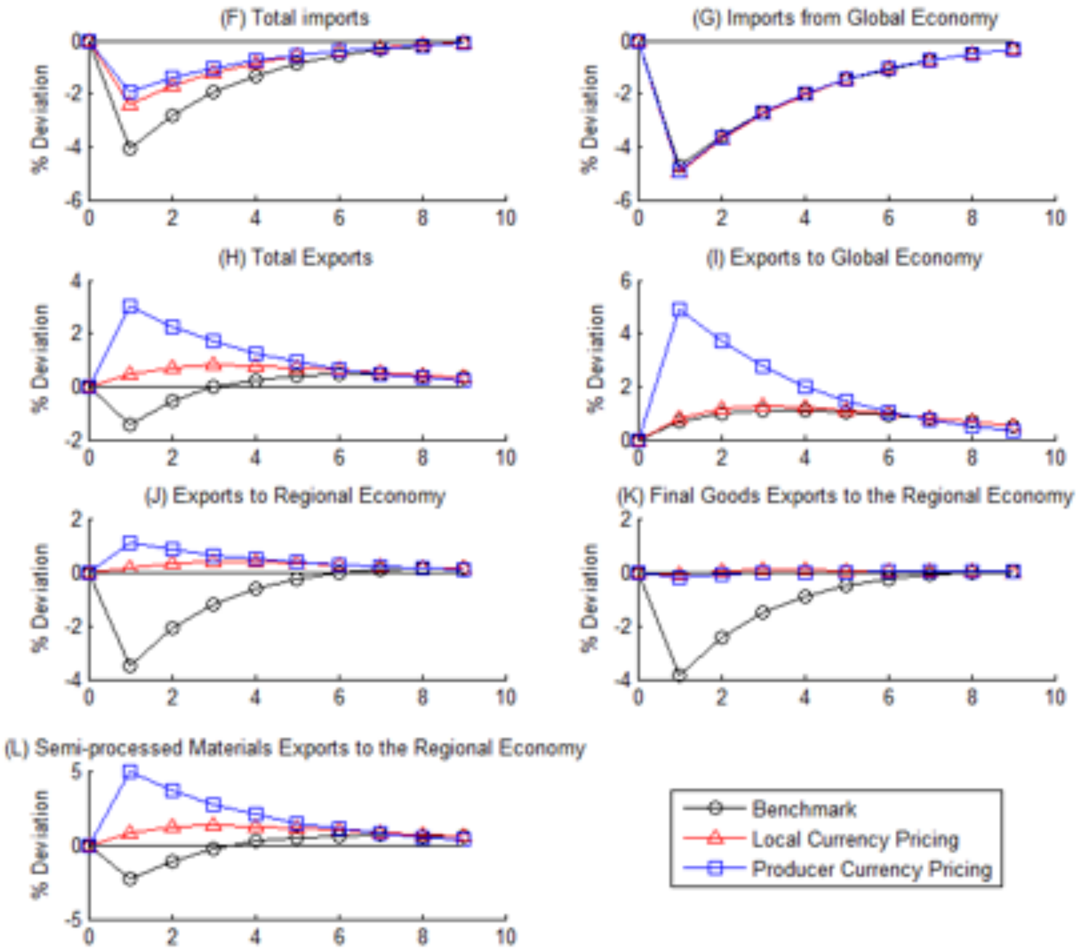
Figure A.1 shows the response of each regional economy to an external interest rate shock under the different pricing models. The figure compares the response under the Local Currency Pricing and Producer Currency Pricing models with the response under the benchmark global Dollar Currency Pricing model. The rise in the external interest rate leads to an exchange rate depreciation under all pricing models as in the benchmark. The depreciation passes through into import prices from the global economy and therefore into the CPI. The policy rate rises temporarily with CPI inflation. The nominal expansion under all specifications leads to a persistent increase in producer prices. This leads to an expansion in employment and output under all pricing models though there is some difference among the pricing models. Consumption declines under all specifications due to the increase in real interest rates. Under Local Currency Pricing, there is little incentive to switch toward domestic value added in final goods consumption, so the impact on domestic output is mitigated relative to the Benchmark model. As shown in the next figure, there is a sharp export

Figure A.1



Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three specifications of the pricing of regional trade: a) the Benchmark dollar currency pricing; b) Local Currency Pricing in the currency of the importer; c) Producer Currency Pricing in the currency of the exporter. This part shows the response of domestic interest rates and exchange rates with the global currency, producer prices, domestic output, and consumption.

Figure A.1 *– cont.*



Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three specifications of the pricing of regional trade: a) the Benchmark dollar currency pricing; b) Local Currency Pricing in the currency of the importer; c) Producer Currency Pricing in the currency of the exporter. This part shows the response of aggregate imports, imports from the global economy, aggregate exports, exports to the global and regional economies, and regional exports by use.

expansion under Producer Currency Pricing which leads to a sharp increase in domestic output.

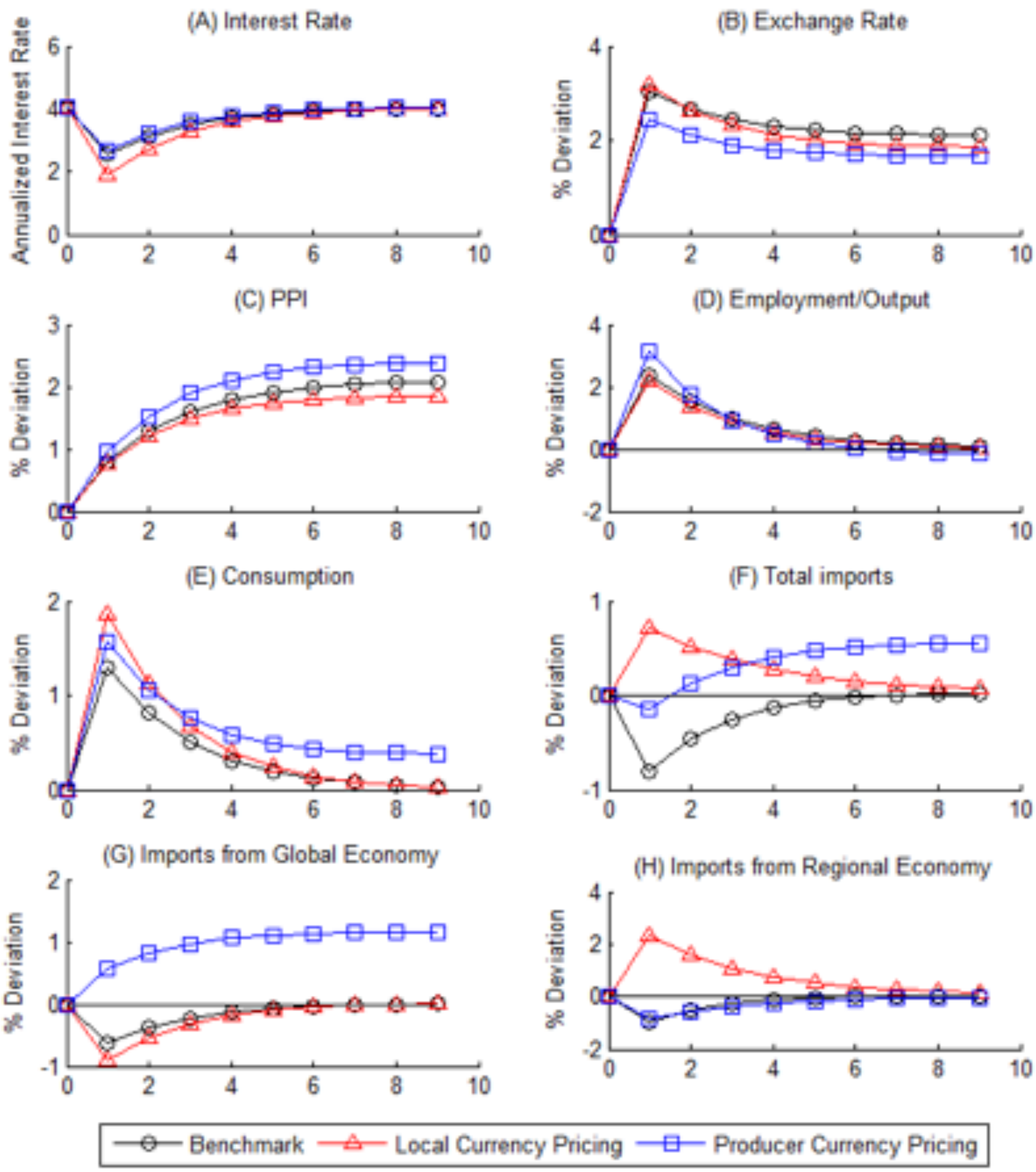
There are sharper differences in the dynamic response of international trade patterns. In Figure A.1, Panel F we see the decline of aggregate imports is stronger in the benchmark model than in the other specifications. Panel G shows that the response of imports from the Global economy are nearly identical suggesting differences in imports are due to differences in the response of regional trade. The response of aggregate exports is contractionary in the benchmark model, but expansionary in the other specifications (see Panel G). The much larger expansion in exports (see Panel H) that occurs under Producer Currency Pricing is due to the expansion in exports to the global economy (see Panel I). The exchange rate depreciation makes exports to the global economy immediately more competitive. Under the Benchmark and Local Currency Pricing specifications, exports to the global economy expand only mildly.

There are stark differences in the response of exports to (and imports from) the regional trading partner (see Panel J). Under the Benchmark, regional exports decline because of the immediate pass-through of the importing partner's economy against the global currency which makes regional exports priced in global currency more expensive. By contrast, under PCP and LCP regional exports mildly expand. This is not true for final goods; since the two regional trading partners do not depreciate or appreciate against each other, the effects on regional final goods exports are small (see Panel K). However, exports of materials expand under PCP due to their use in exports to the global economy which are expanding. Under LCP, exports of materials to the regional value chain expand mildly to suit the mild expansion of global imports (See Panel L).

We also consider the effect of a 1% ceteris parabis monetary shock to Country A's CPI targeting rule with partner Country B engaging in a passive CPI target. Figure A.2 shows the response of Country A to the monetary shock under the different pricing models. The figure compares the response under the Local Currency Pricing and Producer Currency Pricing models with the response under the benchmark global dollar currency pricing model. Though there are minor differences in the aggregate response under the different pricing models, the principal difference is in the response of the pattern of international trade (see Figure A.2 Panel A-E).

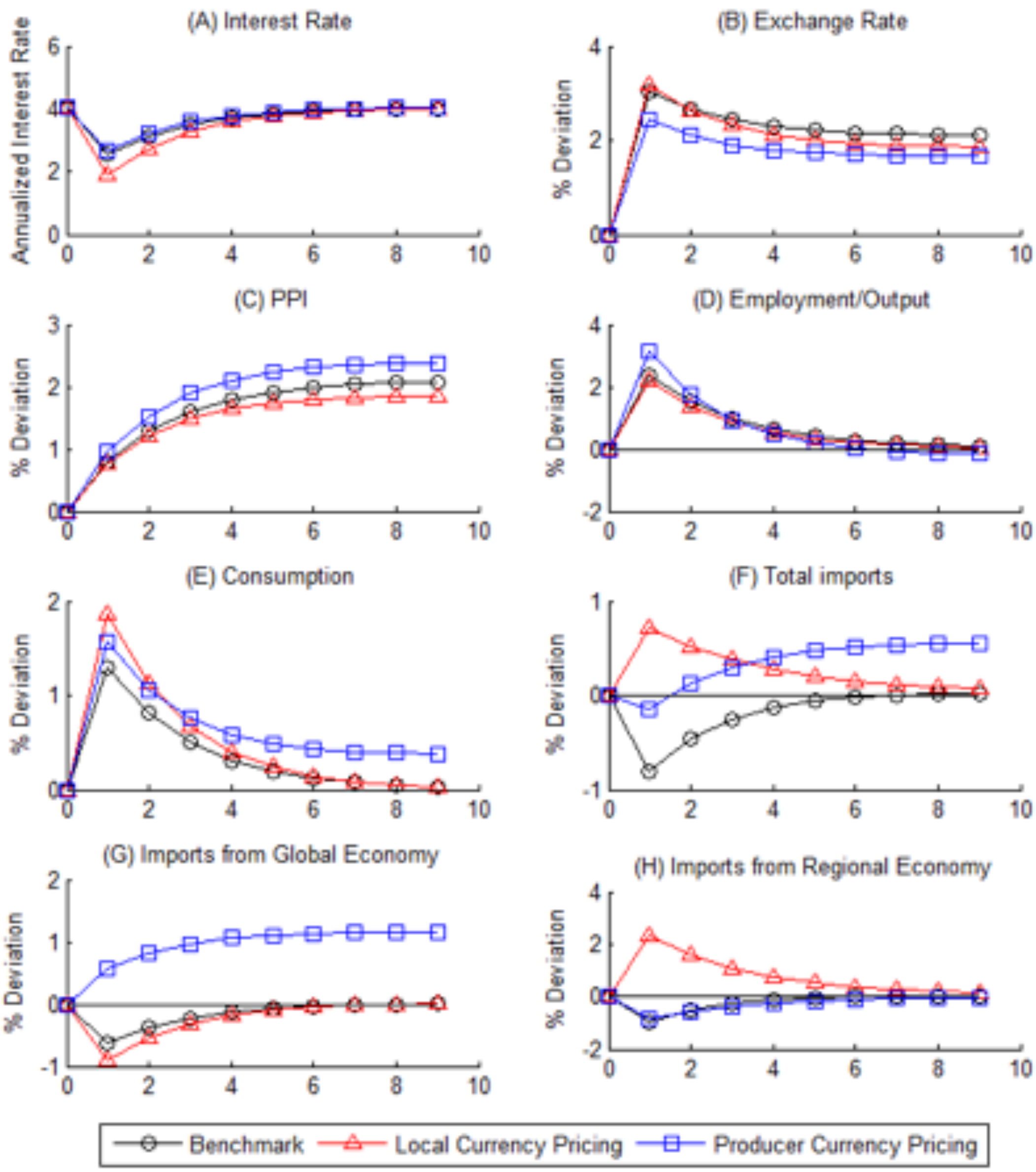
In Figure A.2, Panel F we see the response of imports is qualitatively different under the different pricing models. Under the Benchmark, imports contract; under Local Currency Pricing, imports expand; while under Producer Currency Pricing, there is a mild initial contraction coupled with a longer term expansion. There are two channels impacting imports. First, aggregate consumption demand expands in Country A (see panel E). Second,

Figure A.2



Notes Impulse responses of a regional economy to an expansionary interest rate cut. The response of the small open economy engaging in expansionary monetary policy is examined under three specifications of the pricing of regional trade: a) the Benchmark dollar currency pricing; b) Local Currency Pricing in the currency of the importer; c) Producer Currency Pricing in the currency of the exporter. These figures assume a passive CPI target by the other trading partner. This part shows the response of domestic interest rates and exchange rates with the global currency, producer prices, domestic output, and consumption. In addition, this figure shows total imports, imports from the global economy and imports from the regional economy.

Figure A.2 – *cont.*



Notes: Impulse responses of a regional economy to an expansionary interest rate cut. The response of the small open economy engaging in expansionary monetary policy is examined under three specifications of the pricing of regional trade: a) the Benchmark dollar currency pricing; b) Local Currency Pricing in the currency of the importer; c) Producer Currency Pricing in the currency of the exporter. These figures assume a passive CPI target by the other trading partner. This part shows the response of regional imports by use, aggregate exports, exports to the global and regional economies, and regional exports by use.

the exchange rate relative to the international economy (and the passive regional trading partner, Country B) depreciates more than producer price index inflates (see panel B and C). This potentially leads to a change in relative prices. Panel G and H show the response from imports from the global and regional economy. We see that under LCP as under the Benchmark, imports from the global economy decrease as under the Benchmark but imports from the regional economy expand. The exchange rate depreciation passes through directly into the price of imports from the global economy but not into prices from the regional economy under LCP. As a result of this pricing model, imports from the regional economy expands approximately proportionately with aggregate demand. Conversely, the pass through of depreciation causes global imports to experience some decline. Under PCP, depreciation passes through into all export and import prices immediately. Since imports from the regional economy decline are a direct substitute for domestic production which is expanding, global imports mildly increase but regional imports decline. This pattern is reflected in final goods imports from the regional economy (see Figure A.2 Part ii, Panel I).

Semi-processed materials imports decline sharply in the Benchmark economy but only mildly under PCP. Under both pricing models, regional imports become immediately more expensive due to exchange rate depreciation. However, under producer currency pricing, the exchange rate pass through also passes through into export prices. As a result, exports expand across the board in all categories as they become more competitive, while there is minimal impact on exports under Local Currency Pricing or benchmark global dollar currency pricing (see Panel K-O). The expansionary response of exports to the global economy under PCP buoys imports of semi-processed materials (see Panel O).

A.2 Platform Exports Specifications

We also compare the Benchmark model with models with different structures for inter-regional trade of semi-processed materials for the global market. First, we drop the assumption that domestic value added industries and export platforms are separate industries that interact through sticky price domestic firms. Instead we assume that competitive firms jointly produce value for domestic final goods firms, regional exports and semi-processed materials for export to the global economy. Optimal choice of semi-processed materials replaces (2.12) with:

$$\frac{VH_t^j}{V_t^j} = d \cdot \left(\frac{MCY_t^j}{MCV_t^j}\right)^{-\nu} \tag{A.5}$$

so that domestic materials are sourced at marginal cost. Equilibrium is given by

$$CH_t^j = H_t^j \qquad DH_t^j \cdot H_t^j + DX_t^j \cdot EX_t^j + VH_t^j = Y_t^j \tag{A.6}$$

We refer to this as the *Unified Industry* model.

We also construct a model in which there is no cross-regional trade in semi-processed goods. Instead, export demand (2.23) is replaced by

$$WM_t^j = f \cdot \left(\frac{IPI_t^j}{P_t^W}\right)^{-\varsigma} \cdot Y_t^W \tag{A.7}$$

and equilibrium exports (2.14) is

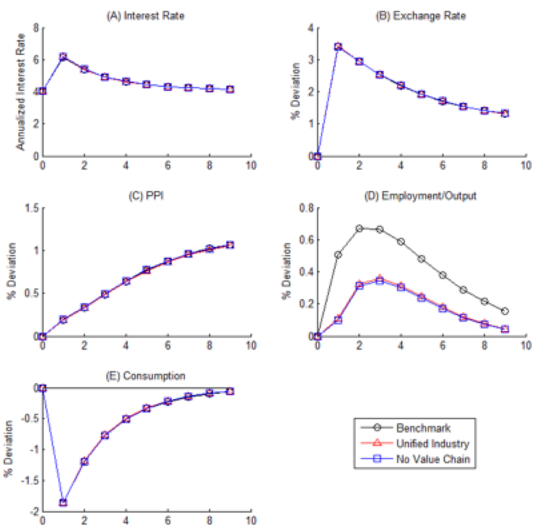
$$CH_t^j = H_t^j \qquad CM_t^{\neq j} + WM_t^j = EX_t^j \tag{A.8}$$

We refer to this as the *No Value Chain* model.

Figure A.3 shows the symmetric response of each regional economy to an external interest rate shock under the different export models. The nature of the export industry has little impact on the dynamic response of the exchange rate, CPI inflation or the response of the policy interest rate (see Panel A-C). Given the rise in the real interest rate, there is a persistent contraction in consumption (see Panel E). However, domestic output increases as the passthrough of exchange rates into final goods imports cause domestic consumers to substitute domestic value added (see Panel D). This occurs more strongly in the Benchmark model as the export platform sector in this specification shifts toward domestic value added when the exchange rate depreciation versus global currency makes regional materials imports less competitive. In the Unified Industry model, the nominal expansion flows directly into the cost of domestic value added leading the platform export sector to shift very little toward domestic value added. In the No Value Chain specification, there is no option of shifting away from imported materials in the platform sector.

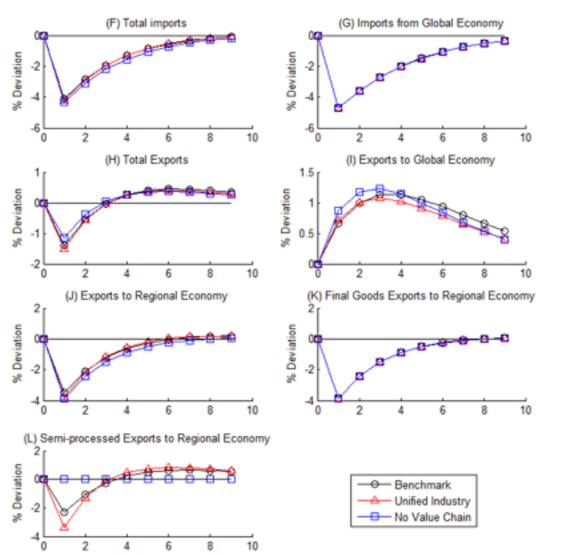
Figure A.3 also shows the impact on international trade. Panel F shows there is little difference in the response of imports. The response of imports from the global economy are essentially identical (see Panel G). In all of the models, the dynamic response of exports is contractionary though this is somewhat weaker in the model in the No Value Chain model and sharpest in the Unified Industry model (see Panel H). Exports of final goods either to the global economy (see Panel I) or the regional trading partner (see Panel K) are fairly similar. In the Benchmark model, the exchange rate depreciation versus the global currency reduces the competitiveness of materials trade in the value chain. The increase in interest rates and

Figure A.3



Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three specifications of the structure of the export platform: a) the Benchmark in which a distinct export industry purchases regional and domestic value added subject to pricing friction; b) Unified Industry in which the export platform imports regional materials but produces its own value added not subject to pricing frictions; and c) No Value Chain where global exports use only domestic value added. This part shows the response of domestic interest rates and exchange rates with the global currency, producer prices, domestic output, and consumption.

Figure A.3 – *cont.*



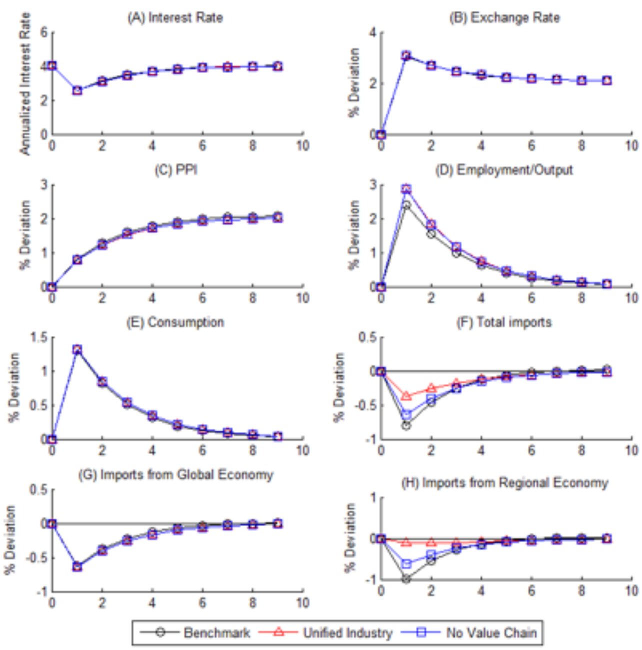
Notes: Symmetric impulse response of either small regional economy to a persistent rise in the external interest rate in the global economy. The response is examined under three specifications of the structure of the export platform: a) the Benchmark in which a distinct export industry purchases regional and domestic value added subject to pricing friction; b) Unified Industry in which the export platform imports regional materials but produces its own value added not subject to pricing frictions; and c) No Value Chain where global exports use only domestic value added. This part shows the response of aggregate imports, imports from the global economy, aggregate exports, exports to the global and regional economies, and regional exports by use.

decline in consumption increases labor supply; the resulting decline in wages passes directly into the costs of domestic value added in the Unified Industry model. In the Unified Industry specification, this exacerbates the shift in the export platform toward domestic value added in the Unified Industry model relative to the Benchmark (see Panel O).

Figure A.4 shows the response to an asymmetric monetary policy shock to the CPI targeting rule in Country A (as in Figure 3.2 and A.2) under the Benchmark economy along with the response to an identical shock in the Unified Industry model and the No Value Chain. Again, all of the model show a similar domestic economy response to the monetary policy shock as the Benchmark (see Panels A-E). Figure 6, Panel F shows the contraction of imports are somewhat milder under the alternative models relative to the Benchmark. Panel G and Panel I show that final goods imports from the global economy and the regional trading partner respond similarly to the Benchmark model. However, there is some change in the response of materials imports as shown in Panel J. In the Benchmark model, imports of semi-processed materials sharply decline in the Benchmark model. Obviously, this response does not occur in the No Value Chain model. Conversely, materials imports sharply expand in the Unified Industry model. Though materials imports are priced in global dollars and Country A's depreciation makes these more expensive. However, the combination of nominal expansion and real expansion increases the marginal cost of producing goods in country A, MCY_t^A, increase even more. Imported materials are substituted for domestic value added. his means that regional imports decline least under the Unified Industry model than in the other models (see Panel H).

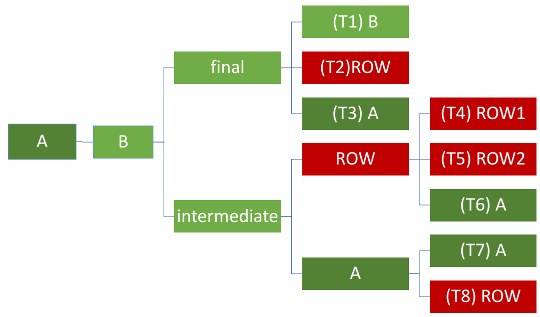
The alternative models also imply differences for the response of exports. In the Benchmark model, exports to the global economy persistently expand (see Panel L) . In the alternative models, exports to the global economy contract. In the Benchmark model, the price of domestic value added in the platform is sticky; combined with the exchange rate depreciation, the price of exports to the global economy becomes more competitive. In the Unified Industry model, the marginal cost of this value added increases faster than the exchange rate depreciates. This cost increase passes through into export prices and global exports decline. Similarly, in the No Value Chain model, the increase in value added marginal cost, slowly passes through into export prices making exports less competitive. Exports to the regional economy (see Panel M-O) are not much impacted by the shock since the importing country does not depreciate relative to the global dollar currency.

Figure A.4



Notes: Impulse responses of a regional economy to an expansionary interest rate cut. The response of the small open economy engaging in expansionary monetary policy is examined under three specifications specifications of the structure of the export platform: a) the Benchmark in which a distinct export industry purchases regional and domestic value added subject to pricing friction; b) Unified Industry in which the export platform imports regional materials but produces its own value added not subject to pricing frictions; and c) No Value Chain where global exports use only domestic value added. These figures assume a passive CPI target by the other trading partner. This part shows the response of domestic interest rates and exchange rates with the global currency, producer prices, domestic output, and consumption. In addition, this figure shows total imports, imports from the global economy and imports from the regional economy.

Figure B.1 – *Schematic Representation of Intermediate export decomposition*



Notes: The diagram illustrates the eight-term decomposition of bilateral intermediate goods trade proposed in Wang, Wei and Zhu (2013, 2017)

B Decomposition of intermediate goods trade

To address these concerns and investigate the role of multiple border crossings and global value chains in explaining the impact of US interest rates on observed patterns in international trade between non-US countries, we exploit a granular decomposition of international trade flows based on Wang, Wei and Zhu (2013, 2017). Starting with an initial shipment of a good from particular sector in the exporting country to a particular importing country, this framework tracks and classifies the flow according to its subsequent journey all the way to the final destination until it is consumed as part of a final good somewhere in the world-which could be either in the importing country, the exporting country itself (back and forth trade) or a third country which is different from both the initial exporter or importer (global value chain trade). For instance, it can separately identify and track the fraction of the initial shipment which remains in the importing country and is used to produce final goods which are either exported or consumed domestically, and the part which is exported by the importing country as further (second-round) intermediate inputs for further processing, either to a third country or back to the source country.

Table 2 provides a summary of the different components of international trade flows that are tracked by this framework, and figure B.1 provides a schematic illustration of the eight-term decomposition. In figure B.1, the starting point is an initial shipment of goods from country A to country B. This shipment can be used either to produce final goods, or to produce intermediate goods. The former can either be consumed in B itself (T1), or it can be exported, either back to country A (T3) or to the global economy (T2). Likewise, the frameworks also traces the subsequent journey of the part of initial intermediate shipments that is used to profuce further intermediate goods as part of deeper global value chains. The

Table 2 *– Decomposition of intermediate goods trade flows*

1. Used by direct importer to produce final goods directly , and then used as:(Figure B.1)
   (a) domestic final goods consumed by the direct importer (T1)
   (b) exported final goods consumed by third countries (T2)
   (c) exported final goods consumed by the source (exporting) country (T3)
2. Used by the direct importer to produce intermediate exports, and then:
   (a) first used by direct importer to produce intermediate goods exports, then used by third countries to produce final goods which are subsequently used as:
      i. domestic final goods consumed in the third country (T4)
      ii. exported final goods consumed by countries other than the source country(exporting country) (T5)
      iii. exported final goods consumed by the source (exporting) country (T6)
   (b) first used by direct importer to produce intermediate exports shipped back to the source (exporting) country as intermediate imports to produce final goods
      i. domestic final goods consumed by the source (exporting) country (T7)
      ii. exported final goods consumed by other countries (T8)

Source: Wang, Wei and Zhu (2013)

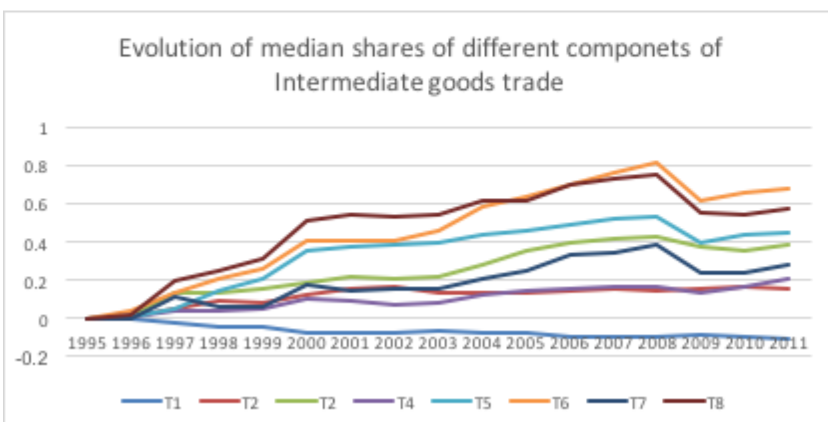
figure uses green to indicate trade flows that remain in the region (constituted by A and B), and red to indicate trade flows that are ultimately absorbed outside the region, i.e in the global economy. As discussed above, the model has different implications for the dynamics of these two categories in response to changes in interest rates.

Table 3 shows the median shares of each of the eight components of intermediate goods exports across all the sectors and countries in the sample for select years in the sample. As is evident, the largest fraction of intermediate exports (>60%) end up being absorbed in the direct importing country itself (T1), which contradicts their use as proxies of global value chain trade, as from the perspective of models of global value chains like the one proposed in this paper, these flows are akin to final goods trade flows as they only cross international borders once. That said, as shown in figure B.2, the share of this component has declined over time, whereas the share of all other components which reflect deeper production fragmentation has ibeen on the rise.

Table 3 *– Evolution of shares of different components in intermediate exports*

Year	1995	2008	2009	2011
T1	69.38	62.75	63.8	62.46
T2	11.09	12.79	12.97	12.91
T3	0.05	0.08	0.07	0.07
T4	14.54	17.18	16.62	17.81
T5	2.74	4.63	4.06	4.27
T6	0.02	0.05	0.04	0.04
T7	0.09	0.13	0.11	0.12
T8	0.02	0.04	0.03	0.03

Figure B.2 *– Evolution of median shares of different componets of Intermediate goods trade*



C Additional estimation results using the eight term gross export decomposition of Wang, Wei and Zhu (2013)

We study the response of different components of trade flows through the following empirical specification:

$$Y_t^{i,j}(s) = \alpha^{i,j}(s) + \eta Y_{t-1}^{i,j}(s) + \beta i_{us,t} + \delta X_t + \epsilon_t^{i,j}(s) \tag{C.1}$$

Here, $Y_t^{i,j}(s)$ denotes a component of bilateral exports from sector s in country i to country j, measured typically as a share of total gross exports.[17] $i_{us,t}$ is the US policy rate, which as above is proxied by the shadow rate in Lombardi and Zhu (2014). X_t is a vector of controls and includes contemporaneous and lagged values of changes in US GDP and inflation, the bilateral exchange rate between the importer and the exporter, change in real GDP and inflation of the importer and exporter, change in total imports by the importer, and change in total imports and exports by the importing country with the US, as well as the change in unit labor cost in the exporting country. A quadratic time trend is also included in the regressions. The impulse responses are computed using the local projection method developed in Jorda (2005).[18] To account for the engoneneity concerns emanating from the inclusion of the lagged dependent variable, the regressions are estimated using the difference GMM estimator based on Arellano and Bond (1992). .The sample runs from 1995-2011 (annual) and covers 35 sectors in 40 countries (See Appendix D for the full list of countries and sectors). The full list of sectors and countries is available in appendix D.

Figure C.1 displays the response of total (left panel) and intermediate (right panel) bilateral exports between non-US countries in response to a monetary contraction in the US. Both measures of exports decline persistently after a small contemporaneous increase. There is no discernable difference between the responses, in contrast to the predictions of the model. As discussed above, however, due to the complex nature of global value chains in the data, a mere two way decomposition of trade data into intermediate and final goods trade is not rich enough to capture the dynamics of global value chain related trade.

To further uncover these mechanisms, we next examine the response of different components of intermediate exports introduced in Table 2 and Figure B.2(scaled by gross exports). Figure C.2 considers the response of the components of intermediate exports that are used

[17]In interpreting these results, we consider each bilateral pair to represent the regional economy (which we match to the model by fcontrolling for the the biltareal exchaneg rate in the regressions), with the rest of the world implicitly capturing the global economy in the background.

[18]The large dimension of the dataset (where we have close to a million data points) makes the typical alternative of using vector autoregression less attractive.

to produce final goods in the direct importing country (T1-T3). Within this category, the top-left panel shows that the share of the component which is consumed as final goods in the direct importing country itself (T1) declines on average, atleast out to three years. This is consistent with the prediction of the model, since in this case the intermediate goods in effect act like final goods insofar as they are consumed by the direct importer, and these trade flows decline unambiguously across all versions of the model, as they become more expensive compared to domestically produced goods from the perspective of consumers in the importing country. On the other hand, the top-right panel shows that the share of intermediate goods that are eventually exported to third countries after converting to final goods rises (T2), which is again consistent with the model as this part of the exports is akin to the platform export component in the model. The bottom panel in figure C.2 shows that the share of the component that is re-exported back to the original exporting country (T3) also declines persistently, a pattern that is again supportive of the mechanism in the model highlighting the fact that back and forth trade becomes more expensive as regional currencies depreciate against the dollar.

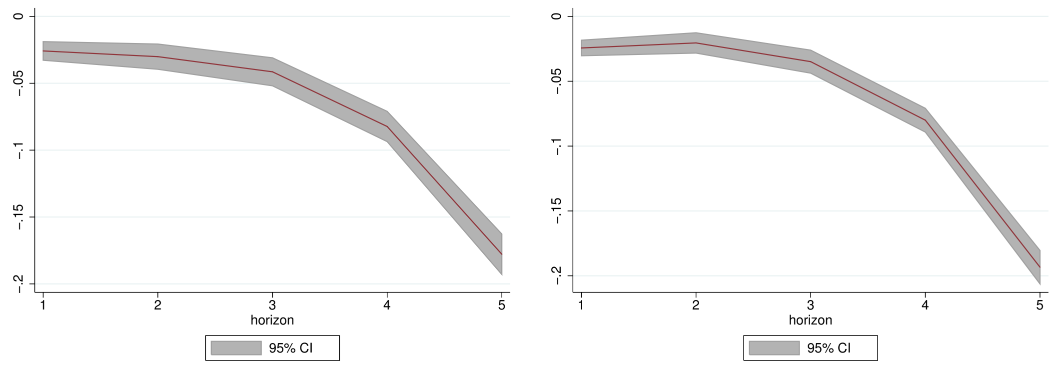
Figure C.3 shows the response of the share of intermediate exports that is used by the direct importer to further produce intermediate goods exports, which is then exported and used by the third countries to produce final goods. Commenting on these results in the context of the model is a bit harder since the stylized nature of the model does not allow for more than two border crossings. However, it is interesting to note in the bottom panel that the component that can be traced and eventually returns to the home country (i.e the original exporting country) falls persistently (T6), in line with the prediction of the model both in terms of a higher dollar making back and fort trade more expensive, as well as the overall decline in imports by the home country. The two top panels are more ambiguous, and do not offer clear evidence for or against the model.

Figure C.4 shows the response of the share of intermediate exports first used by direct importer to produce intermediate exports, which are subsequently shipped back to the source (exporting) country as intermediate imports to produce final goods. Within this, the share of the component that is ultimately absorbed in the original source country experiences a persistent decline (T7; left panel in figure C.4). This is in line with the with the patterns above as well as with the insights obtained form the model, as the higher dollar makes bilateral back and forth trade more expensive than domestic goods, causing consumers to switch towards the latter, with the primary sector once again showing a significantly different patters which points towards the larger role of PCP in this sector. The share of the component that is eventually exported and consumed by other countries on the other hand displays a more ambiguous pattern (T8; right panel in figure C.4).

Figure C.1 *– Response of total and intermediate bilateral exports from non US exporters to non-US importers in response to a shock*

(a) Total bilateral exports (real)

(b) Total bilateral intermediate goods exports (real)

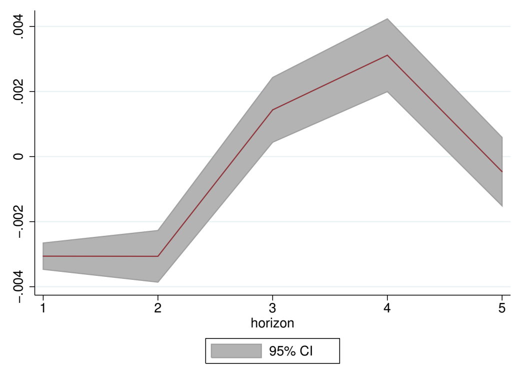


Notes: Percentage deviations from steady state. The shaded error band is the 95% confidence interval for the pooled sample.

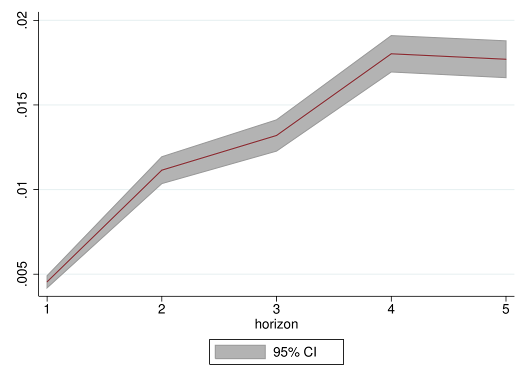
Overall, the results are broadly consistent with the predictions of the model. In particular, in response to an increase in US interest rates, trade flows decline globally, but flows that are more regionally oriented (either final goods, and involved in regional value chains) decline by more than trade flows that are involved in global value chains and eventually serve final consumers outside the region.

Figure C.2 – *Response of intermediate exports used by direct importer to produce final goods..*

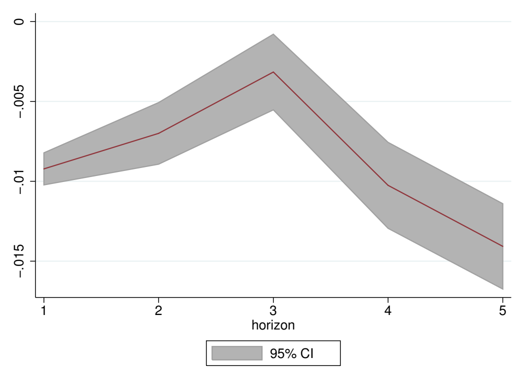
(a) ..consumed domestically (i.e by the direct importer)



(b) ..exported to third countries



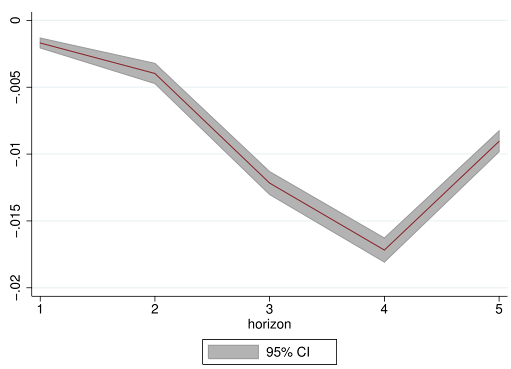
(c) ..exported back to the source country



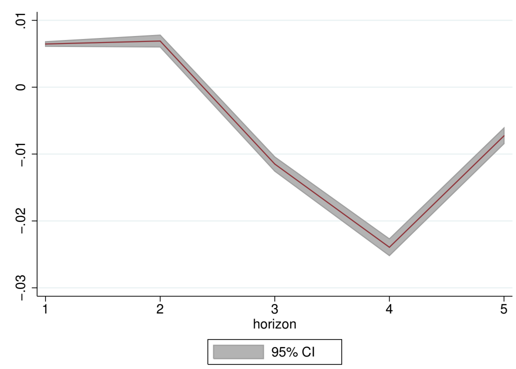
Notes: Percentage deviations from steady state. All variables are standardized by total bilateral exports. The shaded error band is the 95% confidence interval for the pooled sample.

Figure C.3 – *Response of intermediate exports first used by direct importer to produce intermediate goods exports then used by third countries to produce final goods..*

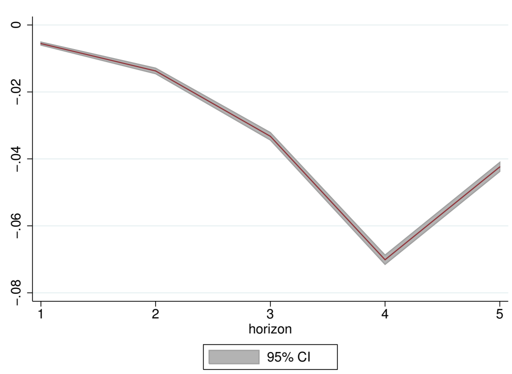
(a) ..consumed domestically (by third country)



(b) ..exported final goods consumed by countries other than the source country(exporting country)



(c) ..exported final goods consumed by the source (exporting) country

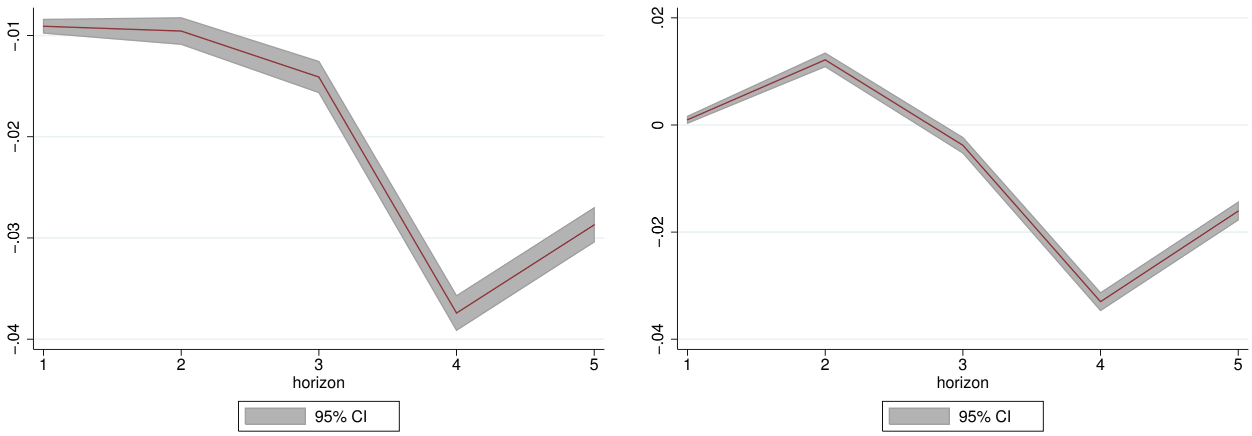


Notes: Percentage deviations from steady state. All variables are standardized by total bilateral exports. The shaded error band is the 95% confidence interval for the pooled sample.

Figure C.4 – *Response of intermediate exports first used by direct importer to produce intermediate exports shipped back to the source (exporting) country as intermediate imports to produce final goods*

(a) ...domestic final goods consumed by the source (exporting) country

(b) ..exported final goods consumed by other countries



Notes: Percentage deviations from steady state. All variables are standardized by total bilateral exports. The shaded error band is the 95% confidence interval for the pooled sample.

In summary, while not all of the above patterns that are perfectly in line with the predications of the model, on the whole, these results can be categorized as being broadly supportive of the predictions of the model vis-a-vis the distinction between the response of final goods trade and supply chain oriented trade to external shocks.

D List of countries and sectors

List of countries: Australia (non EU) Austria Belgium Bulgaria, Brazil(non EU) Canada (non EU) China (non EU) Cyprus Czech Republic Germany Denmark Spain Estonia Finland France United Kingdom Greece Hungary Indonesia (non EU) India (non EU) Ireland Italy Japan (non EU) Korea (non EU) Lithuania Luxembourg Latvia Mexico (non EU) Malta Netherlands Poland Portugal Romania Russia (non EU) Slovak Republic Slovenia Sweden Turkey(non EU) Taiwan(non EU) United States (non EU)

Table 4 *– Sectoral classification and description*

WIOD sector	Sector description	NACE code	Broad 3 sector Classification (Primary, secondary and tertiary)
c01	AGRICULTURE, HUNTING, FORESTRY AND FISHING	AtB	Primary
c02	MINING AND QUARRYING	C	Primary
c03	FOOD , BEVERAGES AND TOBACCO	15t16	Primary
c04	Textiles and textile	17t18	Secondary
c05	Leather, leather and footwear	19	Secondary
c06	WOOD AND OF WOOD AND CORK	20	Secondary
c07	PULP, PAPER, PAPER , PRINTING AND PUBLISHING	21t22	Secondary
c08	Coke, refined petroleum and nuclear fuel	23	Secondary
c09	Chemicals and chemical	24	Secondary
c10	Rubber and plastics	25	Secondary
c11	OTHER NON-METALLIC MINERAL	26	Secondary
c12	BASIC METALS AND FABRICATED METAL	27t28	Secondary
c13	MACHINERY, NEC	29	Secondary
c14	ELECTRICAL AND OPTICAL EQUIPMENT	30t33	Secondary
c15	TRANSPORT EQUIPMENT	34t35	Secondary
c16	MANUFACTURING NEC; RECYCLING	36t37	Secondary
c17	ELECTRICITY, GAS AND WATER SUPPLY	E	Secondary
c18	CONSTRUCTION	F	Secondary
c19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50	Tertiary
c20	Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	Tertiary

Table 4 *– Sectoral classification and description cont.*

WIOD sector	Sector description	NACE code	Broad 3 sector Classification (Primary, secondary and tertiary)
c21	Retail trade, except of motor vehicles and motorcycles; repair of household goods	52	Tertiary
c22	HOTELS AND RESTAURANTS	H	Tertiary
c23	Other Inland transport	60	Tertiary
c24	Other Water transport	61	Tertiary
c25	Other Air transport	62	Tertiary
c26	Other Supporting and auxiliary transport activities; activities of travel agencies	63	Tertiary
c27	POST AND TELECOMMUNICATIONS	64	Tertiary
c28	FINANCIAL INTERMEDIATION	J	Tertiary
c29	Real estate activities	70	Tertiary
c30	Renting of m&eq and other business activities	71t74	Tertiary
c31	PUBLIC ADMIN AND DEFENSE; COMPULSORY SOCIAL SECURITY	L	Tertiary
c32	EDUCATION	M	Tertiary
c33	HEALTH AND SOCIAL WORK	N	Tertiary
c34	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	O	Tertiary
c35	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS	P	Tertiary

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