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6483
2017

Original Version: May 2017
This Version: December 2017

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Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
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Editors: Clemens Fuest, Oliver Falck, Jasmin Gröschl
www.cesifo-group.org/wp

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CESifo *Working Paper No. 6483*
Category 7: Monetary Policy and International Finance

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Abstract

This paper provides an explanation for the observed decline of the exchange rate pass-through into import prices by modeling the effects of financial market integration on the optimal choice of the pricing currency in the context of rigid nominal goods prices. Contrary to previous literature, we explicitly take into account the interdependence of this decision with the optimal portfolio choice of internationally traded financial assets. Following financial integration, agents use equity, additional to bonds, to hedge against shocks. The resulting optimal portfolio includes a higher share of bonds denominated in foreign currency and impacts the correlation structure of costs and sales in such a way that producers move towards more local-currency pricing. Both predictions are in line with novel empirical evidence.

JEL-Codes: F410, F360, F310.

Keywords: exchange rate pass-through, financial integration, portfolio home bias, international price setting.

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December 8, 2017
We thank Agustín Bénétrix, Michael Devereux, Lukas Kohler, Philip Lane, Akito Matsumoto, Guido Schwerdt, and seminar participants at the Deutsche Bundesbank, ECB, EEA annual meeting, FU Berlin, IMF, DFG SPP 1578 conference in Konstanz, VfS annual meetings in M¨unster, and ZEW Mannheim for helpful discussions. The usual disclaimer applies. Part of this research was conducted while Z. Enders was a visiting scholar at the World Bank, whose hospitality is gratefully acknowledged. Z. Enders thanks the DFG for financial support under project number EN 892/1. The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Deutsche Bundesbank or the World Bank.

1 Introduction

Exchange-rate movements play an important role for economic developments, mainly via their impact on international trade and on the valuation of cross-border asset positions. Key variables for both channels, trade and financial, have changed significantly over the recent decades, with the decline in the exchange rate pass-through being the most prominent observation for the trade channel.[1] Previous literature has investigated these two channels separately. We argue that this masks an important part of the picture and take their interdependence explicitly into account. We find theoretically that the composition of international financial portfolios has a strong bearing on the value of the exchange rate pass-through, which allows us to explain the observed decline of the latter over time. Specifically, we demonstrate that international financial integration, measured by the number and nature of available assets, affects the optimal international portfolio of bonds and equities, which in turn strongly influences the exchange rate pass-through. We present supportive novel empirical observations showing that an increase in equity trade is associated with a decline in domestic relative to foreign net debt claims (that is, a tendency to hold more debt assets denominated in foreign currency) and a falling degree of exchange rate pass-through, as predicted by the model.[2]

Over the last two decades, an unparalleled expansion in asset trade has taken place. The left panel of Figure 1 shows the sum of portfolio equity assets and liabilities plus the sum of foreign direct investment (FDI) assets and liabilities over GDP (blue solid line), as reported in the updated and extended version of the data set constructed by Lane and Milesi-Ferretti (2007), over the time period 1990 to 2004 for a broad set of countries.[3] As visible, trade of equity has grown impressively relative to GDP post-1987, the start of the "financial globalization period" (see Kose et al., 2006), as well as relative to total debt assets and liabilities, pictured by the black dashed line in the same panel.[4] At the same time, holdings of net fixed income claims (such as bonds) in domestic relative to foreign currencies have declined internationally. In the right panel of Figure 1, we plot net debt claims in domestic currency less net debt claims in foreign currencies over GDP (blue solid line) and over total debt assets and liabilities (black dashed line), for the same country group as above. The empirical evidence shows a trend towards holding debt assets in foreign currency, so that domestic agents benefit

[1]For example, Ihrig et al. (2006) report a statistically significant decline in the average exchange rate pass-through between 1975-1989 and 1990-2004 in the G-7 countries. Olivei (2002), Marazzi et al. (2005), the International Monetary Fund (2005), and Gust et al. (2010) have established similar results concentrating on the US, while Otani et al. (2003) draws corresponding conclusion for Japan. The study of cross-country trade between EMU and non-EMU countries by Campa et al. (2005) also suggests a decline in the exchange rate pass-through in a majority of countries. di Mauro et al. (2008) support this finding for the euro area with data up to 2007, while the European Central Bank (2013) obtains a declining pass-through for both import prices and inflation starting in 1980 and ending in 2016. Sekine (2006) reports a substantial decline of pass-through into import and consumer prices for a number of advanced economies. Furthermore, the International Monetary Fund (2006b) shows a considerable fall of pass-through into import prices for Canada, France, Germany, Italy, Japan, the UK, and the US from the period 1975-89 to 1990-2002. Frankel et al. (2005) and the International Monetary Fund (2006a) document a particular strong decline for emerging economies. See also Taylor (2000) and Campa and Goldberg (2002).

[2]When referring to equity trade in the empirical and theoretical parts of the paper, we always include FDI. The relevant property for our analysis is the state-dependency of the payoffs that depend on demand and technology, which is shared by both types of investments. We use the words net debt or net debt claims interchangeably to refer to fixed income positions, specifically portfolio debt plus other investment as used in the database of Lane and Milesi-Ferretti (2007). This implies that holding positive net debt constitutes a claim towards foreign countries.

[3]We use this time period throughout the paper due to the availability of data on the currency denomination of foreign debt holdings. Appendix B provides a detailed description of the data, including a country list.

[4]Arguably, falling transaction costs and reduced informational frictions have triggered this development, which we take as given in the present analysis. Exploring the exact reasons for the financial globalization is beyond the scope of this paper.

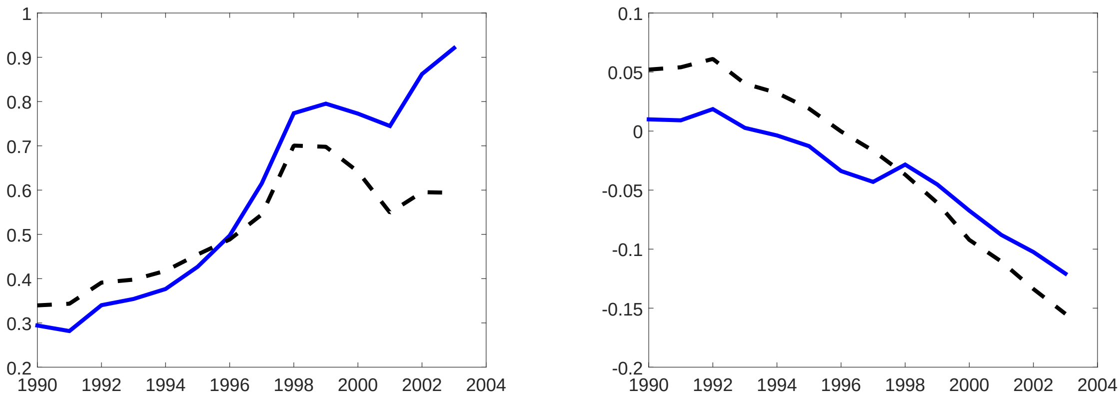

Figure 1: Sum of portfolio equity and FDI assets and liabilities over GDP (left, blue solid line) and divided by sum of debt assets and liabilities (left, black dashed line); average net debt claims in domestic currency minus net debt claims in foreign currencies over GDP (right, blue solid line) and divided by sum of debt assets and liabilities (right, black dashed line) in percentage points. Country sample: see Table B-1. Sources: Lane and Milesi-Ferretti (2007) and Lane and Shambaugh (2010).

from a depreciation of their own currency.[5]

To explain the shifts in the international portfolio composition and the falling exchange rate pass-through simultaneously, we develop a two-country stochastic general equilibrium model of optimal portfolio choice and endogenous pricing currencies, in which we analyze the relationship between the exchange rate pass-through and international financial integration in detail. In particular, starting from a world with trade in nominal bonds only, we add the possibility of trade in equity, representing increased international financial market integration.[6] Households make use of the available financial instruments to hedge against consumption fluctuations. Even with trade in bonds and equity, however, perfect risk sharing cannot be obtained, as the economy features domestic and foreign supply, demand, and monetary policy disturbances. We hence remain in the context of incomplete international financial markets. Efficient risk sharing would require a proportionally high consumption differential (home relative to foreign) whenever the real exchange rate is depreciated (Backus and Smith, 1993). Government spending shocks, however, induce the opposite correlation: they reduce Home's relative consumption and depreciate the exchange rate.[7] Households can, at least partially, hedge against this kind of consumption risk by holding foreign bonds. The depreciation increases their return in times of high taxation, bringing the economies closer to efficient risk sharing. Yet, households hold only modest amounts of foreign bonds, as they carry a disadvantage following monetary disturbances: consumption now falls more than required by efficient risk sharing after a monetary contraction, which triggers an appreciation and hence lower income from the foreign bond position. Regarding price setting in the scenario with trade in bonds only, we find that it is optimal for exporters of both countries to price in the currency of the country with the lower volatility of monetary shocks, see also Devereux et al. (2004). An intermediate value of exchange rate pass-through obtains.

[5] Similarly, Bertaut and Griever (2004) document an increase in the portfolio weights of foreign long-term debt between 1997 until 2001 for Australia, Denmark, the Euro Area, the United Kingdom, and Sweden.

[6] Thus, the degree of international financial integration is measured by the amount of financial instruments available to insure against different types of risk. Kose et al. (2006) argue that this quantity-based measure is best suited to capture international financial integration.

[7] The theoretical predictions for the reaction of the real exchange rate to government spending, technology, and monetary shocks are in line with empirical evidence, see among others, Corsetti et al. (2008), Enders and Müller (2009), Enders et al. (2011), and Corsetti et al. (2014).

Introducing the possibility of equity trade broadens the hedging possibilities for households. In particular, as monetary shocks affect profits and hence equity's payoff, trade in equity allows households to counteract the deviations from efficient risk sharing induced by those shocks. This frees bonds from the burden to balance the effects of both shocks, such that households hold even more foreign bonds to hedge specifically against government spending shocks. We empirically confirm the correlation between equity trade and increased foreign debt holdings in Section 3. Holding international equity positions, however, does not come without a side effect: disturbances that change relative profits, in particular supply shocks, now affect relative financial income and hence the exchange rate. This effect has a strong bearing on optimal price setting, as these disturbances change production costs and the exchange rate simultaneously. Particularly, a negative supply shock increases marginal costs while simultaneously inducing a depreciation. We empirically confirm this prediction regarding the effect of financial integration on the covariance between marginal costs and the exchange rate in Section 3. If firms were to continue pricing in producer currency, they would face high demand in times of high costs, which can be avoided by pricing in the buyer's currency. As a result, financial integration leads to a drop in exchange rate pass-through, which we also find in the data of Section 3.

Despite the importance of the exchange rate pass-through for welfare and optimal monetary policy, there have been relatively few explanations put forward to explain its recent decline.[8] Taylor (2000) points out that in (increasingly prevailing) low-inflation environments the expected persistence of price and cost changes is lower, which reduces the incentives to change prices after exchange-rate movements. Campa and Goldberg (2005) confirm the positive correlation between lower inflation rates and lower pass-through, but attribute this to the shift of imports towards goods that exhibit a lower degree of pass-through.[9] Gust et al. (2010) argue that increased trade integration, combined with higher productivity growth outside the US and a non-constant elasticity of substitution between goods, explains the reduced pass-through in the US. Our explanation via an increased international financial integration does not contradict the above hypotheses as it can be one of several important factors explaining the decline in the exchange rate pass-through.

By modeling the link between the trade and the financial channel, we combine two separate strands of literature, discussed in more detail in Section 2. On the one hand, quite a few theoretical papers deal with the determinants and effects of local-currency pricing vs. producer-currency pricing, while the optimal international portfolio choice is subject of a distinct body of literature. Most importantly, we use the method developed by Devereux and Sutherland (2011) to solve for the optimal composition of each country's debt and equity portfolio in terms of currency denomination. The insights obtained from considering both channels simultaneously might be particularly important for groups of countries that move towards a currency union. The preceding financial market integration can reduce exchange rate pass-through, lowering the costs of giving up the nominal exchange rate as a channel of adjustment after idiosyncratic shocks. To the best of our knowledge this aspect of the endogeneity of optimum-currency-area criteria has not been explored so far.

[8] Obstfeld and Rogoff (2000) highlight the importance of the pass-through by showing that with full exchange rate pass-through it is not desirable for monetary policy to target the nominal exchange rate in terms of welfare. A floating exchange rate allows for an adjustment of relative prices and helps to stabilize output and other macroeconomic variables in response to an external shock. If exchange rate pass-through is incomplete, however, the exchange rate becomes powerless to alter relative prices and, hence, the shock-absorbing mechanism of a floating exchange rate evaporates (Devereux and Engel, 2003). An important consequence is that under this assumption countries should adopt a monetary policy oriented at minimizing exchange-rate fluctuations to improve welfare. Other studies showing the importance of pass-through include Betts and Devereux (1996, 2000), Engel (2000), and Obstfeld and Rogoff (2002).

[9] Campa and Goldberg (2005) find that the combined effects of changing macroeconomic variables and sectoral compositions explain 30% of the observed change in pass-through. There is hence still room for alternative explanations, such as the effects of financial integration, which were not included in the macroeconomic variables of Campa and Goldberg (2005).

The remainder of this paper is organized as follows. In Section 2 we provide a brief survey of the related theoretical literature. Section 3 shows empirical evidence on the link between international financial integration and the decrease in the net currency position of debt assets on one side and the degree of exchange rate pass-through on the other. In section 4 we describe our theoretical framework and lay out the optimal portfolio choice under alternative assumptions regarding financial markets. Section 5 describes analytical results for the interaction between international financial markets and the pricing-currency choice for a simplifying calibration and presents numerical simulations for the general case. Section 6 concludes. In Appendix A we solve the model for unrestricted parameter values, while Appendix B lists the sources and treatments of the data used throughout the paper.

2 Related literature

Several recent papers have either analyzed the consequences of trade in financial assets for the hedging possibilities against a variety of shocks or have assessed the main factors determining the currency choice of firms. Here we discuss the studies which are most closely related to the present paper.

Regarding the literature on trade in financial assets, Engel and Matsumoto (2009) show that an explicit exchange-rate insurance can induce the same allocation as trade in a complete-markets setup, especially when there is a high degree of price stickiness in the economy. In our model with more shocks, full international risk sharing cannot be obtained. Consequently, bond and equity holdings serve as imperfect substitutes for such an insurance. In a model with no pricing frictions on the firm side, Coeurdacier and Gourinchas (2016) provide evidence that the presence of bond trade, additional to trade in equity, matters for the equilibrium portfolio allocations and the hedging possibilities against different sources of economic disturbances. Specifically, having more than one asset allows to specialize on the specific shocks.[10]

Considering the pricing currency choice of firms, Bacchetta and van Wincoop (2005) highlight the importance of the covariance between nominal exchange rate movements and marginal costs in determining the degree of local-currency pricing within internationally complete financial markets. In a similar setting, also Devereux et al. (2004) point towards a positive effect of a higher correlation between marginal costs and the nominal exchange rate on the optimal usage of local-currency pricing. In a previous version, Devereux and Engel (2001) focus on the extreme cases of no or a complete set of internationally traded assets. They show that switching from financial autarky to internationally complete financial markets can increase the importance of relative instead of absolute monetary stability for price setting, depending on risk aversion. Their model features only monetary disturbances as a source of fluctuations.

None of the previous contributions, however, assesses the interdependence of the pricing decision of firms with the optimal portfolio choice and the composition of internationally traded assets. By doing so, we find important interaction effects between these variables. In particular, we show that financial market integration alters optimal portfolios in such a way that price setters move towards more local-currency pricing, resulting in a falling exchange rate pass-through. Since we also nest some of the insights of both strands of literature in one model, we see our paper as complementary to the above mentioned studies.

[10]Harms et al. (2015) show that international trade in equity can insure not only against real exchange rate risk, but also against risk in labor income when the economies are subject to distribution costs.

3 Empirical evidence

We start by investigating the empirical connection between our main variables of interest. This analysis is not meant to deliver a full characterization of the data in order to establish causal links, which is beyond the scope of this paper. It rather gives a motivation and demonstrates that the model predictions are in line with empirical observations. In particular, we use regression analyses to identify the relation between financial integration, measured by international equity trade and FDI, and the exchange rate pass-through. As our theoretical model features a specific channel from financial integration to pass-through, we first analyze two correlations that are crucial for this channel. The first relates to the connection of the optimal bond portfolio with increased equity trade. Specifically, our model predicts a negative correlation between the net currency position of debt assets (NCD) and equity trade. The variable NCD is defined as net debt holdings (assets minus liabilities) in domestic currency minus net debt holdings in foreign currency. The second key prediction concerns one of the main variables for the decision to price in producer or local currency, that is the covariance between marginal costs and the nominal exchange rate. Our model features a positive link between financial integration and this covariance, which we investigate empirically below.

To analyze the connection between increased trade in equity and a falling net currency position of debt assets, we conduct a panel regression analysis of 110 countries covering the time period 1990-2004. In columns (1)-(4), Table 1 shows a significant negative relationship between the sum of portfolio equity and FDI assets and liabilities on the one side and NCD (as defined above) over GDP on the other. We discard outliers and use robust regressions with standard errors clustered at the country level.[11] We control for a set of other variables that might influence the net currency position of debt assets and include time and country fixed effects in the pooled OLS regressions. The controls are net foreign assets (NFA) over GDP, total debt (log of debt assets plus liabilities), the updated Chinn and Ito (2006) index for capital account openness, openness (measured as the sum of exports and imports over GDP), net exports over GDP, log GDP over population, and log population. We include the index of Chinn and Ito as restrictions on debt and equity trade could have an impact on the effects of these two variables. Furthermore, columns (5)-(8) show that the negative effect of total equity trade is also present if NCD over total debt (sum of debt assets and liabilities) is used as the dependent variable. Regarding the size of the effect, an increase of one percentage point in the sum of equity and FDI assets and liabilities over GDP decreases NCD over GDP by around .38 percentage points, and NCD over total debt by around .3 percentage points in our preferred specifications of columns (3) and (7). Importantly, this effect is also present if we control for total debt in both sets of regressions. Both results are statistically significant at the 1% and 5% level, respectively. Specifications (4) and (8) implement the mean group estimator of Pesaran and Smith (1995), allowing for heterogenous slope coefficients across countries. This estimation results in even larger and more significant coefficients for both specifications. We can therefore conclude that the more equity is traded internationally, the lower is the net currency position of debt assets. This is consistent with the interpretation that following increased equity trade, agents choose a debt portfolio from which they benefit more in case of a depreciation of their own currency.

Our theoretical model predicts that financial integration leads to a falling exchange rate pass-through. A key variable for this interaction is the covariance between marginal costs and the nominal exchange rate. In particular, the optimal equity portfolio, if traded, creates a positive correlation between high marginal costs and a depreciated currency. If producers were to set their prices in the domestic cur-

[11] See Appendix B for the country list, data sources, a description of the data selection, as well as summary statistics and correlations. Note that in this specification both the dependent variable and the regressor of interest are divided by GDP. This does not introduce a correlation as we find a negative relationship between the two.

Table 1: Impact of equity trade on net currency position of debt assets over GDP or total debt

	(1) NCD/ GDP	(2) NCD/ GDP	(3) NCD/ GDP	(4) NCD/ GDP	(5) NCD/ Debt	(6) NCD/ Debt	(7) NCD/ Debt	(8) NCD/ Debt
(Eq. & FDI)/GDP	-0.470***	-0.361***	-0.384***	-0.611***	-0.386***	-0.294**	-0.297**	-0.764***
	(0.121)	(0.097)	(0.100)	(0.113)	(0.122)	(0.112)	(0.114)	(0.172)
NFA/GDP	-0.807***	-0.544***	-0.552***	-0.844***	-0.449***	-0.469***	-0.472***	-0.982***
	(0.058)	(0.063)	(0.061)	(0.071)	(0.067)	(0.101)	(0.101)	(0.123)
log(Gross Debt)		0.272***	0.234***	-0.010		-0.064	-0.091	-0.469***
		(0.053)	(0.059)	(0.045)		(0.072)	(0.096)	(0.098)
Chinn-Ito		-0.015	-0.017	0.003		-0.008	-0.008	0.000
		(0.011)	(0.011)	(0.002)		(0.013)	(0.013)	(0.005)
Openness		-0.138***	-0.143***	-0.044		-0.176**	-0.180**	-0.114
		(0.045)	(0.043)	(0.047)		(0.068)	(0.071)	(0.076)
Net Exp./GDP		-0.176**	-0.145*	-0.206***		-0.035	-0.017	-0.218*
		(0.080)	(0.080)	(0.067)		(0.085)	(0.092)	(0.126)
log(GDP/Pop.)			-0.026	-0.106***			-0.032	-0.148***
			(0.041)	(0.024)			(0.065)	(0.049)
log(Pop.)			-0.402**	-1.165**			-0.155	-1.140
			(0.185)	(0.577)			(0.265)	(1.766)
Observations	1379	1319	1319	973	1379	1319	1319	973
Adjusted R^2	0.669	0.731	0.737		0.316	0.385	0.385	

Robust standard errors in parentheses. $p < 0.10$ is denoted by *, $p < 0.05$ by **, $p < 0.01$ by ***. NCD/GDP=net currency position of debt assets (net debt claims in domestic currency minus net debt claims in foreign currencies) over GDP, NCD/Debt=net currency position of debt assets over sum of debt assets and liabilities, (Eq. & FDI)/GDP=sum of equity assets and liabilities plus sum of FDI assets and liabilities over GDP, NFA/GDP=net foreign assets over GDP, log(Gross Debt)=log of sum of debt assets and liabilities, Chinn-Ito=index of financial openness from Chinn and Ito (2006), Openness=Sum of imports and exports over GDP, Net Exp.=net exports over GDP, log(GDP/Pop.)=log of GDP over population, log(Pop.)=log of population. All specifications include country fixed effects. Columns (4) and (8) display results from mean group estimators with group-specific time trends, all other specifications include time fixed effects. Data sources are listed in Appendix B.

rency, this would result in high sales in times of high costs. To avoid this outcome, firms use local-currency pricing, implying a low degree of pass-through. In the first two columns of Table 2, we assess whether the prediction regarding the impact of equity trade on the mentioned covariance is in line with empirical observations. To this end, we regress the covariance between unit labor costs (compensation of employees divided by real GDP, a proxy for marginal costs) and the effective nominal exchange rate (where an increase denotes a depreciation) on the same set of control variables as in Table 1. We add the volatilities of both parts of the covariance, that is the variances of unit labor costs and the exchange rate. Our theoretical model does not feature trend inflation nor inflation volatility. We still include them as controls in Column (2), as both might have a bearing on the covariance. It turns out that increased equity trade is significantly associated with a higher covariance between unit labor costs and the nominal exchange rate (using robust regressions with standard errors clustered at the country level, including time and country fixed effects).

Table 2: Impact of equity trade on covariance between unit labor costs and the exchange rate, share of exports priced in home currency, and exchange rate pass-through

	(1) Cov	(2) Cov	(3) PCP	(4) PCP	(5) PCP+VCP	(6) PCP+VCP	(7) PT	(8) PT
(Eq. & FDI)/GDP	0.021**	0.019**	-0.062*	-0.061*	-0.058***	-0.058***	-0.339*	-0.385**
	(0.008)	(0.007)	(0.033)	(0.033)	(0.011)	(0.012)	(0.187)	(0.182)
NFA/GDP	0.041***	0.039***	-0.018	-0.011	-0.043*	-0.028	-0.117	-0.144
	(0.011)	(0.009)	(0.029)	(0.035)	(0.021)	(0.028)	(0.171)	(0.168)
log(Gross Debt)	0.016***	0.017**	-0.021	-0.025	-0.011	-0.013	0.170**	0.194**
	(0.005)	(0.006)	(0.029)	(0.033)	(0.018)	(0.018)	(0.073)	(0.070)
Chinn-Ito	-0.001	-0.002	0.016***	0.017***	-0.015***	-0.013***	-0.023	-0.006
	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)	(0.076)	(0.085)
Openness	0.055***	0.059***	0.091***	0.085***	0.004	-0.004	-0.109	-0.063
	(0.016)	(0.013)	(0.024)	(0.022)	(0.017)	(0.015)	(0.171)	(0.168)
Net Exp./GDP	-0.140***	-0.147***	0.044	0.063	0.003	0.021	1.133	0.925
	(0.040)	(0.044)	(0.042)	(0.044)	(0.090)	(0.111)	(1.212)	(1.195)
log(GDP/Pop.)	0.032**	0.032***	0.010	0.015	0.027	0.033	0.015	0.046
	(0.014)	(0.011)	(0.011)	(0.011)	(0.016)	(0.020)	(0.101)	(0.112)
log(Pop.)	0.058	-0.000	0.142	0.155	-0.372*	-0.355*	-0.035	-0.014
	(0.054)	(0.089)	(0.097)	(0.094)	(0.193)	(0.191)	(0.058)	(0.057)
Inflation		-0.231		0.113**		0.088		1.644
		(0.217)		(0.040)		(0.109)		(2.492)
Inflation Vol.		27.610		0.703		2.644*		-0.005
		(23.411)		(1.138)		(1.279)		(5.112)
Exch. Rate Vol.	0.002***	0.002***						
	(0.001)	(0.001)						
ULC Vol.	0.271	0.286						
	(0.344)	(0.484)						
Observations	138	137	72	72	63	63	34	32
Adjusted R^2	0.244	0.258	0.537	0.527	0.385	0.371	0.180	0.219

Robust standard errors in parentheses. $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Specifications (7)-(8) are cross-sectional and include the average year of observations, all other specifications include time and country fixed effects. PCP=share of exports set in home currency, PCP+VCP=share of exports set in home currency, US dollar or euro, Exch. Rate Vol. and Inflation Vol.=variances of quarterly nominal effective exchange rate or inflation in the three preceding years, PT=exchange rate pass-through into export prices. For description of other control variables, see Table 1. Data sources are in Appendix B.

Unfortunately, we lack a similar comprehensive data set on exchange rate pass-through. Our analysis is therefore restricted to smaller samples, which can give us only indications of the relationship between pass-through and equity trade. In columns (3)-(6) of Table 2 we focus on invoicing data and assess how financial integration affects the share of exports priced in the currency of the exporting country. Kamps (2006) provides an unbalanced panel of 17 countries, ranging from 1994 until 2004.[12] A lower number indicates that fewer prices are set in the exporter's currency, implying a lower degree of pass-through.[13] Column (3) displays the results of regressing the PCP share on equity trade and FDI, as well as the same control variables as in Table 1. Column (4) additionally includes inflation and inflation volatility.

We find a relatively strong negative relationship between financial integration and producer-currency pricing. There are too few observations per country for a mean group estimator. Export prices that are not set in domestic currency can also be set in vehicle currencies, such as US dollar or euro. This case shares some properties from both local and producer-currency pricing. Developments in the importing countries that affect its exchange rate relative to the vehicle currency alter its import prices. On the other hand, foreign developments that only affect the exporters' exchange rates towards the vehicle currency do not change goods' prices in the currency of the importing country. We hence conduct a robustness check in columns (5)-(6) by using the sum of the shares of export goods priced in home currency, US dollar or euro as the dependent variable. We find a negative relationship between financial integration and producer or producer-plus-vehicle-currency pricing across specifications. All results are based on robust regressions (standard errors clustered at the country level) with time and country fixed effects.

The dependent variable of columns (3)-(6), that is the share of exports priced in the currency of the exporting country, corresponds closest to the main variable of interest in our theoretical model of Section 4. It is nevertheless instructive to relate a direct estimate of pass-through to financial integration. We are not aware of a large panel of pass-through coefficients, such that we employ cross-sectional data from Choudhri and Hakura (2015). They estimate, among others, the short-run pass through of the nominal effective exchange rate into export prices for 34 countries. We regress their values (based on the period 1979-2010) on the averages of our independent variables over our sample period. Given that we end up with only 34 observations, we do not drop outliers in this regression but weight observations to obtain robust standard errors (see Hamilton 1991). Because of the small sample size the results, presented in columns (7) and (8) of Table 2, have to be taken with caution. They are, however, consistent with the previous finding of a negative impact of equity trade cum FDI on pass-through.

We can summarize our empirical assessment by three main findings: higher levels of international equity trade and FDI are associated with a lower net currency position of debt assets, a higher covariance between unit labor costs and the exchange rate, as well as fewer exporting firms pricing in producer currency (a smaller degree of exchange rate pass-through). The next section presents a model that is able to replicate these empirical patterns by allowing for both, an endogenous portfolio choice by households and optimal price-setting behavior by firms.

[12] Countries and descriptive statistics are listed in Appendix B.

[13] PCP rates and pass-through are positively correlated as long as foreign-currency prices of those firms that do not use PCP react less to exchange-rate movements than one-to-one. That is, firms may increase foreign-currency prices after a depreciation of the currency of the export market, but by less than the degree of depreciation. The empirical evidence summarized by Burstein and Gopinath (2014) supports this assumption. Specifically, they observe that "border [that is, import] prices, in whatever currency they are set in, respond only partially to exchange rate shocks at most empirically estimated horizons." Moreover, even conditioning on a price change in the currency of pricing, they find that exchange rate pass-through in case of PCP is higher than that of LCP. Lastly, note that, based on product-level regressions, Devereux et al. (2017) find for imports from the US to Canada, pass-through is highest for goods priced in US dollar, lowest for goods priced in Canadian dollars, and in between for goods priced in euro.

4 The Model

This section presents a formal analysis of the effects of international asset trade on the exchange rate pass-through. The analysis builds on Devereux and Engel (2003) and similar models. There is a stochastic two-country world in which agents of Home, H, and Foreign, F, produce traded goods. Both countries are of the same size, have symmetric structures, and their inhabitants are indexed by numbers in the interval $[0, 1]$. Home agents consume a continuum of differentiated home and foreign goods. Each household provides labor to the domestic monopolistic firms. Firms set their home and export prices prior to the realization of aggregate technology disturbances, monetary policy shocks, and demand disturbances. The latter are induced by the fiscal authority in each country. Firms meet demand at the pre-set price. Foreign country conditions, whose variables are indicated by an asterisk, are defined analogously.

There are two periods. In period $t = 0$ no output is produced and no consumption takes place but households trade assets in international financial markets *before* any shocks occur in the economies in period $t = 1$. Two different international financial asset market structures are assessed. Households can either choose the amount of money they like to invest in home and foreign nominal bonds (*NB* case), or in home and foreign nominal bonds as well as equities (i.e., claims on the future profits of home and foreign firms, *NBE* case). Moving from an asset market where only nominal bonds are traded to financial markets where both nominal bonds and equities are held across borders is interpreted as international financial market integration. After asset trade has taken place, firms decide whether to pre-set the price of their export good for the next period in their own currency (i.e., producer-currency pricing, PCP) or in the currency of the importing country (i.e., local-currency pricing, LCP). In period $t = 1$ households decide about money balances, consumption, and labor supply, while firms produce and sell the amount of goods that consumers demand, once uncertainty is resolved. For ease of notation, we only denote period 0 variables with a time index.

4.1 Households, firms and international financial markets

Preferences and demand for goods Expected utility of the representative household is increasing in the aggregate consumption index C and real money balances M/P, and decreasing in the disutility of work effort L, all in period 1:

$$U = E_0 \left[\frac{C^{1-\rho} - 1}{1-\rho} + \chi \ln \frac{M}{P} - K \frac{L^v}{v} \right]. \tag{1}$$

The expectation operator across states of nature in period $t = 1$ given date $t = 0$ information is denoted by E_0. The parameter $\rho > 0$ is the degree of relative risk aversion, $v \geq 1$ is the inverse of the elasticity of labor supply while χ and K are strictly positive parameters. Total labor supply L of the representative household is distributed across monopolistic firms of unit mass, indexed by z, so that $L = \int_0^1 L(z)dz$. The consumption index C is a composite of domestic goods and goods produced abroad,

$$C = \left[a^{\frac{1}{\eta}} C_H^{\frac{\eta-1}{\eta}} + (1-a)^{\frac{1}{\eta}} C_F^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad \text{with} \quad P = \left[a P_H^{1-\eta} + (1-a) P_F^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{2}$$

being the home consumer price index. The elasticity of substitution between home and foreign goods $\eta > 0$ governs the sensitivity of the allocation between home and foreign goods with respect to relative price changes. The parameter $a = 1 - n/2$ measures the share of home goods in the home consumption basket in case of equal prices (see Sutherland, 2005), where trade openness is measured by the parameter $0 \leq n \leq 1$. This formulation accounts for the empirical consumption bias towards tradable goods produced locally. In case of complete trade openness ($n=1$), there is no home bias in consumption, i.e., domestic and foreign households consume equal shares of home and foreign goods. In case of $n=0$, both countries are completely closed. Home and foreign goods are each consumed in constant-elasticity-of-substitution bundles of differentiated products, with $\sigma > 1$ reflecting the elasticity of substitution between differentiated goods. All home goods sold domestically by local firms are priced in domestic currency, resulting in the bundle $C_H = (\int_0^1 C_H(z)^{\frac{\sigma-1}{\sigma}} dz)^{\frac{\sigma}{\sigma-1}}$ with the corresponding price index $P_H = (\int_0^1 P_H(z)^{1-\sigma} dz)^{\frac{1}{1-\sigma}}$. Imports can be priced either in the consumer's (LCP) or exporting firm's (PCP) currency. We assume that the fraction $\tilde{z}^*$ of firms in the foreign country employs LCP, and the remaining fraction $1 - \tilde{z}^*$ are engaged in PCP, such that

$$P_F = \left(\int_0^{\tilde{z}^*} P_F(z)^{1-\sigma} dz + \int_{\tilde{z}^*}^1 (SP_F^*(z))^{1-\sigma} dz \right)^{\frac{1}{1-\sigma}} \quad \text{for} \quad C_F = \left(\int_0^1 C_F(z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}}. \quad (3)$$

The nominal exchange rate S reflects the home currency price of one unit of foreign currency. Analogous conditions hold for the export goods of the home country H, with $\tilde{z}$ reflecting the fraction of home firms deciding for LCP, while the remaining fraction $1 - \tilde{z}$ of firms follows PCP. Maximizing (2) subject to $PC = P_H C_H + P_F C_F$ leads to the following demand functions for home and foreign goods

$$C_H = a \left(\frac{P_H}{P} \right)^{-\eta} C \quad \text{and} \quad C_F = (1-a) \left(\frac{P_F}{P} \right)^{-\eta} C, \quad (4)$$

with the demand functions for individual home and foreign goods given by

$$\begin{aligned} C_H(z) &= (P_H(z)/P_H)^{-\sigma} C_H && \text{for } z = 0, ..., 1, \quad (5) \\ C_F(z) &= \left(\frac{P_F^{LCP}(z)}{P_F} \right)^{-\sigma} C_F && \text{for } z = 0, ..., \tilde{z}^*, \\ C_F(z) &= \left(\frac{SP_F^{PCP}(z)}{P_F} \right)^{-\sigma} C_F && \text{for } z = \tilde{z}^*, ..., 1, \end{aligned}$$

as $\tilde{z}^*$ foreign firms provide the home country with the foreign good at a price charged in home currency and $1 - \tilde{z}^*$ at a price in foreign currency. Analogous demand functions apply for the home good consumed in the foreign country. Our goal will be to derive $\tilde{z}$ and $\tilde{z}^*$ in equilibrium, given the underlying international financial market structure.

International financial markets and budget constraints We assume two different international financial market structures: in period $t=0$, international asset trade may take place in nominal bonds (*NB*) or in nominal bonds and equity (*NBE*). Thus, the degree of international financial integration is measured by the amount of financial instruments available to insure against different types of risk.

Trade in bonds only (NB economy)
When international financial markets are less integrated, we assume that only trade in home and foreign nominal bonds can be conducted in period $t = 0$. Bonds are in zero net supply in each period such that

$$B_H + B_H^* = 0 \qquad \text{and} \qquad B_F + B_F^* = 0, \quad (6)$$

where B_H (B_F) are domestic (foreign) nominal bonds held by domestic households and B_H^* (B_F^*) are domestic (foreign) bonds held by foreign consumers. Home bonds are denominated in home currency and foreign bonds in foreign currency. For given prices of home, p_B, and foreign bonds, p_B^*, and an initial net foreign asset position of zero, the home household faces the following budget constraint at time $t=0$

$$p_B B_H^* - S_0 p_B^* B_F = 0. \tag{7}$$

The foreign budget constraint at $t = 0$ can be written in terms of the currency of country H as $S_0 p_B^* B_F = p_B B_H^*$. Furthermore, due to symmetry the price for bonds is initially identical and $S_0 = 1$. Consequently, $p_B = p_B^*$ holds and $B_H = -B_F$ and $B_H^* = -B_F^*$. If country H (F) goes short in its own bonds, $B_H < 0$ ($B_F^* < 0$), this implies that the respective country holds a positive position of foreign bonds, B_F (B_H^*). Using (6), this can be written as

$$B_H = B_F^* \qquad \text{and} \qquad B_H^* = B_F.$$

We can thus summarize holdings of the respective own bonds as $B = B_H = B_F^*$. Our goal will be to solve for B. $B < 0$ then implies that country H borrows in domestic currency and lends in foreign currency. H would in this case benefit from a depreciation of its currency. After the realization of shocks in period $t = 1$, the representative household derives its income by supplying labor at the nominal wage rate and by receiving nominal profits from domestic firms as well as returns from bond holdings determined in the previous period. Turning to the expenditure side, the household consumes, holds money M, and pays lump-sum taxes T, given the initial money stock M_0. The budget constraints of the representative households in countries H and F in period $t = 1$, both expressed in terms of country H's currency, are then given by

$$\begin{aligned} \Pi + B_H - SB_F^* + WL &= PC + M - M_0 + T, \\ S\Pi^* - B_H + SB_F^* + SW^*L^* &= SP^*C^* + S\left(M^* - M_0^* + T^*\right), \end{aligned} \tag{8}$$

respectively. Total nominal profits from home and foreign sales of the domestic and foreign firms are Π and Π^*. W and W^* denote the nominal wage rate at home and abroad. The Euler equations that characterize the domestic household's optimal portfolio choice decision are given by

$$\lambda_0 p_B = E_0\left(\lambda\right), \qquad \lambda_0 p_B^* = E_0\left(\lambda S\right),$$

where $\lambda = \frac{C^{-\rho}}{P}$ is the Lagrange multiplier associated with the period $t = 1$ budget constraint. Since $p_B = p_B^*$, the marginal returns of both types of assets have to be equal in expected terms if expressed in the same currency. Hence, the following equations define the asset market equilibrium conditions at home and abroad,

$$E_0\left(\frac{C^{-\rho}}{P}\right) = E_0\left(\frac{C^{-\rho}}{P}S\right) \quad \text{and} \quad E_0\left(\frac{C^{*-\rho}}{SP^*}\right) = E_0\left(\frac{C^{*-\rho}}{P^*}\right). \tag{9}$$

Note that due to the zero net foreign asset positions, either no or both bonds will be held, such that the Euler equations have to hold for both bonds.

Trade in bonds and equity (NBE economy)
If financial markets are integrated, two types of financial assets are traded, bonds and equities. Initially, households fully own their local firms and the net foreign asset position is zero. The relevant budget constraint in the *NBE* economy at $t=0$ is then

$$p_B B_H - S_0 p_B^* B_F^* + \phi p_E + \varphi S_0 p_E^* = p_E, \tag{10}$$

where p_E (p_E^*) is the price for a home (foreign) equity share and ϕ (φ) is the amount of home (foreign) shares purchased by domestic consumers. Since the supply of home and foreign shares is normalized to unity, the equilibrium in the asset market is characterized by $\varphi = 1 - \varphi^*$. Moreover, it follows from initial symmetry that $\varphi^* = \phi$, which implies that $\varphi = 1 - \phi$. Our goal will be to derive the optimal equity and bond positions. In period $t=1$ the budget constraints of the representative consumers in countries H and F are given by

$$\begin{aligned} \phi\Pi + (1-\phi)\, S\Pi^* + B_H - SB_F^* + WL &= PC + M - M_0 + T, \\ \phi S\Pi^* + (1-\phi)\,\Pi - B_H + SB_F^* + SW^*L^* &= SP^*C^* + S\left(M^* - M_0^* + T^*\right), \end{aligned} \tag{11}$$

where households derive their financial income from holding nominal bonds and receiving nominal profits from domestic and foreign firms according to the amounts of shares held, determined in the previous period. For trade in equities, the Euler equations with respect to equity equalize the marginal costs of buying an additional share in period $t=0$ to the marginal gains in period $t=1$. They are given by

$$\lambda_0 p_E = E_0\left(\lambda\Pi\right) \quad \text{and} \quad \lambda_0 p_E = E_0\left(\lambda S\Pi^*\right),$$

where the fact that $p_E = p_E^*$ because of initial symmetry has been taken into account. Plugging the Lagrange multiplier associated with the period $t=1$ budget constraint into the above equation, the Euler equations can be written as

$$E_0\left(\frac{C^{-\rho}}{P}\Pi\right) = E_0\left(\frac{C^{-\rho}}{P}S\Pi^*\right) \quad \text{and} \quad E_0\left(\frac{C^{*-\rho}}{SP^*}\Pi\right) = E_0\left(\frac{C^{*-\rho}}{P^*}\Pi^*\right), \tag{12}$$

which define the equity market optimality conditions at home and abroad. The optimality conditions regarding the bonds market are as in the *NB* economy, given in Equation (9).

Money demand and labor supply In period $t=1$ the representative consumer maximizes her utility function (1) with respect to consumption, money balances, and work effort, subject to the budget constraint (8) or (11). The first-order conditions associated with consumption, money holdings and the labor supply decision imply

$$\frac{M}{P} = \chi C^{\rho} \qquad \text{and} \qquad \frac{W}{P} = \frac{KL^{\upsilon-1}}{C^{-\rho}}. \tag{13}$$

The second equation states that the marginal rate of substitution between consumption and leisure is equal to their relative price. As in Devereux and Engel (2001), we assume in the following that $\upsilon = 1$, which implies an infinite wage elasticity of labor supply. The foreign country has similar first-order conditions. The first-order conditions associated with money holdings allow us to state the money market conditions as functions of nominal spending at home and abroad as

$$PC = \frac{1}{\chi}\frac{M}{C^{\rho-1}} \quad \text{and} \quad P^*C^* = \frac{1}{\chi}\frac{M^*}{C^{*\rho-1}}. \tag{14}$$

Expressing the two conditions in domestic currency units and rearranging yields

$$S = \frac{M}{M^*}\left(\frac{PC}{SP^*C^*}\right)^{-\rho}\left(\frac{SP^*}{P}\right)^{1-\rho}. \tag{15}$$

In addition to relative money balances and prices, the nominal exchange rate will be affected by the underlying international financial market integration that determines differences in nominal spending, $PC/(SP^*C^*)$, as shown by equations (8) and (11).

Monetary and fiscal authorities The money supply in each country has an expected value of $E_0(\ln M) = E_0(\ln M^*) = 0$ and a finite variance $Var(\ln M)$ and $Var(\ln M^*)$, where the home and foreign monetary disturbances are uncorrelated. The home government finances its consumption spending by means of taxes and seigniorage. Its budget constraint equals $PG = T + M - M_0$, where T denotes lump-sum taxes. We assume that total government expenditure G is a random demand component with a mean value of $E_0(\ln G) = 0$ and a finite variance $Var(\ln G)$. A similar expression holds for the foreign country. The government in each country consumes the same shares of local and foreign products as the private sector, such that home government's demand for home and foreign goods takes the same form as the private demand functions in (4), $G_H = a\,(P_H/P)^{-\eta}\,G$ and $G_F = (1-a)\,(P_F/P)^{-\eta}\,G$. Consequently, the government demand functions for individual goods are the same as in (5) and hold correspondingly for the foreign country. We assume that home and foreign government spending shocks are uncorrelated.

Profits and firms' price-setting decisions Firms produce differentiated goods under monopolistic competition and hire labor L at the nominal wage rate W. In $t = 0$, firms set their future prices and decide in which currency the exported goods are priced to maximize expected profits from sales in $t = 1$. The production function of firm z and market clearing for its goods are given by

$$Y(z) = AL(z) = C_H(z) + G_H(z) + C_H^*(z) + G_H^*(z)\,,$$

where A is a productivity parameter with a mean value of $E_0(\ln A) = 0$ and a finite variance $Var(\ln A)$. A similar expression holds for the foreign country. We assume that home and foreign shocks are not correlated. The associated expected profits for domestic sales are

$$E_0(\pi(z)) = E_0 d\,(P_H(z) - mc)\left(\frac{P_H(z)}{P_H}\right)^{-\sigma}\left(\frac{P_H}{P}\right)^{-\eta} D.$$

Profits are discounted with the stochastic discount factor $d = C^{-\rho}/P$ since firms are owned initially by domestic households and future profits from production will be evaluated according to households' marginal utility of consumption.[14] D denotes a home demand variable which consists of private (aC) and state (aG) demand and is taken as given by firms. Marginal costs are equal to

$$mc = \frac{W}{A}. \tag{16}$$

The profit-maximizing price for domestic sales of an individual home firm equals

$$P_H(z) = \frac{\sigma}{\sigma - 1}\frac{E_0(d\;mc\;D)}{E_0(d\;D)},$$

given the respective individual demand functions. When firms decide whether to set the export price in their own currency (PCP) or in the local currency (LCP), they compare their expected profits from selling under PCP to those under LCP. The profit function of a home firm from sales to the foreign country under LCP can be written as

$$\pi^{LCP}(z) = d\left(SP_H^{*LCP}(z) - mc\right)\left(\frac{P_H^{*LCP}(z)}{P_H^*}\right)^{-\sigma}\left(\frac{P_H^*}{P^*}\right)^{-\eta} D^*. \tag{17}$$

[14] In the case of trade in bonds and equity, it does not matter whether profits are discounted with the domestic or the foreign discount factor. In equilibrium, the price of equity corresponds to expected discounted profits and is equalized across countries.

Thus, profits under LCP are linear in the nominal exchange rate. This means that under LCP domestic currency revenues increase one-to-one with a nominal exchange rate depreciation. Costs are unaffected by changes in the nominal exchange rate since exchange-rate movements do not induce any changes in total demand. The profit-maximizing price for local-currency pricing firms is $P_H^{*LCP}(z) = \frac{\sigma}{\sigma-1}E_0(mcZ^*)/E_0(SZ^*)$, for $z = 0, ..., \tilde{z}$, with $Z^* = dP_H^{*\sigma-\eta}P^{*\eta}D^*$. Using this solution, the expected discounted profits from export sales in the domestic currency are

$$E_0\left(\pi^{LCP}(z)\right) = \tilde{\sigma}\left(E_0(S\,Z^*)\right)^{\sigma}\left(E_0(mc\,Z^*)\right)^{1-\sigma}, \tag{18}$$

where $\tilde{\sigma} = (1/(\sigma-1))(\sigma/(\sigma-1))^{-\sigma}$. The first term of the right-hand side of Equation (18) reflects expected revenues from sales, while the second term shows the cost component of expected profits. The dependence of expected profits on exchange-rate volatility can be seen more clearly when taking a second-order approximation of profits under LCP:

$$E_0\left(\widehat{\pi}^{LCP}(z)\right) \propto \sigma\frac{Var(\widehat{S})}{2} - (\sigma-1)\left[\frac{Var(\widehat{mc})}{2} + \frac{Var(\widehat{Z^*})}{2} + Cov(\widehat{mc},\widehat{Z^*})\right], \tag{19}$$

where $\widehat{X} = \ln X - \ln\overline{X}$ denotes the percentage deviation of variable X from its steady state $\overline{X}$. Furthermore, $\widehat{XY} = (\ln X - \ln\overline{X}) + (\ln Y - \ln\overline{Y})$ reflects the sum of the percentage deviations of the variables X and Y from their respective steady states. The variance of X is denoted by $Var(\widehat{X}) = E_0(\widehat{X}^2)$ and $Cov(\widehat{X},\widehat{Y}) = E_0(\widehat{X}\cdot\widehat{Y})$ reflects its covariance with variable Y. Equation (19) shows that expected profits under LCP are increasing in nominal exchange rate volatility via its effect on expected revenues. Furthermore, changes in the nominal exchange rate do not affect expected costs. The profit function of a home firm from sales to the foreign country under PCP can be written as

$$\pi^{PCP}(z) = d\left(P_H^{PCP}(z) - mc\right)\left(\frac{P_H^{PCP}(z)}{SP_H^*}\right)^{-\sigma}\left(\frac{P_H^*}{P^*}\right)^{-\eta}D^*. \tag{20}$$

Under PCP, profits are convex in the nominal exchange rate. Due to the expenditure-switching effect, a nominal exchange rate depreciation increases foreign demand for domestic goods by more than one-for-one since $\sigma > 1$. This means that, ceteris paribus, following a rise of the nominal exchange rate, revenues from sales under PCP increase relative to LCP. However, in contrast to LCP, a depreciation has a positive impact on expected costs and hence a negative one on expected profits. The corresponding profit-maximizing price for firms that employ producer-currency pricing is then given by $P_H^{PCP}(z) = \frac{\sigma}{\sigma-1}E_0(mcS^{\sigma}Z^*)/E_0(S^{\sigma}Z^*)$, for $z = \tilde{z}, ..., 1$. Using this solution, the expected discounted profits from export sales are given as

$$E_0\left(\pi^{PCP}(z)\right) = \tilde{\sigma}\left(E_0(S^{\sigma}Z^*)\right)^{\sigma}\left(E_0(mcS^{\sigma}Z^*)\right)^{1-\sigma}. \tag{21}$$

The influence of exchange-rate behavior on expected profits can be illustrated by taking a second-order approximation of expected profits under PCP:

$$E_0\left(\widehat{\pi}^{PCP}(z)\right) \propto \sigma^2\frac{Var(\widehat{S})}{2} - (\sigma-1)\left[\frac{Var(\widehat{mc})}{2} + \frac{Var(\widehat{Z^*})}{2} + Cov(\widehat{mc},\widehat{Z^*}) + \sigma Cov(\widehat{mc},\widehat{S})\right]. \tag{22}$$

Under PCP, nominal exchange rate variability increases expected revenues. However, changes in the nominal exchange rate also induce demand changes. As the firm has to meet demand at the given price, it has to increase its labor inputs after an exchange-rate depreciation. If this happens in times of high marginal costs, i.e., $Cov(\widehat{mc}, \widehat{S}) > 0$, expected total costs are higher relative to LCP. This fact will be of importance when assessing the role of international financial market integration on the export-price setting behavior of firms, as financial integration affects the properties of the nominal exchange rate. Following Bacchetta and van Wincoop (2005) and Devereux et al. (2004), we obtain the decision rule of the home firm whether to set its export price in its own or in the local currency by subtracting (19) from (22). The firm will use PCP (LCP) as long as expected profits under PCP (LCP) are higher than under LCP (PCP), which is the case if

$$\frac{Var(\widehat{S})}{2} - Cov(\widehat{mc}, \widehat{S}) > 0, \ \ (< 0). \tag{23}$$

The optimal pricing currency condition (23) holds under the assumption that the discount factor, prices of other firms, foreign total demand, and foreign prices are exogenous to an individual firm and its pricing-currency decision. Analogously, a foreign firm has equivalent profit structures and will decide to price its exports to the domestic economy in the foreign (home) currency if

$$\frac{Var(\widehat{S})}{2} + Cov(\widehat{mc^*}, \widehat{S}) > 0, \ \ (< 0). \tag{24}$$

The last two equations determine the optimal values of $\tilde{z}$ and $\tilde{z}^*$ and thereby the equilibrium home (foreign) exchange rate pass-through, $1 - \tilde{z}$ $(1 - \tilde{z}^*)$, conditional on the financial market structure.

4.2 Equilibrium and steady state

The rational expectations equilibrium is a set of values for consumption, output, labor, wages, prices, and the optimal portfolio shares, given the distribution of shocks to technology, government spending, and money supplies at home and abroad, (A, A^*, G, G^*, M, M^*). The model is solved by linearizing (first order, except where noted otherwise) around the symmetric non-stochastic steady state where the economic disturbances equal zero. Steady-state variables are denoted by a bar. The above described optimality and market clearing conditions are then used to determine the endogenous variables in equilibrium, in particular the equilibrium home exchange rate pass-through, $1-\tilde{z}$ (for Foreign: $1-\tilde{z}^*$), as well as the portfolios of equity, ϕ, and of bonds,

$$b \equiv B/\overline{PC},$$

which corresponds to the net currency position of debt assets. In steady state, a country's sales revenues are given by $\overline{REV} = \overline{YP_H} = \overline{PC}$. It follows that profits and labor income are shares of a country's income, given by $\overline{\Pi} = (1/\sigma)\overline{REV}$ and $\overline{WL} = ((\sigma-1)/\sigma)\overline{REV}$, respectively. Because of symmetry across countries, purchasing power parity holds in steady state, such that $\overline{SP^*} = \overline{P}$. Furthermore, producer prices are given by $\overline{P_H} = ((\sigma-1)/\sigma)\overline{W}/\overline{A}$. As the two countries are identical in steady state, the law of one price holds within and across goods, $\overline{P_H} = \overline{SP_H^*} = \overline{P_F} = \overline{SP_F^*}$. Having described the optimal pricing and portfolio conditions, the equilibrium, and the steady state, we will now show how the integration of international asset markets affects the exchange rate pass-through via the optimal portfolio choice.

5 Financial Markets and the exchange rate pass-through

To illustrate the mechanisms at work we first make use of a simplifying calibration in Section 5.1, for which we derive an analytical solution. Section 5.2 reports results of numerical simulations for general calibrations of the model, whose unrestricted equilibrium conditions together with additional intuition is presented in Appendix A. In the following we draw on these equations for deriving the simplified version.

5.1 Analytical solution for a simple calibration

As a first step, we assume that there is no home bias in household and government consumption, such that $a = 0.5$. Furthermore, we assume log-utility, i.e., $\rho = 1$, and that the elasticity of substitution between home and foreign traded goods, η, equals unity.[15] This allows us to derive a closed-form solution. With the solution at hand we first discuss the portfolio allocation problem and then show how it relates to the price-setting behavior of firms. We solve for the nominal exchange rate by making use of the money market equilibrium. Expressing (15) in log-linear terms yields

$$\widehat{S} = (\widehat{M} - \widehat{M}^*) - (\widehat{PC} - \widehat{SP^*C^*}). \tag{25}$$

In equilibrium the nominal exchange rate will not only be affected by the relative money supplies but also by the differences in nominal spending, $\widehat{PC} - \widehat{SP^*C^*}$. How this difference reacts to shocks depends on the amount and types of assets traded.

5.1.1 Trade in bonds only

Consider first Equations (8), which show that relative nominal spending in case of trade in bonds only equates to

$$\widehat{PC} - \widehat{SP^*C^*} = -2b\widehat{S} + (\widehat{REV} - \widehat{SREV^*}) - (\widehat{G} - \widehat{G^*}), \tag{26}$$

with $\widehat{G} = G/\overline{C}$. The financial return to the bond holdings b is given by the negative of the nominal exchange rate movement, $-\widehat{S}$, while revenues of firms from sales to the home and foreign consumers are non-financial income, denoted by REV. In the following we use the linearization $\widehat{REV} = \frac{1}{\sigma}\widehat{\Pi} + \frac{\sigma-1}{\sigma}\widehat{WL}$ and the fact that $B_H = B_F^*$, as $S_0 = 1$. b is the equilibrium amount of bonds we are looking for. Given Equation (26), we can express the nominal exchange rate (25) in the economy with trade in bonds only as

$$\widehat{S} = \frac{\widehat{M} - \widehat{M}^*}{1 - 2b} + \frac{\widehat{G} - \widehat{G}^*}{1 - 2b}, \tag{27}$$

observing that $\widehat{REV} - \widehat{SREV^*} = 0$ in our simple model structure with $\eta = 1$, since expenditure-switching effects offset higher relative revenues in the domestic currency one-for-one after exchange-rate movements.

What will be the amount of equilibrium bonds b held within this financial market structure? Optimally, households would use the available hedging possibilities to reach efficient risk sharing, characterized

[15] The assumption of $\eta = 1$ implies Cobb-Douglas preferences across home and foreign goods. In this case, the terms of trade provide a risk-sharing role, as shown by Cole and Obstfeld (1991), and the asset market structure might not be relevant. However, this is only true when there are only productivity shocks and international asset positions are zero. In the case of demand shocks, such as government spending shocks, risk sharing requires relative income to move asymmetrically, which causes optimal non-zero nominal bond positions, i.e., $b \neq 0$, as shown by equations (28) and (39) below, as well as international trade in equities, i.e., $\phi \neq 1$, as shown by Equation (38) for the nominal bond and equity case.

by $\widehat{C} - \widehat{C^*} = \widehat{SP^*} - \widehat{P}$, see Backus and Smith (1993). In other words, Equation (26) optimally remains at zero following disturbances. Given that the only hedging instrument in the *NB* case are international bonds, households cannot obtain efficient risk sharing. There are three shocks in each country, of which only two need to be hedged. Technology shocks affect the division of income between workers and firms, but do not change aggregate demand because of pre-set prices and the fact that profits are distributed domestically in the bonds-only case. International borrowing and lending does hence not need and cannot be used to insure against this type of shocks. The remaining shocks to government spending and the money supply, however, may lead to deviations from efficient risk sharing, as explained in the following on the basis of equations (26) and (27).[16]

If no international bonds are held, that is $b = 0$, monetary shocks do not need to be hedged, given that they do not change available resources directly (for unchanged government spending, seignorage is rebated via lower taxes) and move relative consumption and the real exchange rate proportionally in opposite directions. Specifically, after an expansionary monetary shock relative consumption increases, seen from the home perspective, while the real exchange rate depreciates, such that $\widehat{PC} - \widehat{SP^*C^*}$ remains constant. Government spending shocks, on the other hand, lead to a direct resource loss (called taxation) for households that decreases consumption. According to Equation (26), holding foreign bonds ($b < 0$) counteracts the consumption drop. Equation (27) shows that a positive government spending shock depreciates the nominal exchange rate, such that the domestic-currency value of foreign bonds increases. However, Equation (27) also shows that the nominal exchange rate reacts to changes in the money supply as well. This additional volatility reduces the incentive to hold assets whose returns depend on the exchange rate, i.e., foreign bonds. The larger are absolute international debt positions ($|b| > 0$), the larger are their payoffs and therefore deviations from optimal risk sharing after monetary shocks (see Equation 26). Facing this tradeoff, households will opt for an intermediate solution by holding a relatively small amount of foreign bonds to partially hedge against consumption risk associated with government spending shocks, without inducing a too large volatility of financial returns. Put differently, as households have only one hedging instrument at their disposal, efficient risk sharing is not obtainable.

To calculate the equilibrium portfolio choice of b we follow the approximation method by Devereux and Sutherland (2011) and take a second-order approximation of the asset market equilibrium condition for the home country (9) and its foreign counterpart. The full details of the derivations can be found in Appendix A. From Equation (A-10), the solution for the equilibrium bond portfolio is given by

$$b^{NB} = -\frac{Var(\widehat{G} + \widehat{G}^*)}{2Var(\widehat{M} + \widehat{M}^*)}. \tag{28}$$

This bond position implies that the home country lends in foreign currency and borrows in its own since $b < 0$. Thus, in states when the domestic currency is weak, the equilibrium bond position ensures that the home country will receive net payments from abroad. In line with the above intuition, this effect is more pronounced the larger are the variances of government spending relative to those of money supply shocks.

Given that technology shocks do not change relative international income, the exchange rate only transmits two of the three possible economic disturbances across countries, see Equation (27). This has additional implications for the price-setting decision of firms. Consider the linearized version of

[16] The sign of these deviations, including the effects of a technology shock if trade in equity is allowed for, are in line with recent empirical evidence in, e.g., Enders et al. (2011).

home marginal costs, Equation (16), together with Equation (13) and its foreign counterpart

$$\widehat{mc} = \widehat{M} - \widehat{A} \qquad \text{and} \qquad \widehat{mc}^* = \widehat{M}^* - \widehat{A}^*. \tag{29}$$

It follows that the covariance between marginal costs and the nominal exchange rate can be written as

$$Cov(\widehat{mc}, \widehat{S}) = \frac{Var(\widehat{M})}{1-2b} \quad \text{and} \quad Cov(\widehat{mc}^*, \widehat{S}) = -\frac{Var(\widehat{M}^*)}{1-2b}. \tag{30}$$

Note that when only nominal bonds are traded, only monetary disturbances affect the covariance relationship between marginal costs and the nominal exchange rate. Since all shocks are uncorrelated, the variance of the nominal exchange rate equals

$$Var(\widehat{S}) = \frac{Var(\widehat{M} + \widehat{M}^*)}{(1-2b)^2} + \frac{Var(\widehat{G} + \widehat{G}^*)}{(1-2b)^2}, \tag{31}$$

with $Var(\widehat{G} + \widehat{G}^*)$ and $Var(\widehat{M} + \widehat{M}^*)$ reflecting the sum of domestic and foreign variances of the government spending and monetary policy shocks. The magnitude of the variance of the exchange rate and its covariance with marginal costs also depends on the equilibrium bond holdings b, which implies that the bond holdings have direct implications for firms' pricing decisions. Substituting the equilibrium bond portfolio (28) into the decision rule of firms (23) with (30) and (31), we obtain the difference $\mathcal{R}^{NB}$ between expected profits under PCP and LCP as

$$\mathcal{R}^{NB} = \frac{1}{2} \frac{Var(\widehat{M}^*) - Var(\widehat{M})}{\frac{Var(\widehat{M}+\widehat{M}^*)+Var(\widehat{G}+\widehat{G}^*)}{Var(\widehat{M}+\widehat{M}^*)}}. \tag{32}$$

As long as the variance of the domestic money supply is less volatile than the foreign one, i.e., $Var(\widehat{M}^*) > Var(\widehat{M})$, domestic firms will decide to set their export prices in PCP while foreign firms will use LCP, resulting in global pass-through of 0.5. A similar result has been derived by Devereux et al. (2004), who point out that firms tend to set their export prices in the currency that is governed by the more stable monetary growth. If foreign money supply is very volatile, the exchange rate moves a lot, while the covariance between marginal costs and the exchange rate depends only on the variability of the domestic money supply in such an economy.[17] According to equations (23) and (24), firms of both countries hence optimally set their prices in the same currency.[18]

5.1.2 Trade in bonds and equities

When financial markets become more integrated, households in the model have the possibility to trade not only nominal bonds internationally, but also equity. Since those assets have a different risk profile, the two countries optimally exchange equity to better smooth fluctuations in consumption across different states of nature. Country differences of the linearized $t=1$ budget constraints (11) for the home country and its foreign counterpart result in this case in

$$\widehat{PC} - \widehat{SP^*C^*} = \frac{2\phi - 1}{\sigma}(\widehat{\Pi} - \widehat{S\Pi^*}) - 2b\widehat{S} - (\widehat{G} - \widehat{G^*}) + \frac{\sigma - 1}{\sigma}(\widehat{WL} - \widehat{SW^*L^*}). \tag{33}$$

[17] As technology shocks do not move the exchange rate without equity trade, they also have no impact on this covariance, see also Devereux and Engel (2001).

[18] If firms are indifferent between both pricing options because money supply variances are equal in Home and Foreign, $\tilde{z}$ and $\tilde{z}^*$ can take any value on the continuum between 0 and 1. The probability that all firms will use the same pricing strategy, ($\tilde{z}, \tilde{z}^* = 0$ or 1) is hence zero. Consequently, there is neither full nor zero exchange rate pass-through, i.e., $0 < \tilde{z}, \tilde{z}^* < 1$. However, this indeterminacy only arises if the volatility of monetary shocks are exactly equal across countries.

In equilibrium the relative total returns on equity, $\widehat{\Pi} - \widehat{S\Pi^*}$, are given by the difference between total revenues and labor income at home and abroad,

$$\widehat{\Pi} - \widehat{S\Pi^*} = \sigma(\widehat{REV} - \widehat{SREV^*}) - (\sigma - 1)(\widehat{WL} - \widehat{SW^*L^*}).$$

Remember from above that $\widehat{REV} - \widehat{SREV^*} = 0$ in our simple model structure. Relative labor income is obtained by combining the optimal labor supply condition of households with the market clearing condition and the production function of the representative firm. We then have

$$\widehat{\Pi} - \widehat{S\Pi^*} = -(\sigma - 1)(\widehat{WL} - \widehat{SW^*L^*}) = (\sigma - 1)\left[(\widehat{A} - \widehat{A}^*) - (\widehat{M} - \widehat{M}^*) + \frac{\tilde{z} + \tilde{z}^*}{2}\widehat{S}\right]. \quad (34)$$

Note that under this calibration the government consumes equal parts of domestic and imported goods, such that its effect on relative profits works only via the exchange rate. An exchange-rate depreciation, in turn, increases foreign costs expressed in domestic currency and raises domestic wage demands due to rising import prices if there is at least some pass-through. In case of complete pass-through ($z = z^* = 0$), these effects cancel. In the following we solve for the optimal portfolio positions. Given the above equations, we can express the nominal exchange rate (25) as

$$\widehat{S} = \frac{[2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1](\widehat{M} - \widehat{M}^*) - 2(\phi - 1)\frac{\sigma - 1}{\sigma}(\widehat{A} - \widehat{A}^*) + (\widehat{G} - \widehat{G}^*)}{1 - 2b + 2(\phi - 1)\zeta}, \quad (35)$$

with $\zeta = \frac{\sigma - 1}{\sigma}\frac{\tilde{z} + \tilde{z}^*}{2}$, where $\sigma/(\sigma - 1)$ is the monopolistic markup. The equilibrium outcome of the nominal exchange rate depends on the equilibrium portfolio allocation of bonds, b, and equities, ϕ. Furthermore, in contrast to the economy in which only nominal bonds can be traded, holdings of equity let the exchange rate transmit all three economic disturbances across countries. If agents hold more or less than 100% of claims to their profits, i.e., $\phi \neq 1$, technology shocks affect aggregate income via altered profits instead of just shifting the division between domestic labor and profit income, as it is the case if only nominal bonds are traded internationally. Hence, the covariance between marginal costs and the nominal exchange rate is affected not only by monetary disturbances, but also by productivity shocks. From (29) and (35) it follows that this covariance can be written as

$$\begin{aligned} Cov(\widehat{mc}, \widehat{S}) &= \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1}{1 - 2b + 2(\phi - 1)\zeta} Var(\widehat{M}) + \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma}}{1 - 2b + 2(\phi - 1)\zeta} Var(\widehat{A}), \quad (36) \\ Cov(\widehat{mc}^*, \widehat{S}) &= -\frac{2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1}{1 - 2b + 2(\phi - 1)\zeta} Var(\widehat{M}^*) - \frac{2(\phi - 1)\frac{\sigma - 1}{\sigma}}{1 - 2b + 2(\phi - 1)\zeta} Var(\widehat{A}^*). \end{aligned}$$

The variance of the nominal exchange rate results from (35) as

$$Var(\widehat{S}) = \frac{[2(\phi - 1)\frac{\sigma - 1}{\sigma} + 1]^2 Var(\widehat{M} + \widehat{M}^*) + [2(\phi - 1)\frac{\sigma - 1}{\sigma}]^2 Var(\widehat{A} + \widehat{A}^*) + Var(\widehat{G} + \widehat{G}^*)}{[1 - 2b + 2(\phi - 1)\zeta]^2}. \quad (37)$$

The sign and magnitude of the covariance of the nominal exchange rate with marginal costs and its variance will depend on both the equilibrium amount of bonds and equities held as well as on the exchange rate pass-through (via ζ).

What determines the equilibrium portfolio within this economy? Remember that households were not able to hedge completely against government spending shocks in the bonds-only economy because of the additional deviations from efficient risk sharing that arise if more foreign bonds are held.

These deviations were induced by the impact of monetary shocks on the exchange rate. In the bonds-and-equity economy, households can make use of the additional instrument of cross-border equity holdings to counteract this higher volatility of income. Specifically, since monetary shocks increase consumption and therefore wages, they raise marginal costs and thus lower profits. Going long in domestic equity will hence reduce the income volatility that monetary policy shocks generate via the payoff of foreign bond holdings: this payoff increases after a monetary expansion while the returns from domestic equity holdings fall.[19] This is visible in equations (33) and (35) or, more directly, in the positive relationship between domestic equity holdings and foreign bond holdings, as the impact of the latter ($-b^{NBE}$) on the former (ϕ) increases in the volatility of monetary shocks:

$$\begin{aligned}\phi &= 1 - \frac{\sigma}{\sigma-1}\frac{Var(\widehat{M}+\widehat{M}^{*})}{Var(\widehat{A}+\widehat{A}^{*}) + \frac{2-z-z^{*}}{2}Var(\widehat{M}+\widehat{M}^{*})}b^{NBE} \\ &= \frac{2Var(\widehat{A}+\widehat{A}^{*}) + \frac{\sigma}{\sigma-1}Var(\widehat{G}+\widehat{G}^{*})}{2Var(\widehat{A}+\widehat{A}^{*})}, \end{aligned} \tag{38}$$

which was again derived with the approximation method for computing the equilibrium portfolio positions developed by Devereux and Sutherland (2011).[20] There is also a direct benefit from going long in own equity: as positive government spending shocks depreciate the exchange rate, they increase relative profits at the same time when they reduce consumption, see above. Own equity can hence (partially) hedge against those shocks. Choosing $\phi \neq 1$, however, creates an impact of technology shocks on aggregate income via financial income from bonds (through the exchange rate) and equity (through profits), which tends to induce deviations from efficient risk sharing (see equations 33-35). This counteracts the incentive to deviate from the initial holdings of 100% of the own stocks, where technology shocks had no bearing on aggregate income. The term $2Var(\widehat{A}+\widehat{A}^{*})$ in the denominator reflects this tendency towards $\phi = 1$ whenever technology shocks are important.

Given that the volatility induced by monetary shocks on the return of foreign bond holdings can be counteracted by the new equity position, agents can now hedge more effectively against government spending shocks. As in the bonds-only economy, they do so by buying foreign bonds. This time, however, they have to worry less about the effects of monetary shocks and hence buy more.[21]

$$\begin{aligned}b^{NBE} &= b^{NB} - \frac{\sigma-1}{\sigma}\left(1 - \frac{z+z^{*}}{2}\right)(\phi-1) \\ &= -\frac{Var(\widehat{G}+\widehat{G}^{*})[Var(\widehat{A}+\widehat{A}^{*}) + \frac{2-\tilde{z}-\tilde{z}^{*}}{2}Var(\widehat{M}+\widehat{M}^{*})]}{2Var(\widehat{A}+\widehat{A}^{*})Var(\widehat{M}+\widehat{M}^{*})}. \end{aligned} \tag{39}$$

[19]Going long in own equity corresponds to values of ϕ above unity (that is, domestic agents own claims to more than 100% of future dividends). Some other authors obtain this result in related models, see Matsumoto (2007). Obstfeld (2007) discusses the case of a long position in non-tradeable equity. We understand $\phi > 1$ as a shortcut to portfolio rebalancing, which generates empirically plausible, procyclical capital flows, see, for example, Kaminsky et al. (2005), Reinhart and Rogoff (2011), Gourinchas et al. (2010), and Araujo et al. (2017). Specifically, as our model employs a 2-period setup, it neglects the possibility of portfolio rebalancing following structural shocks that would emerge endogenously in a model with more periods. Nevertheless, cross-border equity trade in our model generates capital flows that correlate with the business cycle, while the long position causes procyclicality. The correlation of expected capital flows with the state of the economy is important when analyzing optimal portfolio positions. Our modeling shortcut fulfills this role.

[20]The term $\frac{2-z-z^{*}}{2}Var(\widehat{M}+\widehat{M}^{*})$ in the denominator of the first expression counteracts the fact that b^{NBE} increases if pass-through falls, see below. It offsets this effect exactly if the equilibrium value of b^{NBE} is inserted.

[21]The term $-\frac{z+z^{*}}{2}$ in the first line of Equation (39) stems from the additional usage of foreign debt to offset the volatility of income that arises from the impact of exchange-rate movements on the payoff of international equity holdings, see Equation (34).

Comparing equations (28) and (39) shows that

$$b^{NBE} \leq b^{NB},$$

in line with the empirical finding in Section 3. The interaction between price setting and the portfolio choice becomes evident in the optimal asset and bond holdings: the payoff of equity holdings depends on the level of pass-through, while portfolio decisions influence the effects of disturbances on relative income. The latter impacts the volatility of the exchange rate and its covariance structure with marginal costs, which are the crucial variables for firms' LCP/PCP decision. Specifically, substituting (38) and (39) into (23) yields the expression for the decision rule of firms

$$\begin{aligned}\mathcal{R}^{NBE} = & \frac{Var(\widehat{M}^*) - Var(\widehat{M})}{2\Phi^2 / \left\{ Var(\widehat{M} + \widehat{M}^*) \left[Var(\widehat{G} + \widehat{G}^*) + Var(\widehat{A} + \widehat{A}^*) \right] \right\}^2} \\ & + \frac{Var(\widehat{A}^*) - Var(\widehat{A})}{2\Phi^2 / \left[Var(\widehat{G} + \widehat{G}^*) Var(\widehat{M} + \widehat{M}^*) \right]^2} \\ & - \frac{Var(\widehat{M})}{\Phi^2 / \{ Var(\widehat{G}+\widehat{G}^*) Var(\widehat{M}+\widehat{M}^*) Var(\widehat{A}+\widehat{A}^*) [Var(\widehat{G}+\widehat{G}^*) + Var(\widehat{A}+\widehat{A}^*)] \}} \\ & - \frac{Var(\widehat{A})}{\Phi^2 / \{ Var(\widehat{G}+\widehat{G}^*) Var(\widehat{M}+\widehat{M}^*) Var(\widehat{A}+\widehat{A}^*) [Var(\widehat{G}+\widehat{G}^*) + Var(\widehat{M}+\widehat{M}^*)] \}},\end{aligned}$$

with

$$\Phi = Var(\widehat{M} + \widehat{M}^*) Var(\widehat{A} + \widehat{A}^*) + Var(\widehat{G} + \widehat{G}^*) Var(\widehat{A} + \widehat{A}^*) + Var(\widehat{G} + \widehat{G}^*) Var(\widehat{M} + \widehat{M}^*).$$

A corresponding expression holds for the foreign country. Simple algebra shows that at least one of the two conditions (one for Home, one for Foreign) is negative. Global pass-through is therefore equal or below 0.5. When moving towards internationally more integrated financial markets, i.e., switching from the nominal bond economy to an economy where both bonds and equities are traded internationally, the exchange rate pass-through hence declines.[22] This is in line with empirical evidence in Section 3.

To gain some intuition for this result, note that the second and fourth term of $\mathcal{R}^{NBE}$ show that variability in domestic supply disturbances causes firms to set their export prices in LCP. This decision is driven by the increased covariance between marginal costs and the nominal exchange rate. The increase results from the higher impact of technological and monetary disturbances on both variables, induced by international equity holdings. Given that agents go long in own equity, positive technology shocks increase their aggregate income and hence appreciate the exchange rate (S decreases). At the same time marginal costs fall, increasing their covariance with the nominal exchange rate, see Equation (36). Positive monetary shocks have a similar effect, as they increase marginal costs via higher consumption and thus wage demands, but depreciate the exchange rate, which is behind the third term of $\mathcal{R}^{NBE}$. This pattern would let exporters, if they employed PCP, sell especially many goods at times when marginal costs are high. They will hence set their export prices in the local currency of the consumers, isolating their export demand from movements in the exchange rate. As in the *NB* case, the endogenous portfolio choice is therefore again crucial for the determination of the equilibrium

[22] In case of equal shock variances across countries, firms of both countries choose LCP. Pass-through is thus zero in this case, as easily visible in the $\mathcal{R}^{NBE}$ condition.

pass-through. As a result, the higher the integration of financial markets, the more firms will price their export goods in foreign currencies and the lower will be the exchange rate pass-through.[23]

It should be mentioned that the simple calibration with a unitary trade-price elasticity η omits one further interaction between price setting and the portfolio choice that lets the net currency position of debt assets fall further following financial integration. Specifically, in case $\eta > 1$, lower pass-through reduces the boost in business revenue that follows an exchange-rate depreciation and serves as an automatic hedge against government spending shocks. Since financial integration reduces pass-through, this hedge is partially replaced by holding foreign debt. See further explanations in Section 5.2.1.

Note that, by choosing the optimal bond and equity portfolios, households can reduce the expected deviations from efficient risk sharing. For illustrative purposes, let us assume equal variances of unity for all shocks: Then the risk-sharing condition $\widehat{PC} - \widehat{SP^*C^*}$ rises by 0.5 in the *NB* economy after a unitary shock to $M - M^*$ and falls by the same amount after a unitary shock to $G - G^*$. This results in an unconditional variance of this expression of 0.5. However, using also equity for hedging purposes in the *NBE* economy reduces the deviations to 1/3 after unitary shocks to $M - M^*$ and $A - A^*$, as well as -1/3 after a unitary shock to $G - G^*$. This reduces the variance of $\widehat{PC} - \widehat{SP^*C^*}$ to 1/3, moving the economies closer to efficient risk sharing. Note that the signs of the reaction of the risk-sharing condition to all three shocks remain the same in the general case of Section 5.2 and are in line with empirical evidence, see Footnote 16.

Agents hence achieve a stabilization of consumption. To see this, consider Equations (13), which hold under both financial market structures. Considering the difference between consumption under the two financial market structures and assuming a unitary variance of all home and foreign shock disturbances, the relative variability of consumption in the nominal bond economy is higher, since

$$Var(\widehat{C}^{NB} - \widehat{C}^{NBE}) = \frac{(1 - \tilde{z}^{NB})^2}{4},$$

for $b^{NB} = -1/2$ (the optimal choice for unitary shock variances). Consumption is thus less volatile under more integrated international financial markets, as households can hedge consumption risk more effectively.

In the next section we show that the analytical conclusions of this section also apply to settings with more general parameter values.

5.2 Numerical simulations for general calibrations

In the previous section we have concentrated on the model's main implications within a simplified framework. In the following we generalize the findings by relaxing the assumptions about the model's

[23] Qualitative results are robust against considering optimal monetary policy. For the *NBE* case, we obtain the same results as Corsetti and Pesenti (2015), with an analogous intuition. That is, there are two equilibria, one with full and one with zero global pass-through. Note that optimal monetary policy excludes monetary policy shocks. Given that only technology and government spending shocks remain, agents have enough financial instruments to obtain efficient risk sharing, which also prevails in the model of Corsetti and Pesenti (2015). In the *NB* case, however, our results deviate from Corsetti and Pesenti (2015). Here, agents cannot reach efficient risk sharing as there is only trade in bonds. Optimal monetary policy hence faces a tradeoff between stabilizing markups and achieving efficient risk sharing. Facing this trade-off, monetary authorities move the exchange rate in a way to (partially) stabilize the risk-sharing condition $\widehat{PC} - \widehat{SP^*C^*}$. This results in a higher exchange-rate volatility, which induces firms to always follow PCP pricing. Hence, when moving from the *NB* to the *NBE* case, both with the corresponding optimal monetary policy, we move from a situation with full pass-through to one with either full or zero pass-through. As a result, we obtain either no or a negative change in global exchange rate pass-through rates.

Parameter	Value	Source
ρ	1.25	Devereux et al. (2004)
η	1.5	Devereux et al. (2004)
a	.88	U.S. average
σ	6	Rotemberg and Woodford (1993)
σ^2_M	$.0043\%$	US data
σ^2_A	$.0036\%$	US data
σ^2_G	$.0052\%$	US data
$\sigma^2_{M^*}$	$.0043\% * 1.1$	Avoiding indet.
$\sigma^2_{A^*}$	$.0036\%$	Symmetry
$\sigma^2_{G^*}$	$.0052\%$	Symmetry

Table 3: Baseline parameter values for the numerical simulation of the model.

structural parameters. By numerically simulating the model for a variety of parameter values we can show that the result of declines in the exchange rate pass-through and the net currency position of debt assets remains valid within this more realistic setting. The simulations use the solution of the full model in Appendix A.

For the baseline calibration we use parameter values, where applicable, from Devereux et al. (2004). In particular, we set the trade price elasticity between domestically produced and imported goods to $\eta = 1.5$. The coefficient of relative risk aversion is $\rho = 1.25$.[24] Trade openness is calibrated to $a = 0.88$, the empirical average for the US over recent decades. The elasticity of substitution between varieties is set to $\sigma = 6$, corresponding to a steady-state markup of 20%. To obtain values for the variances of the shocks, we estimate AR(1)-processes for the quarterly HP-filtered logs of M2, Government consumption plus investment, and Solow residuals for the US and use identical values for the foreign country.[25] The variances of the error terms result in $\sigma^2_M = 0.0043\%$, $\sigma^2_G = \sigma^2_{G^*} = 0.0052\%$, and $\sigma^2_A = \sigma^2_{A^*} = 0.0036\%$. The foreign volatility of the money supply is set 10% higher, $\sigma^2_{M^*} = 0.0047\%$, such that firms are not indifferent regarding the pricing-currency decision in the bonds-only case, see above. For the following results it does not matter which country has a higher volatility of the money stock. The calibration is summarized in Table 3. For all volatility values, we conduct robustness checks further below.

5.2.1 Interaction between optimal portfolio choice and global exchange rate pass-through

Before investigating the effects of shifting from a bonds-only economy to a world with bond and equity trade, we first analyze the interdependence between global pass-through (i.e., $1 - (\tilde{z} + \tilde{z}^*)/2$) and bond and equity portfolios for the general case. Specifically, we investigate the influence of one variable on the other by fixing different values for the former and calculating optimal values for the latter.[26] The exogenously fixed variable is hence not set optimally, allowing us to generate a one-directional dependence.

[24] Results are robust to changing these parameters, see Table 4.

[25] See Appendix B for data sources.

[26] Note that because the countries have symmetric structures, only the value of global pass-through matters for portfolio allocations. This can be seen by the fact that all relevant equations feature $\tilde{z} + \tilde{z}^*$ instead of individual values. Similarly, there is a unique mapping from b and ϕ to global pass-through.

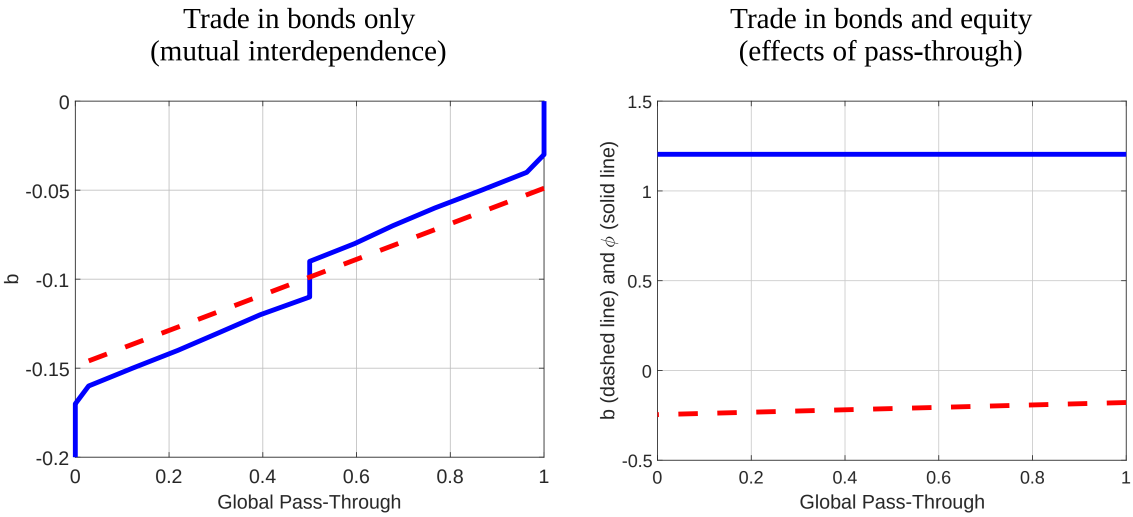

Figure 2: Left panel: dependence of global pass-through on net currency position of debt assets (blue solid line) and vice versa (red dashed line) in bonds-only case. Right panel: dependence of net currency position of debt assets (red dashed line) and equity home bias (blue solid line) on global pass-through in bonds-and-equity case.

Trade in bonds only (NB economy)

The left panel of Figure 2 shows this interaction for the bonds-only case. The red dashed line depicts the dependence of b (values on the vertical axis) on the value of the global pass-through (treated as exogenous, on the horizontal axis). Technically, we replace firms' decision rules (23) and (24) with exogenous values for $\tilde{z}$ and $\tilde{z}^*$. When varying global pass-through, we start at $\tilde{z} = \tilde{z}^* = 0$ and let first $\tilde{z}$ increase to unity, after which $\tilde{z}^*$ rises from zero to one.[27] As visible by the positive slope of the red line, global pass-through has a positive impact on the net currency position of debt assets. This effect arises if $\eta > 1$. Under complete LCP, business revenues from foreign sales increase only linearly with exchange-rate depreciations (foreign prices remain constant, but increase in terms of the domestic currency). If the pass-through increases, however, business income rises overproportionally after depreciations due to expenditure-switching effects. This increased business income automatically fulfills some of the hedging properties of the foreign debt holdings (against government spending shocks, that is), such that their amount can be reduced to avoid fluctuations induced by monetary policy shocks. See also Equation (A-4) in the appendix, which demonstrates that the optimal b rises in the covariance between business revenue and the exchange rate.

The blue solid line in the left panel of Figure 2 shows optimal pass-through (on the horizontal axis) if we set the net currency position of debt assets on the vertical axis exogenously. These values are calculated by replacing Equation (A-10) by exogenous values of b. We observe that pass-through is zero for low values of b. Starting at this point, raising b has an amplifying effect on exchange-rate volatility, visible in Equation (31). This is due to the fact that a low value of b raises Home's financial income (and hence demand) after a depreciation, thereby counteracting the depreciation. Thus, increasing b towards zero lets $\tilde{z}$ fall to zero. Put differently, raising the net currency position of debt assets lets Home switch from LCP to PCP.[28] This situation, in which both countries price in Home's currency,

[27] Since only the value of the global pass-through matters, this procedure is without loss of generality.

[28] More generally, firms in the country with the lower money-supply volatility switch first to price in their own currency. 'Home' refers to this country in the following.

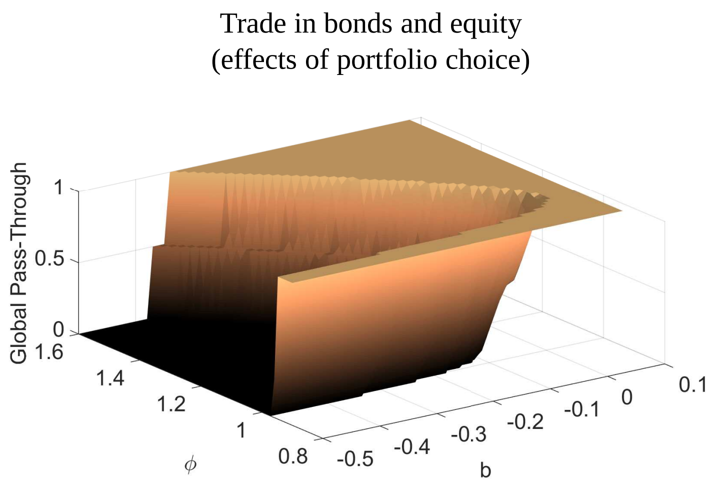

Figure 3: Bonds and equity case: dependence of global pass-through (vertical axis) on home bias in equity (left axis) and net currency position of debt assets (right axis).

remains an equilibrium for intermediate values. We hence obtain a broader range of a pass-through of 0.5. The higher the difference in volatilities of the money supply, the broader is this range. Further raising b increases exchange-rate volatility even more, such that more and more foreign exporters switch to PCP. An increasing level of global pass-through obtains. Financial autarky is reached at $b=0$, yielding a pass-through coefficient of unity.[29] As visible in the graph, both lines are increasing functions of their respective arguments. We obtain a unique solution at their intersection (in this case at a pass-through of 0.5). A stronger dependency of the pass-through on the net currency position of debt assets is also visible, while the reverse dependence is fairly limited. Specifically, pass-through changes from absent to complete, depending on the portfolio choice. The net currency position of debt assets, in contrast, does not reverse its sign, independently of the prevailing pass-through.

Trade in bonds and equity (NBE economy)

Figure 2 (right panel) depicts the effects of global pass-through (horizontal axis) on b and ϕ (both on the vertical axis) for trade in bonds and equity. As in the bonds-only case, the decision rules (23) and (24) were replaced by exogenous values of $\tilde{z}$ and $\tilde{z}^*$. Figure 3 shows how global pass-through (measured on the vertical axis) depends on b and ϕ (horizontal axes). Here, the optimal portfolio choices of Equation (A-20) were replaced by exogenous values for b and ϕ. As the global pass-through now depends on the net currency position of debt assets and the home bias in equities, Figure 3 is three-dimensional. For a better understanding of the figure, consider an exogenously set value of $\phi = 1$. This situation corresponds to the *NB* case, as no equity is traded across countries. Moving along the b-axis in Figure 3 hence yields the same relation between b and pass-through as depicted by the blue solid line in the left panel of Figure 2 (except for the switched axes). Financial

[29]This finding stands in contrast to Devereux and Engel (2001), whose setup is nested in ours. They state that pass-through can be lower than 0.5 under financial autarky if ρ is sufficiently high. The reason for this differential prediction lies in our consideration of government spending shocks: they increase exchange-rate volatility, which induces firms to price according to PCP (see Equation 23). Generally speaking, government spending shocks shift the blue solid line in the left panel of Figure 2 downwards, increasing pass-through for each level of b. Raising the volatility of monetary shocks shifts the line upwards, as those shocks induce a positive correlation between marginal costs and the exchange rate, reducing pass-through for each level of b.

autarky is reached at the intersection of $b = 0$ and $\phi = 1$, with the above discussed conclusions. Because there are unique mappings from pass-through to the optimal net currency position of debt assets (red dashed line in the right panel of Figure 2) and to the equity home bias (blue solid line), as well as a unique mapping from each combination of these parameters to pass-through (Figure 3), we again obtain a unique solution at their mutual intersection.

Regarding the pricing decisions of firms, the same pattern as in the *NB* case is visible in Figure 3. Increasing the value of b induces first the home country to switch from LCP to PCP (increasing global pass-through), followed by a small region of a constant pass-through. Finally, the foreign country also uses PCP if b rises further, until complete pass-through is reached. Looking at the reaction to a changing ϕ, the pattern is quite different. Intuitively, intermediate values of ϕ stabilize relative income and therefore the exchange rate. Producers hence choose LCP, while more extreme values of ϕ induce a high volatility of financial income. By raising exchange-rate volatility, this lets firms switch to PCP, such that global pass-through increases.[30] We can draw similar conclusions as in the bonds-only case. Financial markets, in terms of home bias in both bonds and equity, matter highly for pass-through. The reverse is not true, according to Figure 2 (right panel). While the net currency position of debt assets varies but stays negative if global pass-through changes from zero to one (following the same intuition as in the bonds-only case), the home bias in equity is independent of the level of pass-through. The value of pass-through has hence only a limited feedback to financial markets. We conclude that financial markets matter quantitatively and qualitatively more for pass-through than vice versa. Investigating the trade channel of exchange-rate movements without simultaneously considering the financial channel thus risks neglecting an important determinant of the former.

5.2.2 Equilibrium effects of financial integration

Given that the model cannot be solved analytically for the general calibration, we resort to numerical simulations in this section. In particular, we want to explore whether the predictions of a declining pass-through and a falling net currency position of debt assets is also valid for alternative, plausible parameter values. The upper-left panel of Table 4 displays the levels and changes of both variables under the baseline calibration. As explained in more detail in Section 5.1, when moving towards trade in bonds and equity agents can make better use of both instruments for hedging purposes. In particular, cross-border equity holdings can be used to mitigate the negative side effects of holding foreign debt, such that more international bonds can be bought to hedge against government spending (demand) shocks. Cross-border equity holdings also induce changes in relative income after productivity disturbances, such that these are now linked to the exchange rate. A stronger covariance between marginal costs and the exchange rate obtains, reducing the optimal amount of exchange rate pass-through.[31] At the same time, a lower pass-through reduces the positive effects of exchange-rate depreciations on business income. This reinforces households' decision to hold more foreign debt to compensate for this lost automatic hedge against government spending shocks.

[30] More precisely, for a given intermediate value of b, a low level of ϕ lets both producers follow PCP. This is represented by the 'full pass-through plateau' in the foreground of the figure. For increasing values of ϕ, foreign exporters switch to LCP first, implying a falling pass-through. Some home firms, however, switch to LCP already before all foreign firms have done so. Home firms are then first to go back to PCP for even higher values of ϕ, followed by their foreign counterparts once all home firms use PCP.

[31] Productivity shocks are hence responsible for another difference to Devereux and Engel (2001), additional to the one discussed in Footnote 29. Considering only monetary shocks, they obtain a pass-through coefficient of 0.5 in the case of complete markets. Allowing for supply disturbances in our (incomplete-market) setting increases the mentioned covariance, which reduces optimal pass-through to lower values.

Baseline Calibration		
	PT	NCD
NB	0.5	-0.10
NBE	0.0	-0.25
Δ	-0.5	-0.15

Alternative Calibrations	
Δ PT for all calibrations	-0.5
Δ NCD for different calibrations	see tables

η \ ρ	1.00	1.55	2.10	2.65	3.20	3.75
0.75	-0.06	-0.08	-0.08	-0.08	-0.06	-0.04
1.40	-0.13	-0.15	-0.15	-0.15	-0.13	-0.11
2.05	-0.19	-0.21	-0.22	-0.22	-0.20	-0.18
2.70	-0.26	-0.28	-0.29	-0.28	-0.27	-0.25
3.35	-0.33	-0.35	-0.36	-0.35	-0.34	-0.31
4.00	-0.40	-0.42	-0.43	-0.42	-0.41	-0.38

σ_M^2 \ $\sigma_{M^*}^2$	0.24	0.38	0.52	0.66	0.80	0.95
0.22	-0.11	-0.13	-0.14	-0.15	-0.12	-0.12
0.34	-0.13	-0.14	-0.15	-0.15	-0.16	-0.12
0.47	-0.14	-0.14	-0.15	-0.15	-0.16	-0.16
0.60	-0.14	-0.15	-0.15	-0.16	-0.16	-0.16
0.73	-0.15	-0.15	-0.16	-0.16	-0.16	-0.16
0.86	-0.12	-0.16	-0.16	-0.16	-0.16	-0.17

σ_G^2 \ $\sigma_{G^*}^2$	0.26	0.42	0.57	0.73	0.88	1.04
0.26	-0.11	-0.13	-0.14	-0.15	-0.15	-0.15
0.42	-0.13	-0.14	-0.15	-0.15	-0.15	-0.16
0.57	-0.14	-0.15	-0.15	-0.15	-0.16	-0.16
0.73	-0.15	-0.15	-0.15	-0.16	-0.16	-0.16
0.88	-0.15	-0.15	-0.16	-0.16	-0.16	-0.15
1.04	-0.15	-0.16	-0.16	-0.16	-0.15	-0.15

σ_A^2 \ $\sigma_{A^*}^2$	0.18	0.29	0.40	0.50	0.61	0.72
0.18	-0.21	-0.18	-0.17	-0.15	-0.14	-0.13
0.29	-0.18	-0.17	-0.15	-0.14	-0.13	-0.12
0.40	-0.17	-0.15	-0.14	-0.13	-0.12	-0.12
0.50	-0.15	-0.14	-0.13	-0.12	-0.12	-0.11
0.61	-0.14	-0.13	-0.12	-0.12	-0.11	-0.11
0.72	-0.13	-0.12	-0.12	-0.11	-0.11	-0.10

σ_{M,M^*}^2 \ σ_{A,A^*}^2	0.18	0.29	0.40	0.50	0.61	0.72
0.22	-0.15	-0.12	-0.11	-0.10	-0.09	-0.08
0.34	-0.19	-0.15	-0.13	-0.12	-0.11	-0.10
0.47	-0.22	-0.17	-0.14	-0.13	-0.11	-0.11
0.60	-0.23	-0.18	-0.15	-0.13	-0.12	-0.11
0.73	-0.24	-0.18	-0.15	-0.14	-0.12	-0.11
0.86	-0.24	-0.19	-0.16	-0.14	-0.12	-0.11

Table 4: Upper left: levels and changes of net currency position of debt assets (NCD) and pass-through (PT) under baseline calibration. Rest: changes in NCD ($b^{NBE} - b^{NB}$) for varying parameter values. Parameters not reported in respective tables are kept at their baseline values. All variances were multiplied by 10^4 before reporting for better readability.

The remaining panels of Table 4 display the changes in the net currency position of debt assets (NCD) when switching from a bonds-only economy to international financial markets with bonds and equity for different values of the key parameters of the model. The change in the net currency position of debt assets corresponds to $b^{NBE} - b^{NB}$, as b denotes the amount of net debt held in domestic currency. We do not display the change in global exchange-rate pass-through, as it falls for all shown combinations by 0.5 (as stated in the upper-left panel of Table 4). This results from the fact that one country always switches from PCP to LCP.

The upper-right panel of Table 4 reports the change in the net currency position of debt assets for different values for ρ and η. The middle-left panel shows the same statistic for different values of the volatilities of the shocks to the money supply, while in the middle-right panel the variances of government spending shocks are altered (always between half and double the baseline value). The bottom-left panel of Table 4 displays this change for different volatilities of the shocks to technology in both countries. Finally, in the bottom-right panel of Table 4 we change the volatility of monetary shocks, set to the reported value at Home and at a 10% higher rate at Foreign to avoid indeterminacy,

and technology shocks simultaneously across countries.
Summarizing the information in the tables, increased financial integration leads to reductions in pass-through and the net currency position of debt assets, independently of realistic parameter constellations. Both predictions are in line with the empirical evidence in Section 3. Given that financial integration has increased considerably over the recent decades, the described mechanism can explain the observed changes of these variables over time. Specifically, the model predicts a plausible reduction in the net currency position of debt assets by around 10-20 percentage points for calibrations close to the baseline. Also in line with the empirical observations presented in the right panel of Figure 1, it implies a negative net currency position of debt assets. As it is a stylized 2-period model, however, we are mainly interested in the qualitative changes following financial integration.

6 Conclusion

In this paper we have put forward a new explanation for the decline of the exchange rate pass-through into import prices. Crucial for our theoretical model is the impact of financial globalization, modeled as an increase in the number and nature of tradable financial assets, on the portfolio decision of households and the pricing decisions of firms. In the model, we take the impact of financial globalization and the mutual interaction between the optimal portfolio and the choice of the invoicing currency explicitly into account.
The main impact of financial globalization on pass-through works via better possibilities to hedge against specific shocks. Following financial integration, households hold more foreign debt assets as the new international equity positions counteract undesirable movements in the return of those debt assets. At the same time, cross-border equity holdings increase the correlation between marginal costs and the exchange rate, as cost reductions change profits, trigger international capital flows and thereby change international relative demand. Firms react by pricing more in local currency compared to a world in which only debt is traded internationally. As a result, optimal pass-through falls. Finally, a lower pass-through mitigates the increase in business income after depreciations, which is compensated for by holding even more foreign debt assets. We present empirical evidence supporting the negative effects of gross equity holdings on the net currency position of debt assets and the exchange rate pass-through, as well as their positive effect on the covariance between marginal costs and a depreciated currency. An important policy implication concerns the design of monetary unions: if preceded by financial integration, the effect of the nominal exchange rate on relative prices is reduced because of the lower exchange rate pass-trough. Moving towards abolishing the nominal exchange rate altogether is therefore likely to have smaller real consequences.

Appendix

A Equilibrium of the full model

In this appendix we derive the optimal portfolio solutions under the different degrees of international financial market integration for unrestricted parameter values and show how they influence the equilibrium behavior of the nominal exchange rate and marginal costs.[32]

Money market equilibrium and the nominal exchange rate First, we use the money market equilibrium to solve for the nominal exchange rate. Expressing (15) in log-linear terms yields

$$\widehat{S} = \frac{\widehat{M} - \widehat{M^*}}{\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)} - \frac{\rho(\widehat{PC} - \widehat{SP^*C^*})}{\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)}. \tag{A-1}$$

For future use we define $\Theta_M^S = [\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)]^{-1}$ and $\Theta_{PC}^S = \rho\Theta_M^S$, such that $\widehat{S} = \Theta_M^S(\widehat{M} - \widehat{M^*}) - \Theta_{PC}^S(\widehat{PC} - \widehat{SP^*C^*})$. The equilibrium nominal exchange rate will hence not only be affected by the relative money supplies but also via the differences in nominal spending, $\widehat{PC} - \widehat{SP^*C^*}$, and by the types of assets traded, as shown below.

A.1 Trade in bonds only

We follow the approximation method for computing equilibrium portfolio positions developed by Devereux and Sutherland (2011) and take a second-order approximation of the asset market equilibrium condition for the home country (9) and its foreign counterpart. The differences of these two equations lead to the following arbitrage condition

$$Cov(-\widehat{S}, \widehat{PC} - \widehat{SP^*C^*}) = \frac{1-\rho}{\rho} Cov(-\widehat{S}, \widehat{Q}), \tag{A-2}$$

which relates the covariance between excess returns on domestic nominal bonds (given by nominal exchange rate deviations, $\hat{R}_{Fin}^B = -\widehat{S}$) and relative nominal consumption expenditures, $\widehat{PC} - \widehat{SP^*C^*}$, to the covariance between excess returns on nominal bonds and the real exchange rate $\widehat{Q} = \widehat{SP^*} - \widehat{P}$. Linearizing the period $t = 1$ budget constraints for the home and foreign country (8) and taking country differences, we get an expression for relative nominal consumption expenditures. In doing so we take the government budget constraints into consideration and assume that the log of government expenditures is equal to zero in the deterministic steady state. The relative budget constraint equals

$$\widehat{PC} - \widehat{SP^*C^*} = 2b\hat{R}_{Fin}^B + (\widehat{REV} - \widehat{SREV^*}) - (\widehat{G} - \widehat{G^*}), \tag{A-3}$$

where we have used the fact that $B_H = B_F^*$ for $S_0 = 1$. b is the equilibrium amount of foreign bonds we are looking for. Relative sales revenues are defined as the non-financial return, $\hat{R}_{Fin}^{Non} = \widehat{REV} - \widehat{SREV^*}$.

[32] A more detailed description of the steps taken in the derivations is available from the authors upon request.

Optimal nominal bond portfolio Plugging (A-3) into the asset market arbitrage condition (A-2) and rearranging terms we get

$$b = \frac{1}{2}\left(\frac{1-\rho}{\rho}\frac{Cov(\hat{R}^B_{Fin},\widehat{Q})}{Var(\widehat{S})} - \frac{Cov(\hat{R}^B_{Fin},\hat{R}^{Non}_{Fin})}{Var(\widehat{S})} + \frac{Cov(\hat{R}^B_{Fin},\widehat{G}-\widehat{G^*})}{Var(\widehat{S})}\right). \tag{A-4}$$

This expression states that the optimal equilibrium bond holdings b (i.e., the net currency position of debt assets) depend on three components: the covariance between relative nominal bond returns (i.e., minus the nominal exchange rate) and the real exchange rate, the covariance between relative nominal bond returns and relative sales revenues, as well as the covariance between relative nominal bond returns and relative government expenditures, all weighted by the inverse of the variance of relative nominal bond returns, i.e., the nominal exchange rate.
By making an optimal portfolio choice, the representative household wants to hedge its marginal utility of consumption. Households hedge consumption risk stemming from variations in their purchasing power, reflected by movements in the real exchange rate. Domestic bonds are a good hedge against this risk if domestic bond returns are high whenever the domestic price level is high, i.e., $Cov(\hat{R}^B_{Fin},\widehat{Q})<0$. In the case of $\rho=1$, a unit increase in real returns of bond assets (domestic or foreign) decreases the marginal utility of consumption by one unit, such that bond asset gains evaluated at the marginal utility of consumption vanish and the covariance between relative nominal returns and the real exchange rate becomes irrelevant for the portfolio choice decision.
Furthermore, the representative household wishes to hedge nominal income risks associated with variations in nominal revenues from domestic firms and government expenditures. Domestic bonds are a good hedge if relative domestic bond returns are high whenever domestic revenues are low. For example, an appreciation of the nominal exchange rate causes both, a fall in relative revenues from foreign sales (if $\eta > 1$) and a higher relative domestic bond return, i.e., $Cov(\hat{R}^B_{Fin},\hat{R}^{Non}_{Fin})<0$. Consequently, holding a higher amount of domestic bonds allows to hedge nominal revenue risk. Government expenditures are fully paid by seignorage and lump-sum taxes which reduce nominal disposable income. Foreign bonds are a good hedge against taxation risk if their returns are high whenever the income loss associated with government expenditure is high, i.e., $Cov(\hat{R}^B_{Fin},\widehat{G}-\widehat{G^*})<0$. Since government spending shocks let the exchange rate depreciate, holding foreign bonds can at least partly offset this negative effect on income.
To solve for the optimal portfolio bond holdings, we write the nominal exchange rate, nominal consumption spending, and sales revenues as functions of the underlying shocks. We first treat portfolio-based nominal income as exogenous, $\widehat{Ex}_{Fin}=2b\hat{R}^B_{Fin}$. Relative domestic bond returns are obtained by combining equations (A-1) and (A-3):

$$\hat{R}^B_{Fin} = -\Theta^S_M(\widehat{M}-\widehat{M}^*) + \Theta^S_{PC}(\widehat{Ex}_{Fin}+\hat{R}^{Non}_{Fin}) - \Theta^S_{PC}(\widehat{G}-\widehat{G}^*), \tag{A-5}$$

where the coefficients Θ^S_M and Θ^S_{PC} are defined above and are given in Table A-1. Furthermore, non-financial income can be obtained from the sales revenue of firms, given total demand for their goods sold at home and abroad:

$$\widehat{REV} - \widehat{SREV^*} = \hat{R}^{Non}_{Fin} = \Lambda\widehat{S} - \lambda(\widehat{PC}-\widehat{SP^*C^*}) - \lambda(\widehat{G}-\widehat{G^*}), \tag{A-6}$$

with $\lambda=1-a-a^*$ and $\Lambda=-(1-\eta)(1+\lambda)[a(1-z^*)+a^*(1-z)]$. After substituting (A-1) and (A-3), this can be written as

$$\hat{R}^{Non}_{Fin} = \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\widehat{Ex}_{Fin} + \Theta^{R^{Non}_{Fin}}_{M}(\widehat{M}-\widehat{M}^*) + \Theta^{R^{Non}_{Fin}}_{G}(\widehat{G}-\widehat{G}^*), \tag{A-7}$$

where the resulting parameters $\Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}$, $\Theta^{R^{Non}_{Fin}}_{M}$, and $\Theta^{R^{Non}_{Fin}}_{G}$ are provided in Table A-1. Combining (A-5) and (A-7), we get

$$\hat{R}^{B}_{Fin} = \mathbf{R}_1 \widehat{Ex}_{Fin} + \mathbf{R}_2[(\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \tag{A-8}$$

where $\mathbf{R}_1 = \Theta^S_{PC}\left(1 + \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\right)$ is a scalar and $\mathbf{R}_2 = \left[-\left({\Theta_M}^S - \Theta^S_{PC}\Theta^{R^{Non}_{Fin}}_{M}\right), -\Theta^S_{PC}\left(1 - \Theta^{R^{Non}_{Fin}}_{G}\right)\right]$ is a 1×2 vector. Now we can write the relative discount factor as

$$-\rho(\widehat{PC} - \widehat{SP^*C^*}) + (1-\rho)\,\widehat{Q} = \mathbf{D}_1 \widehat{Ex}_{Fin} + \mathbf{D}_2[(\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \tag{A-9}$$

with $\mathbf{D}_1 = -\Theta^D_{PC}\left(1 + \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\right)$ being a scalar and $\mathbf{D}_2 = \left[\Theta^D_M - \Theta^D_{PC}\Theta^{R^{Non}_{Fin}}_{M}, \Theta^D_{PC}\left(1 - \Theta^{R^{Non}_{Fin}}_{G}\right)\right]$ a 1×2 vector of combinations of structural parameters, where Θ^D_M and Θ^D_{PC} are shown in Table A-1. Given (A-8) and (A-9), the arbitrage condition (A-2) can be written as $\mathbf{R}\Sigma\mathbf{D}' = 0$, where $\mathbf{R} = \mathbf{R}_1\mathbf{H} + \mathbf{R}_2$, $\mathbf{H} = 2b(1 - 2b\mathbf{R}_1)^{-1}\mathbf{R}_2$, and $\mathbf{D} = \mathbf{D}_1\mathbf{H} + \mathbf{D}_2$ are 1×2 vectors. Σ is the 2×2 variance-covariance matrix of the exogenous disturbances to the money supply and government spending. Even though the economies are hit by monetary policy, government spending, and productivity shocks, only the first two change aggregate income and move the exchange rate. Hence, households cannot and do not need to insure themselves against relative productivity movements across countries. Solving for b yields

$$b = \left[\mathbf{R}_2\Sigma\mathbf{D}_2'\mathbf{R}_1' - \mathbf{D}_1\mathbf{R}_2\Sigma\mathbf{R}_2'\right]^{-1}\mathbf{R}_2\Sigma\mathbf{D}_2'/2. \tag{A-10}$$

Nominal exchange rate in the *NB* economy Given the solution to nominal bonds holdings we can express the nominal exchange rate in Equation (A-1) as

$$\widehat{S} = \frac{\left(1 - \rho\Theta^{PC}_M\right)(\widehat{M} - \widehat{M}^*) + \rho\Theta^{PC}_G(\widehat{G} - \widehat{G}^*)}{\rho + (1-\rho)\,(1-a)(2 - \tilde{z} - \tilde{z}^*)}, \tag{A-11}$$

with Θ^{PC}_M and Θ^{PC}_G provided in Table A-1. As explained before, the exchange rate only transmits two of the three possible economic disturbances across countries. The impact of the shocks is affected by the equilibrium portfolio holdings of b since Θ^{PC}_M and Θ^{PC}_G depend on b. The fact that not all disturbances are transmitted via the nominal exchange rate has implications for the price-setting decision of firms since it directly affects the covariance between the nominal exchange rate and marginal costs of firms. Consider the linearized version of marginal costs at Home and Foreign, Equation (29). Together with equations (13) and (A-11) it follows that the covariance between marginal costs and the nominal exchange rate can be written as

$$Cov(\widehat{mc}, \widehat{S}) = \frac{1 - \rho\Theta^{PC}_M}{\rho + (1-\rho)\,(1-a)(2 - \tilde{z} - \tilde{z}^*)} Var(\widehat{M}), \tag{A-12}$$

$$Cov(\widehat{mc}^*, \widehat{S}) = -\frac{1 - \rho\Theta^{PC}_M}{\rho + (1-\rho)\,(1-a)(2 - \tilde{z} - \tilde{z}^*)} Var(\widehat{M}^*), \tag{A-13}$$

respectively. Note that in the *NB* economies only monetary disturbances affect the covariance relationship between marginal costs and the nominal exchange rate. The magnitude of this covariance relationship will depend on the equilibrium bond holdings b. Since all shocks are uncorrelated, the variance of the nominal exchange rate equals

$$Var(\widehat{S}) = \frac{\left(1 - \rho\Theta^{PC}_M\right)^2 Var(\widehat{M} + \widehat{M}^*) + (\rho\Theta^{PC}_G)^2 Var(\widehat{G} + \widehat{G}^*)}{\left[\rho + (1-\rho)\,(1-a)(2 - \tilde{z} - \tilde{z}^*)\right]^2}, \tag{A-14}$$

with $Var(\widehat{G} + \widehat{G}^*)$ and $Var(\widehat{M} + \widehat{M}^*)$ reflecting the sum of the variances of the government spending and monetary policy shocks at home and abroad.

A.2 Trade in bonds and equities

Additional to the asset market equilibrium condition for bonds, Equation (A-2), we also take a second-order approximation of the home Euler equity equation (12) and its foreign counterpart to obtain

$$Cov(\widehat{\Pi} - \widehat{S\Pi^*}, \widehat{PC} - \widehat{SP^*C^*}) = \frac{1-\rho}{\rho} Cov(\widehat{\Pi} - \widehat{S\Pi^*}, \widehat{Q}). \quad \text{(A-15)}$$

As for the *NB* case, we linearize the period $t = 1$ budget constraint for the home country and its foreign counterpart (11). Taking country differences yields

$$\widehat{PC} - \widehat{SP^*C^*} = \frac{2\phi - 1}{\sigma}(\widehat{\Pi} - \widehat{S\Pi^*}) + 2b\hat{R}^B_{Fin} - (\widehat{G} - \widehat{G^*}) + \frac{\sigma - 1}{\sigma}(\widehat{WL} - \widehat{SW^*L^*}).$$

Defining $\hat{R}^E_{Fin} \equiv \frac{1}{\sigma}(\widehat{\Pi} - \widehat{S\Pi^*})$ and $\hat{R}^{Non}_{Fin} \equiv \frac{\sigma-1}{\sigma}(\widehat{WL} - \widehat{SW^*L^*})$, we can rewrite the last equation as[33]

$$\widehat{PC} - \widehat{SP^*C^*} = (2\phi - 1)\hat{R}^E_{Fin} + 2b\hat{R}^B_{Fin} - (\widehat{G} - \widehat{G^*}) + \hat{R}^{Non}_{Fin}. \quad \text{(A-16)}$$

Optimal bond and equity portfolio Given that both bonds and equity are traded, the equilibrium bond position will now depend also on the covariance between the relative returns from equity and bond holdings as well as on equilibrium equity holdings. Following the solution approach of the previous section, non financial income equals

$$\hat{R}^{Non}_{Fin} = \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}} \widehat{\mathbf{Ex}}_{Fin} - \Theta^{R^{Non}_{Fin}}_{A}(\widehat{A} - \widehat{A}^*) + \Theta^{R^{Non}_{Fin}}_{M}(\widehat{M} - \widehat{M}^*) - \Theta^{R^{Non}_{Fin}}_{G}(\widehat{G} - \widehat{G}^*), \quad \text{(A-17)}$$

with $\widehat{\mathbf{Ex}}_{Fin} = [2b, (2\phi - 1)]\ [\hat{R}^B_{Fin}, \hat{R}^E_{Fin}]'$ and $\Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}$, $\Theta^{R^{Non}_{Fin}}_{A}$, $\Theta^{R^{Non}_{Fin}}_{M}$ and $\Theta^{R^{Non}_{Fin}}_{G}$ given in Table A-2. The structural parameters Θ^S_{PC} and Θ^S_M are also shown in Table A-2. Financial returns can be written as

$$[\hat{R}^B_{Fin}, \hat{R}^E_{Fin}]' = \mathbf{R}_1\widehat{\mathbf{Ex}}_{Fin} + \mathbf{R}_2[(\widehat{A} - \widehat{A}^*), (\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad \text{(A-18)}$$

with $\mathbf{R}_1 = \left[\Theta^S_{PC}\left(1 + \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\right), -\left(\Theta^{R_{Fin}}_{PC} + \Theta^{R_{Fin}}_{S}\Theta^S_{PC}\right)\left(1 + \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\right)\right]'$ and $\mathbf{R}_2$ being a 3×2 matrix, which is displayed in the next subsection and contains the additional structural parameters $\Theta^{R_{Fin}}_{PC}$ and $\Theta^{R_{Fin}}_{S}$, given in Table A-2. Finally, the relative discount factor equals

$$-\rho(\widehat{PC} - \widehat{SP^*C^*}) + (1 - \rho)\,\widehat{Q} = \mathbf{D}_1\widehat{\mathbf{Ex}}_{Fin} + \mathbf{D}_2[(\widehat{A} - \widehat{A}^*), (\widehat{M} - \widehat{M}^*), (\widehat{G} - \widehat{G}^*)]', \quad \text{(A-19)}$$

with $\mathbf{D}_1 = -\Theta^D_{PC}\left(1 + \Theta^{R^{Non}_{Fin}}_{Ex_{Fin}}\right)$ being a scalar and $\mathbf{D}_2 = \left[\Theta^D_{PC}\Theta^{R^{Non}_{Fin}}_{A}, \Theta^D_M - \Theta^D_{PC}\Theta^{R^{Non}_{Fin}}_{M}, \Theta^D_{PC}\left(1 + \Theta^{R^{Non}_{Fin}}_{G}\right)\right]$ a 1×3 vector of combinations of the structural parameters, where Θ^D_M and Θ^D_{PC} are defined in Table A-2. Equations (A-17) - (A-19) allow us to write the solution to the bond and equity holding in the *NBE* economy as

$$\begin{bmatrix} 2b & (2\phi - 1) \end{bmatrix}' = \left[\mathbf{R}_2\Sigma\mathbf{D}_2'\mathbf{R}_1' - \mathbf{D}_1\mathbf{R}_2\Sigma\mathbf{R}_2'\right]^{-1}\mathbf{R}_2\Sigma\mathbf{D}_2', \quad \text{(A-20)}$$

where Σ now represents the 3×3 variance-covariance matrix of all three shocks.

[33]Note that the variables of Section A.1 assume different values in this section.

Table A-1: Structural coefficients of the NB economies.

$$\Theta_M^S = [\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)]^{-1}$$

$$\Theta_{PC}^S = \rho\Theta_M^S$$

$$\xi_1 = 2(1-a) - 2(1-\eta)(1-a)a(2-\tilde{z}-\tilde{z}^*)\Theta_{PC}^S$$

$$\Theta_{Ex_{Fin}}^{R_{Fin}^{Non}} = (1-\xi_1)/\xi_1$$

$$\Theta_M^{R_{Fin}^{Non}} = -\left[2(1-\eta)(1-a)a(2-\tilde{z}-\tilde{z}^*)\Theta_M^S\right]/\xi_1$$

$$\Theta_G^{R_{Fin}^{Non}} = \left[1-2a-2(1-\eta)(1-a)a(2-\tilde{z}-\tilde{z}^*)\Theta_{PC}^S - 1 + 2a\right]/\xi_1$$

$$\Theta_M^D = (1-\rho)[1-(1-a)(2-\tilde{z}-\tilde{z}^*)]\Theta_M^S$$

$$\Theta_{PC}^D = \rho + (1-\rho)[1-(1-a)(2-\tilde{z}-\tilde{z}^*)]\Theta_{PC}^S$$

$$\xi_2 = 2(1-a) - [2b + (1-\eta)(1-a)a(2-\tilde{z}-\tilde{z}^*)]\Theta_{PC}^S$$

$$\Theta_M^{PC} = -\left\{\Theta_M^S[2b + (1-\eta)(1-a)a(2-\tilde{z}-\tilde{z}^*)]\right\}/\xi_2$$

$$\Theta_G^{PC} = [2(1-a)]/\xi_2$$

Nominal exchange rate in the *NBE* economy The solution to the nominal exchange rate can be derived from the above. Given the relative budget constraint of households (A-16) and plugging in equations (A-17)-(A-20), we can write the difference in nominal spending as

$$\widehat{PC} - \widehat{SP^*C^*} = \Theta_A^{PC}(\widehat{A} - \widehat{A}^*) + \Theta_M^{PC}(\widehat{M} - \widehat{M}^*) + \Theta_G^{PC}(\widehat{G} - \widehat{G}^*). \tag{A-21}$$

Substituting this back into Equation (A-1) gives

$$\widehat{S} = \frac{\left(1-\rho\Theta_M^{PC}\right)(\widehat{M} - \widehat{M}^*) - \rho\Theta_A^{PC}(\widehat{A} - \widehat{A}^*) - \rho\Theta_G^{PC}(\widehat{G} - \widehat{G}^*)}{\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)}, \tag{A-22}$$

with Θ_A^{PC}, Θ_M^{PC}, and Θ_G^{PC} displayed in Table A-2. In contrast to the *NB* economy, the exchange rate transmits all three economic disturbances across countries. Again, the equilibrium outcome of the nominal exchange rate depends on the equilibrium portfolio allocation of bonds, b, and equities, ϕ. From (29) and (A-22) it follows that the covariance between marginal costs and the nominal exchange rate in the *NBE* economies can be written as

$$\begin{aligned} Cov(\widehat{mc}, \widehat{S}) &= \frac{\left(1-\rho\Theta_M^{PC}\right)Var(\widehat{M}) + \rho\Theta_A^{PC}Var(\widehat{A})}{\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)}, \\ Cov(\widehat{mc}^*, \widehat{S}) &= -\frac{\left(1-\rho\Theta_M^{PC}\right)Var(\widehat{M}^*) + \rho\Theta_A^{PC}Var(\widehat{A}^*)}{\rho + (1-\rho)(1-a)(2-\tilde{z}-\tilde{z}^*)}. \end{aligned}$$

Table A-2: Structural coefficients of the NBE economies.

$$\Theta_A^{R_{Fin}^{Non}} = \left(\frac{\sigma}{\sigma-1} - \left[2a-1+\rho-\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)-1+\rho\right)\right]\}\,\Theta_{PC}^S\right]\right)^{-1}$$

$$\xi_3 = 1-\frac{\sigma-1}{\sigma}\left[2a+\rho-1-\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)+\rho-1\right)\right]\}\,\Theta_{PC}^S\right]$$

$$\Theta_{Ex_{Fin}}^{R_{Fin}^{Non}} = \frac{\sigma-1}{\sigma}\left[2a-1+\rho-\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)-1+\rho\right)\right]\}\,\Theta_{PC}^S\right]/\xi_3$$

$$\Theta_M^{R_{Fin}^{Non}} = \frac{\sigma-1}{\sigma}\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)-(1-\rho)\right)\right]\}\,\Theta_M^S/\xi_3$$

$$\Theta_G^{R_{Fin}^{Non}} = \frac{\sigma-1}{\sigma}\left\{\rho-\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)-1+\rho\right)\right]\}\,\Theta_{PC}^S\right\}/\xi_3$$

$$\Theta_{PC}^{R_{Fin}} = \left[1-2a+(\sigma-1)\rho\right]\sigma^{-1}$$

$$\Theta_S^{R_{Fin}} = \left[(\sigma-1)\{(1-a)\left[\tilde{z}+\tilde{z}^*-(2-\tilde{z}-\tilde{z}^*)\left(1-\rho-2a(1-\eta)\right)\right]-\rho\} - 2\sigma a\,(1-a)\,(1-\eta)\,(2-\tilde{z}-\tilde{z}^*)\right]\sigma^{-1}$$

$$\xi_4 = 1+(2\phi-1)\left(\Theta_{PC}^{R_{Fin}}+\Theta_S^{R_{Fin}}\Theta_{PC}^S\right)-2b\Theta_{PC}^S - \frac{\sigma-1}{\sigma}\{a+(1-a)\left[\tilde{z}+\tilde{z}^*-1+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)+\rho-1\right)\right]\}\,\Theta_{PC}^S$$

$$\Theta_A^{PC} = 2(1-\phi)\frac{\sigma-1}{\sigma}/\xi_4$$

$$\Theta_M^{PC} = \left\{\frac{\sigma-1}{\sigma}\{\rho-(1-a)\left[\tilde{z}+\tilde{z}^*+(2-\tilde{z}-\tilde{z}^*)\left(2a(1-\eta)-(1-\rho)\right)\right]\}-(1-2\phi)\Theta_S^{R_{Fin}}-2b\right\}\Theta_M^S/\xi_4$$

$$\Theta_G^{PC} = \left[(2\phi-1)\frac{1-2a}{\sigma}+\frac{\sigma-1}{\sigma}(1-2a)+1\right]/\xi_4$$

All shocks that affect marginal costs now also impact the nominal exchange rate. Thus, the covariance between marginal costs and the nominal exchange rate is not only affected by monetary disturbances, as in the *NB* economy, but also by productivity disturbances. The sign of this covariance relationship, however, will depend on the equilibrium bond holdings b as well as the equilibrium equity position ϕ. Since all shocks are uncorrelated, the variance of the nominal exchange rate in the *NBE* economy equals

$$Var(\widehat{S}) = \frac{\left(1-\rho\Theta_M^{PC}\right)^2 Var(\widehat{M}+\widehat{M}^*)+(\rho\Theta_G^{PC})^2 Var(\widehat{G}+\widehat{G}^*)}{\left[\rho+(1-\rho)\,(1-a)(2-\tilde{z}-\tilde{z}^*)\right]^2} + \frac{\left(\rho\Theta_A^{PC}\right)^2 Var(\widehat{A}+\widehat{A}^*)}{\left[\rho+(1-\rho)\,(1-a)(2-\tilde{z}-\tilde{z}^*)\right]^2}.$$

A.3 Coefficients of the full model

Table A-1 provides the coefficients for the case of trade in nominal bonds only, while Table A-2 lists the coefficients for economies in which bonds and equity are traded.
The matrix $\mathbf{R}_2$ for the bond and equity case is given by

$$\mathbf{R}_2 = \begin{bmatrix} -\Theta^S_{PC}\Theta^{R^{Non}_{Fin}}_{A}, & \left(\Theta^{R_{Fin}}_{PC} + \Theta^{R_{Fin}}_{S}\Theta^S_{PC}\right)\Theta^{R^{Non}_{Fin}}_{A} + \frac{\sigma-1}{\sigma} \\ -\Theta^S_M + \Theta^S_{PC}\Theta^{R^{Non}_{Fin}}_{M}, & \Theta^{R_{Fin}}_{S}\Theta^S_M - \left(\Theta^{R_{Fin}}_{PC} + \Theta^{R_{Fin}}_{S}\Theta^S_{PC}\right)\Theta^{R^{Non}_{Fin}}_{M} \\ -\Theta^S_{PC}\left(1+\Theta^{R^{Non}_{Fin}}_{G}\right), & \left(\Theta^{R_{Fin}}_{PC} + \Theta^{R_{Fin}}_{S}\Theta^S_{PC}\right)\left(1+\Theta^{R^{Non}_{Fin}}_{G}\right) - \frac{1-2a}{\sigma} \end{bmatrix}'.$$

B Data appendix

B.1 Data sources

We use the below variables from the following, freely accessible, data sets:

- Lane and Shambaugh (2010): debt assets in domestic currency % of GDP, debt assets in foreign currency % of GDP, debt liabilities in domestic currency % of GDP, and debt liabilities in foreign currency % of GDP for 109 countries (after eliminating outliers, see below).

- The updated and extended version of the data set constructed by Lane and Milesi-Ferretti (2007): GDP (US$), Portfolio equity assets (stock), Portfolio equity liabilities (stock), FDI assets (stock), FDI liabilities (stock), Debt assets (stock), Debt liabilities (stock), Portfolio debt assets, Portfolio debt liabilities, and net foreign assets (NFA) for the same countries as in Lane and Shambaugh (2010).

- International Financial Statistics of the IMF: exports of goods and services, imports of goods and services (both in national currencies), official or market exchange rates (to convert into US$), nominal effective exchange rate (linearly detrended), CPI, and population. Inflation is calculated based on CPI and is linearly detrended.

- Chinn and Ito (2006): updated Financial Openness Index.

- OECD Main Economic Indicators: M2. OECD Economic Outlook 92: CGV: Government final consumption expenditure, volume; IGV: Government gross fixed capital formation, volume; GDPV: Gross domestic product, volume, market prices; ET: Total employment; HRS: Hours worked per employee, total economy; from 1970Q1 until 2012Q4, all for the calculation of the shock variances. OECD Quarterly National Accounts: Compensation of employees at CQRS (national currency, current prices, quarterly levels, seasonally adjusted); GDP (expenditure approach) at CQRS; GDP (expenditure approach) at DOBSA (Deflator, OECD reference year, seasonally adjusted); all for the calculation of unit labor costs (ULC). Unit labor costs were derived by dividing compensation of employees by real GDP (nominal GDP divided by GDP deflator) and are linearly detrended. Data on compensation of employees for Brazil, Israel, Turkey, and South Africa obtained from Haver Analytics, with varying starting dates.

- Kamps (2006): percentage of export goods priced in home currency, see her Table A1.

Table B-1: Countries used in the regressions of Section 3.

United States*	El Salvador	**Pakistan**	Tunisia
Austria*	Guatemala	Philippines	Uganda
Denmark*	Haiti	***Thailand***	Burkina Faso
France*	Honduras	Vietnam	Fiji
Germany*	**Mexico**	Algeria	Papua New Guinea
Italy*	Nicaragua	Botswana	Armenia
Netherlands	Paraguay	Cameroon	Azerbaijan
Norway*	Peru	Chad	Belarus
Sweden*	Uruguay	Congo, Republic of	Albania
Canada*	Venezuela, Rep. Bol.	Benin	Georgia
Japan*	Jamaica	Equatorial Guinea	Kazakhstan
Finland*	Trinidad and Tobago	Ethiopia	Kyrgyz Republic
*Greece**	Iran, Islamic Republic of	Gabon	Moldova
Iceland*	Israel*	Ghana	Russia
Ireland	**Jordan**	Guinea	China,P.R.: Mainland
*Portugal**	Oman	Côte d'Ivoire	*Ukraine*
Spain*	Syrian Arab Republic	Kenya	*Czech Republic**
Turkey	Egypt	Madagascar	Slovak Republic*
Australia*	Yemen, Republic of	Malawi	Estonia
New Zealand	Bangladesh	Mali	Latvia
South Africa*	Cambodia	Morocco	***Hungary****
Argentina	Sri Lanka	Mozambique	*Lithuania*
Bolivia	India	Niger	Croatia
Brazil	*Indonesia*	Nigeria	Slovenia
Chile	Korea	Rwanda	Macedonia
Colombia	*Malaysia*	Senegal	Bosnia and Herzegovina
Dominican Republic	Nepal	Tanzania	***Poland****
		Togo	Romania

Countries are ordered according to their IFS code. Countries for which data on unit labor costs and the nominal exchange rate is available and which were hence used in the regressions of Table 2, columns (1)-(2), are marked by an asterisk. Countries for which the pricing currency of exports is available and which were hence used in the regressions of Table 2, columns (3)-(6), are written in italics. Countries for which data on the export pass-through is available in Choudhri and Hakura (2015) and which were hence used in the regressions of Table 2, columns (7)-(8), are written in bold.

- Choudhri and Hakura (2015): Short-run exchange rate pass-through into export prices, see their Table 1.

The time period for our regressions, 1990-2004, is dictated by the length of the series in Lane and Shambaugh (2010) and Kamps (2006).

B.2 Data selection

The financial variables (sum of assets plus liabilities of portfolio equity and FDI over GDP, net foreign assets over GDP, total debt over GDP) feature some outliers. These are mainly financial centers such as Hong Kong, Switzerland etc. and some developing countries with extraordinary large and negative

Table B-2: Summary statistics of variables used in Section 3

	Count	Mean	Var	Min	Max
NCD/GDP	1414	0.28	0.15	-1.05	2.48
NCD/Debt	1414	0.30	0.24	-3.61	3.31
(Eq. & FDI)/GDP	1421	0.30	0.07	0.00	1.36
NFA/GDP	1421	-0.47	0.17	-2.33	0.84
log(Gross Debt)	1421	0.79	0.17	0.15	2.38
Chinn-Ito	1396	0.12	2.16	-1.86	2.46
Openness	1382	0.70	0.15	0.14	3.50
Net Exp.	1382	-0.04	0.01	-0.73	0.55
log(GDP/Pop.)	1421	7.54	2.30	4.28	10.65
log(Pop.)	1421	2.64	2.24	-1.37	7.17
Inflation	1297	0.02	0.00	-0.05	1.11
Inflation Vol.	1252	0.00	0.00	0.00	0.36
Exch. Rate Vol.	809	1.09	2.16	0.00	7.68
ULC Vol.	200	0.00	0.00	0.00	0.14
Cov ULC/EER	196	-0.00	0.00	-0.04	0.03
PCP	88	0.19	0.04	0.00	0.63
PCP+VCP	63	0.94	0.00	0.81	0.98
PT	34	0.65	0.08	-0.18	1.05

See explanations below tables 1 and 2 for description of variables.

net foreign assets. As large parts of the financial centers' assets do most likely not represent asset holdings of their own inhabitants (as assumed in our model), they are not subject of our analysis. In developing countries with large debt, the currency decomposition of net foreign asset reflects most probably choices taken by donor countries instead of optimal portfolio decisions of inhabitants. Using different ways to remove outliers gives similar results. We use the multivariate technique to detect outliers proposed in Hadi (1992, 1994) with a significance level of 0.05 (the results are robust to changes in this value). Alternatively, removing observations above the 90% percentile of the sum of NCD/GDP and gross debt yields very similar results. Furthermore, we have eliminated countries that, according to Ilzetzki et al. (2017), have no separate legal tender in all regressions.

Table B-1 lists the countries which we employed in the regressions of Section 3, Table B-2 summarizes the used variables, while Table B-3 displays their correlations.

Table B-3: Correlations of variables used in Section 3.

	NCD /GDP	NCD /Debt	Eq. +FDI	NFA	GD	CI	Open.	NX /GDP	GDP /Pop.	Pop.	INF	IFV	ERV	ULV	Cov	PCP	PCP +VCP
NCD/GDP	1.00																
NCD/Debt	0.77	1.00															
Eq.+FDI	-0.18	-0.21	1.00														
NFA	-0.84	-0.59	-0.15	1.00													
GD	0.56	0.20	0.13	-0.57	1.00												
CI	-0.29	-0.27	0.34	0.22	0.14	1.00											
Open.	-0.05	-0.18	0.27	-0.16	0.14	-0.06	1.00										
NX/GDP	-0.25	-0.23	0.22	0.23	-0.14	0.03	0.10	1.00									
GDP/Pop.	-0.48	-0.40	0.40	0.45	-0.06	0.56	0.03	0.39	1.00								
Pop.	-0.11	0.05	-0.15	0.20	-0.16	-0.12	-0.38	0.11	-0.10	1.00							
INF	0.08	0.06	-0.20	0.00	-0.02	-0.20	-0.08	0.01	-0.11	0.06	1.00						
IFV	0.03	0.04	-0.10	0.02	-0.03	-0.10	-0.09	0.02	-0.01	0.06	0.53	1.00					
ERV	0.02	0.02	0.03	-0.04	0.09	0.02	-0.03	-0.02	-0.02	-0.06	0.11	0.01	1.00				
ULCV	0.24	0.40	-0.26	-0.09	-0.19	-0.44	-0.03	0.02	-0.34	0.07	0.87	0.77	-0.14	1.00			
Cov	-0.04	0.01	0.05	-0.05	0.10	0.03	-0.06	-0.02	-0.04	0.05	-0.08	0.01	-0.11	0.10	1.00		
PCP	-0.63	-0.63	0.45	0.41	0.66	0.58	-0.52	-0.18	0.81	0.03	-0.33	-0.25	0.30	-0.34	0.28	1.00	
PCP+VCP	-0.00	-0.00	0.25	-0.08	0.06	0.29	-0.38	-0.18	0.45	-0.20	-0.10	-0.03	0.32	-0.50	-0.21	0.26	1.00
PT	-0.00	-0.10	-0.09	-0.00	0.17	-0.04	0.02	-0.00	-0.02	-0.08	0.09	0.13	0.14	0.22	-0.10	0.15	-0.43

NCD/GDP=net currency position of debt assets (net debt claims in domestic currency minus net debt claims in foreign currencies) over GDP, NCD/Debt=net currency position of debt assets over sum of debt assets and liabilities, Eq. & FDI=sum of equity assets and liabilities plus sum of FDI assets and liabilities over GDP, NFA=net foreign assets over GDP, GD=log of sum of debt assets and liabilities, CI=index of financial openness from Chinn and Ito (2006), Open.=Sum of imports and exports over GDP, NX/GDP=net exports over GDP, GDP/Pop.=log of GDP over population, Pop.=log of population, INF=Inflation, IFV=variance of quarterly inflation in the three preceding years, ERV=variance of quarterly nominal effective exchange rate in the three preceding years, ULV=variance of unit labor costs in the three preceding years, Cov=covariance between unit labor costs and nominal effective exchange rate in the three preceding years, PCP=share of exports set in home currency, PCP+VCP=share of exports set in home currency, US dollar or euro, PT=exchange rate pass-through into export prices.

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