Optimal Monetary Policy under Dollar Pricing[*]

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February 14, 2019

Preliminary and Incomplete

Abstract

The recent empirical evidence shows that most international prices are sticky in dollars. This paper studies the optimal *non-cooperative* monetary policy and the welfare implications of dollar pricing in a context of an open economy model with nominal rigidities. We establish the following results: 1) as in a closed economy, the optimal policy in both the U.S. and other economies stabilizes prices of local producers; 2) this policy generates asymmetric spillovers between countries such that the U.S. has a free floating exchange rate and an independent monetary policy, while other countries partially peg their exchange rates to the dollar giving rise to a "global monetary cycle"; 3) capital controls cannot insulate countries from U.S. spillovers; 4) the optimal cooperative policy is hard to implement because of the conflict of interest between countries; 5) there are potential gains from dollar pricing for the U.S., while other countries can benefit from forming a currency union such as the Eurozone.

1 Introduction

The key feature of the international price system is that most prices in global trade are set in dollars and remain sticky in U.S. currency at horizons of up to two years (Gopinath 2016, Goldberg and Tille 2008, Gopinath and Rigobon 2008). A growing empirical literature shows that this fact has important implications for the transmission of monetary shocks between countries. In particular, a depreciation of the U.S. exchange rate decreases import prices relative to prices of domestic goods around the world, which leads to expenditure switching towards foreign goods and increases the volume of global trade (Boz, Gopinath, and Plagborg-Møller 2017). In contrast, a depreciation of other exchange rates does not affect export prices in the currency of destination and hence, has no stimulating effect on exports, so that the trade balance in non-U.S. economies adjusts mostly through changes in imports (Casas, Díez, Gopinath, and Gourinchas 2017). In addition, the countries with a higher share of dollar pricing in trade experience larger spillovers of U.S. monetary policy on output, exchange rates and interest rates (Zhang 2018).[1]

While a lot of progress has been made in understanding the positive implications of dollar currency pricing (DCP), much less is known about its implications for the optimal policy and the welfare effects. These questions are, however, at the heart of recent policy debates: Does U.S. monetary policy generate negative spillover effects on the rest of the world and leads to "currency wars" (Bernanke 2017)? Should the optimal policy focus on price stabilization as in a closed economy or should it also respond to foreign shocks (Engel 2011, Corsetti, Dedola, and Leduc 2018)? Can free floating exchange rates insulate countries from international spillovers (Friedman 1953, Devereux and Engel 2003) and what explains the widespread "fear of floating" in the data (Calvo and Reinhart 2002)? Should countries use capital controls (Blanchard 2017)? Does the U.S. enjoy an "exorbitant privilege" from the dominant status of its currency in global trade (Eichengreen 2011)? Are there gains from forming a currency union such as the Eurozone in this case (Mundell 1961)? Do countries benefit from international cooperation (Benigno and Benigno 2003)? Finally, is the current international price system optimal or is it desirable to move to the one with a more symmetric use of currencies?

We answer these questions in a context of a standard open-economy sticky-price model augmented with dollar pricing and show that the answers are dramatically different from the ones obtained under a conventional assumption of producer currency pricing (PCP). To deliver results in a most transparent way, we start with a simple static version of the model from Gali and Monacelli (2005), which has been actively used as a workhorse model in the recent normative literature (see e.g. Farhi and Werning 2012, 2017). Households use a complete set of Arrow-Debreu securities to share risk between countries, while firms preset domestic prices in local currency and export prices in dollars before productivity shocks are realized. After the uncertainty is resolved, the agents make consumption and production

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[1] Auer, Burstein, and Lein (2018) show that currency choice of exporters matters not only for prices at the dock, but also determines the pass-through into retail prices.

decisions taking as given the preset prices, the transfers between the countries, and the monetary policy in each country. Importantly, we allow for foreign inputs in production, which reflects the fact that most imported goods are used either as intermediates or have to go through wholesale and retail sectors before reaching consumers (see Johnson and Noguera 2012, Burstein, Neves, and Rebelo 2003). We solve for the optimal non-cooperative policy under both discretion and commitment and compare it to the optimal cooperative policy. To show the robustness of the results and gain additional insights, the last section of the paper extends the model in several dimensions including dynamic price setting and incomplete asset markets.

Our first main result is that while price stability remains the optimal target in the non-U.S. economies under DCP as under PCP, such policy no longer implements the first-best allocation and also leads to an implicit peg to the dollar. Because both prices and demand for exported goods is completely exogenous in case of the non-U.S. economies, the best outcome the policy can achieve is to implement the optimal production and consumption of domestic goods by stabilizing the prices of local producers. While the optimal policy can be formulated in terms of domestic target, it does respond to foreign shocks. Given that all international prices are set in dollars, an appreciation of U.S. exchange rate increases the prices of imported intermediates in other economies and puts upward pressure on local prices. To keep them constant, other countries have to tighten their monetary policy, "leaning against the wind" and effectively introducing a partial peg to the dollar. The result shows that the widespread anchoring of exchange rates to the dollar in the data (see Ilzetzki, Reinhart, and Rogoff 2017) can be due not only to the global financial cycle (Rey 2015), but also to the dominant status of the dollar in international trade. This result is also consistent with the fact that rising import prices are among main factors mentioned by policymakers in emerging economies when explaining their decision to stabilize the exchange rate.

Interestingly, we show that additional fiscal instruments such as capital controls cannot insulate countries from foreign spillovers and restore efficient allocation in the global economy. This finding is especially surprising in light of the result from Farhi and Werning (2016) that the laissez-faire risk sharing is generically inefficient when monetary policy cannot implement the first-best allocation. This discrepancy comes from the fact that even though efficient allocation cannot be achieved in our setting, the optimal policy does eliminate the aggregate demand externality and closes the gap between the social and private value of insurance. Importantly, this result does not rely on the assumption that asset markets are complete and remains true for arbitrary structure of the financial markets. It also shows that the nature of the international spillovers is important for the optimal policy: while capital controls and other macroprudential policies might be efficient in curbing financial spillovers (see e.g. Farhi and Werning 2013, Aoki, Benigno, and Kiyotaki 2016), they are unlikely to help with the spillovers arising from DCP.

We then show that although the optimal discretionary policy in the U.S. also targets the prices of local producers, the resulting spillovers and welfare are highly asymmetric between countries. Indeed, the stickiness of import prices in dollars insulates the U.S. economy from foreign shocks allowing it

to have a free floating exchange rate and to set monetary policy independent from other countries. Furthermore, in contrast to the rest of the world, the depreciation of the U.S. exchange rate allows the country to stimulate its exports. The optimal policy in the U.S. therefore stabilizes not only domestic production and consumption, but also implements the optimal exports. As a result, for realistic values of parameters, the welfare of the U.S. under DCP is on average higher than of other economies This "exorbitant privilege" is, however, mostly due to the negative spillovers on other countries that decrease their welfare. In contrast, the optimal *cooperative* policy would use the U.S. policy to stabilize the average export prices in dollars across the world rather than local prices in U.S. economy. While beneficial for other countries and the global economy, such policy can only decrease the welfare of the U.S., which therefore has no incentives to coordinate its policy with other countries. This result contrasts with the conventional wisdom that the cooperative policy is Pareto improving as it eliminates the terms-of-trade externality and benefits all countries.

Our analysis also reveals a new source of gains from forming a currency union such as the Eurozone. While the standard critique — that a member of a currency area loses an independent monetary policy and cannot use it to stabilize the economy — still applies in our setting, forming a currency union can boost the welfare if it promotes the status of the common currency in the global trade. Interestingly, to achieve the same level of welfare as the U.S., it is sufficient that the trade flows between the union and the rest of the world are invoiced in its currency, while the trade between third countries can remain to be invoiced in dollars. In other words, as long as both import and export prices of the union are set in euros, there are no additional gains for the Eurozone from the euro replacing the dollar as a global vehicle currency.

The important methodological contribution of the paper is that we solve for the optimal non-cooperative monetary policy away from two knife-edge parametrizations used by the previous literature. The first one relies on log preferences and has been famously described by Cole and Obstfeld (1991). The second one assumes no home bias and a Cobb-Douglas consumption aggregator between home and foreign goods. In either case, the country's trade balance is independent from monetary policy, which significantly simplifies the normative analysis and leads to several stark results such as the independence of the optimal policy from the openness of the economy and no gains from cooperation under producer currency pricing (see e.g. Clarida, Galı́, and Gertler 2002, Pappa 2004).[2] Little is known about the optimal non-cooperative monetary policy away from this special case.[3] A few papers that allow for more general parameter values ignore the country's budget constraint in the planner's problem (see e.g. De Paoli 2009, Faia and Monacelli 2008). We find it very hard to rationalize this assumption and show it is not satisfied under either commitment or discretion. Hardly surprising, the optimal policy is quite different once the country's budget constraint is taken into account.

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[2]See also Casas, Dı́ez, Gopinath, and Gourinchas (2017), Goldberg and Tille (2009) for the optimal policy under DCP and the Cole-Obstfeld parametrization.

[3]More analysis has been done on the non-cooperative *fiscal* policy (see Engel 2016, Farhi and Werning 2012, 2017).

2 Baseline Model

We start with a simple model to illustrate our main results in the most transparent way. To emphasize the role of the international price system, we introduce dollar currency pricing (DCP) and global input-output linkages in an otherwise conventional open-economy sticky-price model a la Gali and Monacelli (2005) that has been extensively used in the normative literature (see e.g. Farhi and Werning 2017).

The world consists of a continuum of symmetric small open economies. To disentangle the role of the dominant currency, we assume that the U.S. is a small economy and is symmetric to other countries in all respects except for the use of dollar in international trade. There is only one period. The international asset markets are complete and agents use Arrow-Debreu securities to share the risk before the realization of shocks. We discuss below, however, that most of our insights do not depend on the completeness of asset markets. After the uncertainty is resolved and the transfers between countries are made, the households decide how much to work and to consume. The prices of goods are preset by monopolistic firms before the realization of shocks and remain fully sticky in the currency of invoicing afterwards.

Motivated by the recent empirical literature, we deviate from the conventional assumptions about the international price system in two ways. First, we assume that all international prices are set in dollars rather than the currency of producer or buyer. While this is an extreme assumption, the empirical evidence shows that it provides a good first-order approximation to the real world (Gopinath 2016).[4] Domestic products are invoiced in local currency. Second, we allow for input-output linkages in production to capture the fact that intermediate goods account for most of the international trade (see e.g. Koopman, Wang, and Wei 2014).

2.1 Households

There is only one period and a continuum of countries indexed by $i \in [0, 1]$ with $i = 0$ corresponding to the U.S. A representative household in country i has preferences

$$U_i = \mathbb{E} \left[\frac{C_i^{1-\sigma}}{1-\sigma} - \frac{L_i^{1+\phi}}{1+\phi} \right] \tag{1}$$

over labor supply L_i and consumption bundle C_i:

$$C_i = \left[(1-\gamma)^{\frac{1}{\theta}} C_{ii}^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} \int C_{ji}^{\frac{\theta-1}{\theta}} \mathrm{d}j \right]^{\frac{\theta}{\theta-1}}, \tag{2}$$

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[4]For simplicity, we take firms' currency as exogenous. Mukhin (2018) discusses the interactions between the optimal monetary policy and firms' invoicing decisions. See also Gopinath and Stein (2017), Drenik, Kirpalani, and Perez (2018), Chahrour and Valchev (2017), Rey (2001), Krugman (1980) for models of endogenous currency choice.

where C_{ji} denotes country i's consumption of goods produced in country j, and $1 - \gamma$ reflects the home bias in consumption that can arise due to trade costs or preferences for locally produced goods. For simplicity, we assume the same elasticity of substitution θ between goods produced in different countries. Bundle C_{ji} in turn aggregates the continuum of unique varieties ω produced in country j:

$$C_{ji} = \left(\int C_{ji}(\omega)^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}\omega \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3}$$

where ε is the elasticity of substitution between products produced in a given country.

The asset markets are complete, and before the shocks are realized the agents trade a full set of Arrow-Debreu securities subject to the ex-ante budget constraint:

$$\sum_h Z^h B_i^h = 0, \tag{4}$$

where B_i^h denotes country i's holdings of the security that pays one dollar in state $h \in H$ and zero in all other states of the world, and Z^h is the price of such security. Because asset markets are complete, the assumption that Arrow-Debreu securities are denominated in dollars is without loss of generality in most applications below.

After the state of the world h is revealed, households face the ex-post budget constraint

$$P_i C_i = W_i L_i + \Pi_i + T_i + \mathcal{E}_i B_i^h, \tag{5}$$

where Π_i and T_i denote the profits of local firms and the net transfers from the government, and $\mathcal{E}_i$ is country i's exchange rate against the U.S.: an increase in $\mathcal{E}_i$ corresponds to depreciation of local currency. To simplify the notation, the state index h is suppressed whenever possible. Let all prices be expressed in the currency of destination and define the price index for products exported from j to i as $P_{ji} = \left(\int P_{ji}(\omega)^{1-\varepsilon} \mathrm{d}\omega \right)^{\frac{1}{1-\varepsilon}}$. The consumer price index is then

$$P_i = \left[(1 - \gamma) P_{ii}^{1-\theta} + \gamma \int P_{ji}^{1-\theta} \mathrm{d}j \right]^{\frac{1}{1-\theta}}. \tag{6}$$

The sum of local and foreign demand for goods produced in country i is

$$Y_i = C_{ii} + X_{ii} + \int (C_{ij} + X_{ij}) \mathrm{d}j = (1 - \gamma) \left(\frac{P_{ii}}{P_i} \right)^{-\theta} (C_i + X_i) + \gamma \int \left(\frac{P_{ij}}{P_j} \right)^{-\theta} (C_j + X_j) \, \mathrm{d}j, \tag{7}$$

where X_i is firms' demand for intermediate goods. Finally, the market clearing in the asset markets requires that for every $h \in H$,

$$\int B_i^h \mathrm{d}i = 0. \tag{8}$$

2.2 Firms

In each country i, there is a continuum of firms, each using a constant returns to scale technology

$$Y_i = A_i X_i^\alpha L_i^{1-\alpha} \tag{9}$$

to produce a unique variety ω from labor and intermediate goods X_i:

$$X_i = \left[(1-\gamma)^{\frac{1}{\theta}} X_{ii}^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} \int X_{ji}^{\frac{\theta-1}{\theta}} \mathrm{d}j \right]^{\frac{\theta}{\theta-1}}. \tag{10}$$

For simplicity, we assume a roundabout production with the same bundle of goods used in consumption and production. It follows that the marginal costs of production are $MC_i = \frac{1}{A_i} \left(\frac{P_i}{\alpha} \right)^\alpha \left(\frac{W_i}{1-\alpha} \right)^{1-\alpha}$.

The firms preset prices in domestic and foreign markets before shocks are realized and cannot change them afterwards. Consider first a representative non-U.S. economy. Because of the constant returns to scale assumption, the price-setting problem of a firm is separable across markets. The optimal price in the domestic market is fixed in local currency and solves

$$\max_P \ \mathbb{E}\, \Theta_i \left(P - \tau_i MC_i \right) \left(\frac{P}{P_{ii}} \right)^{-\varepsilon} (C_{ii} + X_{ii}), \tag{11}$$

where the local demand shifter C_{ii} is defined in (7), τ_i denotes (gross) production tax/subsidy, and $\Theta_i \equiv C_i^{-\sigma}/P_i$ is the stochastic discount factor. Exporters are assumed to set a uniform price P in dollars for all foreign markets of destination:

$$\max_P \ \mathbb{E}\, \Theta_i \left(\mathcal{E}_i P - \tau_i MC_i \right) \int \left(\frac{\mathcal{E}_j \Psi_i P}{P_{ij}} \right)^{-\varepsilon} (C_{ij} + X_{ij}) \mathrm{d}j, \tag{12}$$

where the foreign demand shifters C_{ij} are defined in (7), and Ψ_i denotes the export tax, so that consumers in foreign markets pay $\Psi_i P$ dollars for one unit of good. As explained in detail below, this second fiscal instrument plays an important role in our analysis as it allows the government to eliminate both the monopolistic distortion and the terms-of-trade externality.[5] The government runs a balanced budget and transfers the net revenues from taxes to households.

The case of the U.S. is slightly different because local firms set the same price for both domestic and foreign customers and hence, the law of one price holds for goods produced in the U.S.[6] The firms set prices to maximize the total expected profits from all markets:

$$\max_P \ \mathbb{E}\, \Theta_i \left(P - \tau_i MC_i \right) \left[(1-\gamma) \left(\frac{P}{P_{ii}} \right)^{-\varepsilon} (C_{ii} + X_{ii}) + \gamma \int \left(\frac{\mathcal{E}_j \Psi_i P}{P_{ij}} \right)^{-\varepsilon} (C_{ij} + X_{ij}) \mathrm{d}j \right]. \tag{13}$$

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[5]One can use import tariff instead of the export tax as the Lerner symmetry holds in the model.

[6]Note that the law of one price here means that the prices are equal up to an export tax.

2.3 Equilibrium conditions

The equilibrium is such that households maximize expected utility subject to the ex-ante and ex-post budget constraints, firms maximize expected profits, the government's budget constraint is satisfied, and the markets clear. We next show how the set of equilibrium conditions can be reduced to just a few constraints in the planner's problem (see Appendix for details). Following Farhi and Werning (2012), it is convenient to divide the equilibrium conditions into the "demand block" that does not depend on the price setting and is the same for all countries and the "supply block" that is different for the U.S. and other economies.

Demand block: denote the dollar export price of a representative firm from country i with P_i^*. The import price index for all countries is then $P^* = \left(\int P_i^{*1-\theta} \right)^{\frac{1}{1-\theta}}$. Define for each country i the real exchange rate Q_i, the terms-of-trade S_i, and the deviation of export price from the domestic one Φ_i:[7]

$$Q_i \equiv \frac{\mathcal{E}_i P^*}{P_i}, \qquad S_i \equiv \frac{P^*}{P_i^*}, \qquad \Phi_i \equiv \frac{\mathcal{E}_i P_i^*}{P_{ii}}. \tag{14}$$

Combining these definitions with the ideal price index P_i from (6), we obtain the first constraint:

$$Q_i^{\theta-1} = \gamma + (1-\gamma)\left(\Phi_i S_i\right)^{\theta-1}. \tag{15}$$

The risk-sharing (Backus-Smith) condition that follows from countries' trading of Arrow-Debreu securities can be compactly written as

$$C_i = \left(\frac{Q_i}{\Lambda_i}\right)^{\frac{1}{\sigma}} \bar{C}, \tag{16}$$

where $\bar{C} \equiv \int Q_j^{-\frac{1}{\sigma}} C_j \mathrm{d}j$ and Λ_i is a state-invariant constant determined from the country's budget constraint. Intuitively, the *relative consumption* is higher in the states of the world, in which prices are lower (the real exchange rate is depreciated) and hence, consumption is cheaper. The average *level of consumption*, on the other hand, depends on the expected (permanent) income and is captured by Λ_i.

Combining household and government budget constraints, firms' profits, and the risk-sharing condition, we obtain the country's ex-post budget constraint:

$$NX_i + B_i^h = 0, \quad NX_i = \gamma P^* \left[S_i^{\theta-1} \int Q_j^{-\theta} \left(C_j + \frac{\alpha}{1-\alpha} C_j^\sigma L_j^{1+\phi} \right) \mathrm{d}j - Q_i^{-\theta} \left(C_i + \frac{\alpha}{1-\alpha} C_i^\sigma L_i^{1+\phi} \right) \right]. \tag{17}$$

The two terms in NX_i correspond to the dollar value of country i's exports and imports, each including

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[7]Notice that the ratio of the real exchange rates (terms-of-trade) of countries i and j satisfies the conventional definition of bilateral real exchange rates (terms-of-trade).

consumption goods as well as intermediate ones. The countries use asset markets to transfer resources B_i^h across the states of the world and to benefit from non-zero net exports, but have to respect the ex-ante budget constraint:

$$\mathbb{E}\bar{C}^{-\sigma}B_i^h = 0, \tag{18}$$

where $\bar{C}^{-\sigma}$ reflects the global stochastic discount factor for dollar-denominated securities, which is the same for all countries under complete markets.

While generically equations (17)-(18) impose important constraints on the planner's decision, there are two special cases when given the risk-sharing condition (16), the net exports are constant across the states of the world and the budget constraint becomes a side equation that determines the value of Λ_i independent from the policy. In either case, one needs to assume no intermediate goods $\alpha = 0$ — as their demand is not pinned down by the risk-sharing equation — and the Cobb-Douglas aggregator between goods produced in different countries $\theta = 1$, so that changes in the terms of trade have no effect on net exports. In addition, one needs to ensure that net exports are also independent from movements in the real exchange rate. This requires either no home bias in consumption $\gamma = 1$ or the Cole and Obstfeld (1991) parametrization $\frac{1}{\sigma} = \theta = 1$. In the former case the PPP holds and $Q_i = 1$ for any realization of shocks, while in the latter case the risk sharing exactly offsets changes in the purchasing power across countries. These two parametrizations have been extensively used in the previous normative literature and, as we discuss below, are behind several important results.

Lemma 1 (Balanced trade) *Assume no intermediate goods $\alpha = 0$, Cobb-Douglas aggregator $\theta = 1$, and either (i) no home bias $\gamma = 1$, or (ii) intertemporal elasticity equal to the intratemporal one $\frac{1}{\sigma} = \theta$. Then trade is always balanced $NX_i = 0$ and Λ_i is independent from monetary policy.*

Lastly, substitute the demand for intermediate goods $X_i = \frac{\alpha}{1-\alpha}C_i^\sigma L_i^{1+\phi}$, the definition of prices from (14), and the labor supply condition $C_i^\sigma L_i^\phi = \frac{W_i}{P_i}$ into the market clearing (7):

$$A_i \left(\frac{\alpha}{1-\alpha}\right)^\alpha C_i^{\sigma\alpha} L_i^{\phi\alpha+1} = (1-\gamma)(\Phi_i S_i)^\theta Q_i^{-\theta}\left(C_i + \frac{\alpha}{1-\alpha}C_i^\sigma L_i^{1+\phi}\right)$$
$$+\gamma S_i^\theta \int Q_j^{-\theta}\left(C_j + \frac{\alpha}{1-\alpha}C_j^\sigma L_j^{1+\phi}\right)\mathrm{d}j. \tag{19}$$

This is the last constraint imposed by the demand block on the planner's problem.

Price-setting in non-U.S. countries: the optimality condition for domestic prices implies

$$\mathbb{E}\left[\left(Q_i - \frac{\varepsilon}{\varepsilon-1}\tau_i\Phi_i S_i \frac{C_i^{\sigma(1-\alpha)}L_i^{\phi(1-\alpha)}}{\alpha^\alpha(1-\alpha)^{1-\alpha}A_i}\right)C_i^{-\sigma}Q_i^{-\theta}\left(C_i + \frac{\alpha}{1-\alpha}C_i^\sigma L_i^{1+\phi}\right)\Phi_i^{\theta-1}\right] = 0. \tag{20}$$

The intuition behind the first bracket is straightforward: on average, firm's price should be equal to its marginal costs and an optimal markup. In other words, while producers can have low and even

negative profits in some states of the world, they have to be compensated by higher profits in other states. The other terms in this equation can be interpreted as weights of different states of the world determined by the demand shifters and by the household stochastic discount factor.

The second constraint comes from the optimal price-setting for exports:

$$\mathbb{E}\left[\left(Q_i - \frac{\varepsilon}{\varepsilon-1}\tau_i\Psi_iS_i\frac{C_i^{\sigma(1-\alpha)}L_i^{\phi(1-\alpha)}}{\alpha^\alpha(1-\alpha)^{1-\alpha}A_i}\right)C_i^{-\sigma}\int Q_j^{-\theta}\left(C_j + \frac{\alpha}{1-\alpha}C_j^\sigma L_j^{1+\phi}\right)\mathrm{d}j\right] = 0. \quad (21)$$

While the "weights" in this expression are determined by the global rather than local demand, the first bracket is very similar to the one for domestic prices in (20) as firms have to earn monopolistic profits in expectation. Notice that the only difference in the first bracket between (20) and (21) is that Φ_i is replaced with Ψ_i in the second case. Since domestic and export prices are sticky in different currencies, the monetary policy can generate state-dependent deviations from the law of one price. However, under rational expectations, the law of one price should hold in expectation, and the monetary policy cannot make prices systematically deviate from it.

Price-setting in the U.S.: because U.S. firms set the same price for local and foreign customers, the law of one price holds in the U.S. (up to the export tax)

$$\Phi_i = \Psi_i \quad (22)$$

and the monetary policy cannot affect the wedge between domestic and export prices. The price-setting constraint is therefore

$$\mathbb{E}\left[\left(Q_i - \frac{\varepsilon}{\varepsilon-1}\tau_i\Psi_iS_i\frac{C_i^{\sigma(1-\alpha)}L_i^{\phi(1-\alpha)}}{\alpha^\alpha(1-\alpha)^{1-\alpha}A_i}\right)C_i^{-\sigma}\times\right.$$
$$\left.\times\left((1-\gamma)\Psi_i^{\theta-1}Q_i^{-\theta}\left(C_i + \frac{\alpha}{1-\alpha}C_i^\sigma L_i^{1+\phi}\right) + \gamma\int Q_j^{-\theta}\left(C_j + \frac{\alpha}{1-\alpha}C_j^\sigma L_j^{1+\phi}\right)\mathrm{d}j\right)\right] = 0. \quad (23)$$

As before, the first bracket corresponds to the deviations of the preset price from the optimal level, while the other terms reflect demand shifters and the stochastic discount factor.

Equilibrium: the next lemma summarizes equilibrium conditions from above that are relevant for the planner's problem.

Lemma 2 (Implementability) *For given fiscal instruments $\{\tau_i, \Psi_i\}$, an allocation $\{C_i, L_i, \Lambda_i, B_i^h\}$ and relative prices $\{Q_i, S_i, \Phi_i\}$ constitute a part of the equilibrium if and only if equations (15)–(23) hold.*

In other words, the allocation is implementable if it satisfies the market clearing and the optimal risk-sharing conditions, respects countries' budget constraints and firms' price-setting behaviour. As is

standard in the literature, we abstract from the issues how exactly the optimal policy is implemented. For example, the planner can use money supply as an instrument in the presence of the cash-in-advance constraint or money in the utility, or alternatively, rely on nominal interest rates in a dynamic version of the model (see e.g. Atkeson, Chari, and Kehoe 2010).

3 Optimal Monetary Policy

This section outlines the main results of the paper. To build the intuition, we first characterize the optimal policy under PCP, which provides a sharp benchmark for other results. We then add dollar currency pricing, but assume that policy is discretionary and is set after the realization of shocks. This setting is more tractable than the one with commitment and provides clear intuition about the optimal policy under DCP and its welfare implications for the U.S. and other countries. Finally, we describe the additional mechanisms that arise under full commitment. All our results in this section are exact and do not require any approximations or taking a non-uncertainty limit with shocks being completely unexpected.

3.1 PCP benchmark

We start with the PCP case for two reasons. First, it provides an important benchmark for further analysis and allows us to disentangle two assumptions about the international price system — intermediate goods in production and the dollar pricing. Second, we show how our approach differs from the literature and extends and refines some of the previous results.

Consider first the optimal allocation that would be chosen by the social planner who is not subject to the price-setting constraints. The following lemma shows there are two margins in the economy the planner might want to improve relative to the equilibrium allocation.

Lemma 3 (Flexible-prices) *Assume that prices are flexible. Then*

1. *the optimal cooperative allocation can be implemented with $\tau_i = \frac{\varepsilon-1}{\varepsilon}$ and $\Psi_i = 1$,*

2. *the optimal non-cooperative allocation can be implemented with $\tau_i = \frac{\varepsilon-1}{\varepsilon}$ and $\Psi_i = \frac{\theta}{\theta-1}$.*

The lemma shows that it is always optimal to eliminate the monopolistic distortion in the domestic market, which can be done with one fiscal instrument, i.e. the production subsidy τ_i. Since there are no other inefficiencies in the world, such policy is sufficient to implement the optimal global allocation. The optimal non-cooperative policy, on the other hand, exploits the terms-of-trade externality: given a downward sloping foreign demand for country's goods, it is optimal to set a markup on exports equal to $\frac{\theta}{\theta-1}$. Thus, two fiscal instruments — a production subsidy and an export tax — are sufficient to implement the efficient non-cooperative allocation. Importantly, both instruments are time-invariant

and do not need to adjust in response to shocks. From now on, we assume that production subsidy is optimal $\tau_i = \frac{\varepsilon-1}{\varepsilon}$ and vary only the export tax.

Assume next that prices are sticky in the currency of producer. The nominal rigidities generate additional inefficiencies in the economy, but they also allow the monetary policy to affect the equilibrium allocation. It turns out that in the case of PCP, the monetary policy can always replicate the flexible-price equilibrium. To gain intuition, start with the flexible-price allocation. Since the latter is independent from monetary policy, we can assume in particular, that it fully stabilizes the marginal costs of local producers. This policy implies that firms have no incentives to change their prices no matter how sticky they are and the allocation always coincides with the one under flexible prices. Notice that the PCP assumption is crucial as it guarantees that the number of sticky nominal prices is equal to the number of policy instruments — one per country. Given that the flexible-price allocation is implementable, the question is whether the monetary policy can do better than that. The answer is, of course, negative when the fiscal instruments ensure that the flexible-price equilibrium is efficient. Thus, the optimal policy implementes the (corresponding) efficient allocation both with and without cooperation, under discretion and under commitment.[8]

Definition *We say that the policy stabilizes marginal costs if it implements $\frac{MC_i}{P_{ii}} = 1$ in all states of the world. We say there is a partial peg of currency i to currency j if the monetary policy in country i depreciates local exchange rate in response to a depreciation of currency j.*

Proposition 1 (PCP) *Assume either cooperative or non-cooperative policy and that fiscal instruments are at the corresponding optimal level. Then under PCP, the optimal monetary policy stabilizes marginal costs, implements the efficient allocation and is time consistent.*

Is the optimal policy inward-looking under PCP? Turns out, the answer is "yes and no". On the one hand, the *optimal target* for the monetary policy — the marginal costs of local producers — is independent from the openness of the economy and coincides with the one in a closed one. On the other hand, because of imported intermediate goods, the *optimal policy* does respond to foreign shocks. For example, a tight monetary policy in one country leads to appreciation of its currency and increases the import prices for the rest of the world. The optimal response of other economies is then to tighten the monetary policy to stabilize the marginal costs of local firms.[9] This partially offsets initial movements in exchange rates and implements a partial peg between countries. The result contrasts with the previous literature that assumes no imported intermediates, so that the marginal costs of producers depend exclusively on local shocks and the optimal policy does not respond at all to foreign shocks. Thus, the input-output linkages play crucial role in generating international spillovers and making monetary policy interdependent between countries. This novel mechanism is likely to be strong in the data, given

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[8]To ensure time consistency under no cooperation, we assume that Arrow-Debreu securities are denominated in terms of a basket of imported goods rather than dollars, so that the U.S. monetary policy cannot devalue its foreign debt.

[9]The effects are of course infinitely small when only one economy changes its policy.

that intermediate goods account for most of the international trade in manufacturing goods and even final goods have to go through a wholesale and retail sectors before arriving to final consumers (see e.g. Johnson and Noguera 2012, Burstein, Neves, and Rebelo 2003, Gopinath and Neiman 2013).

Corollary 1 (Spillovers) *Given a positive share of foreign intermediates in production $\gamma\alpha > 0$, the optimal monetary policy under PCP responds to foreign monetary shocks.*

The main insight of Proposition 1 is not new: it underlies the classic argument in favor of free floating exchange rates that has been famously advocated by Friedman (1953) and formalized in a cooperative setting by Devereux and Engel (2003). At the same time, while the extension to the non-cooperative case is straightforward, we are not aware of any paper that proves such result. In particular, we deviate from the previous literature in two important ways. First, as argued above, the two fiscal instruments are crucial to ensure that the flexible-price equilibrium is efficient in the non-cooperative case and the monetary authorities have no incentives to deviate from it. This contrasts with a standard assumption that there is only one fiscal instrument — production subsidy — that has to balance two distortions, i.e. the monopolistic markups and the terms-of-trade externality (see e.g. Corsetti and Pesenti 2001). In general case, the relative effect of these distortions on the welfare depends on shocks. As a result, a state-invariant subsidy cannot fully offset them leaving a room for the monetary policy to improve upon the flexible-price allocation: while the rational expectations imply the monetary policy cannot eliminate the *average* price distortions, it can "redistribute" them across the states of the world in a socially optimal way.[10] While one can argue that the use of export taxes can be limited in practice due to the trade agreements enforced by the WTO, they are not less common than the production subsidy. Instead, we prefer to think of both instruments as convenient assumptions that allow us to isolate the distortions arising purely from nominal rigidities that are arguably of primary importance for the monetary policy.

Second, the planner has to respect the country's budget constraint and internalizes the effect of policy on Λ_i. In contrast, other papers either focus on two knife-edge cases described in Lemma 1 when $NX_i = 0$ and Λ_i is effectively exogenous (e.g. Clarida, Galı́, and Gertler 2002, Gali and Monacelli 2005), or postulate that $\Lambda_i = 1$ due to a symmetry across countries and drop the budget constraint (e.g. Faia and Monacelli 2008, De Paoli 2009). While the latter approach is often motivated by the assumption that agents trade the Arrow-Debreu securities before the policy is chosen (see Sutherland 2004), this argument is hardly convincing: as we show below, it is the promised transfers B_i^h that the planner takes as given in this case rather than Λ_i. Notice, in particular, that under such "naive complete markets" the risk-sharing condition (16) implies $C_i = Q_i^{\frac{1}{\sigma}}\bar{C}$ and the policymaker can generate arbitrary large transfers from the rest of the world to the home economy by depreciating the real exchange rate. Not

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[10]There are two notable exceptions when one fiscal instrument is sufficient to implement the flexible-price equilibrium: (i) when there is only one distortion because economy is closed $\gamma = 0$ or fully open $\gamma = 1$, and (ii) when the weights of two distortions are state-invariant under $\theta = \frac{1}{\sigma}$.

surprisingly, the optimal policy is quite different in two cases.[11]

3.2 Discretion

Consider next the baseline model with all international prices set in dollars. We start with the discretionary case when the planner in each country chooses the optimal monetary policy after the realization of shocks and takes as given both the preset prices and the asset positions of the agents. The private agents, in turn, form rational expectations about the future policy and use them to make their ex ante decisions.

3.2.1 Non-U.S. economies

The planner's problem in a representative non-U.S. country is:

$$\max_{C_i, L_i, \Phi_i} \frac{C_i^{1-\sigma}}{1-\sigma} - \frac{L_i^{1+\phi}}{1+\phi}$$

$$\text{s.t.} \quad (15), \ (17), \ (19).$$

Because agents sign international financial contracts before the policy is chosen, the planner takes as given the dollar transfers B_i^h between countries. Thus, from a perspective of a policymaker, the risk-sharing condition (17) is closer to the case of financial autarky rather than to the "naive complete markets". The dollar denomination of the transfers also implies that local monetary policy cannot affect its real value, e.g. to devalue the foreign debt.

 With both import and export prices sticky in dollars, the terms of trade are predetermined and are taken as given by the planner. Effectively, the policymaker has one instrument — a nominal exchange rate or, equivalently, Φ_i, while equilibrium consumption C_i is then determined by the country's budget constraint (17) and labor supply L_i is pinned down by the market clearing condition (19). Assuming for a moment there are no intermediate goods in production $\alpha = 0$, one can then solve these constraints for the marginal effect of exchange rate depreciation on consumption and labor, which characterizes the consumption-leisure trade-off faced by the planner.

$$\frac{\mathrm{d}C_i}{\mathrm{d}L_i} = \frac{\partial C_i/\partial \Phi_i}{\partial L_i/\partial \Phi_i} = A_i \frac{P_{ii}}{P_i}. \tag{24}$$

Intuitively, suppose that the policymaker makes households increase their supply of labor by one unit, which raises production by A_i units. Under DCP, the monetary policy cannot change the country's exports: the export prices are fixed in dollars and hence, the depreciation of exchange rate does not affect the prices that consumers in other countries face. It follows that all additional units of output

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[11]This problem does not arise in the cooperative case: under complete markets, the global planner can generate any transfers between countries and is not constrained by the individual budget constraints.

have to be sold at home for $A_i P_{ii}$, which can then be used to buy $A_i \frac{P_{ii}}{P_i}$ units of consumption bundle. At the optimum, the marginal rate transformation between consumption and labor should be equal to the marginal rate of substitution $\frac{\partial U_i/\partial L_i}{\partial U_i/\partial C_i} = C_i^\sigma L_i^\phi$, which implies $P_{ii} = P_i \frac{C_i^\sigma L_i^\phi}{A_i} = \frac{W_i}{A_i}$. Given that P_{ii} is fixed, it follows that the optimal monetary policy stabilizes the marginal costs. The result holds more generally in the presence of intermediate goods and can be written as

$$\frac{\Phi_i S_i}{Q_i} \frac{C_i^{\sigma(1-\alpha)} L_i^{\phi(1-\alpha)}}{\alpha^\alpha (1-\alpha)^{1-\alpha} A_i} = 1. \tag{25}$$

Proposition 2 (Non-U.S.) *The optimal non-cooperative discretionary policy in a non-U.S. country stabilizes marginal costs. The resulting allocation is not efficient.*

Thus, just as in the PCP case, the optimal discretionary policy under DCP targets the marginal costs of local producers to ensure that domestic prices are at the optimal level. This similarity, however, masks several important differences between the two currency regimes. First, while in both cases a depreciation of the local currency generates expenditure switching from imports to local goods, there is no expenditure switching on the export side under the dollar pricing. This means that the monetary policy is less efficient under DCP than under PCP and cannot implement the optimal allocation. The surprising result, which was first shown by Casas, Díez, Gopinath, and Gourinchas (2017) and generalized here in a static setting, is that the optimal policy does not try to compensate its lower effectiveness with a stronger response to exogenous shocks.

Second, though the optimal policy reaction to local productivity shocks is the same under two currency regimes, the dollar pricing generates highly asymmetric response to foreign shocks. As in the PCP case, the stabilization of marginal costs means that the monetary policy depends on prices of imported intermediates. The dollar invoicing, however, implies that import prices depend solely on the monetary policy of the U.S.: an appreciation of dollar exchange rate increases the prices of all internationally traded goods inducing other countries to tighten their monetary policy as well and to implement a partial peg to the dollar. Thus, a global monetary cycle can emerge since the policy is positively correlated across all countries even when productivity shocks are completely idiosyncratic.[12]

Finally, notice that while the optimal policy under PCP stabilizes marginal costs only if export tax eliminates the terms-of-trade externality, Proposition 2 holds for arbitrary export tax Ψ_i and terms of trade S_i. The difference is due to the fact that terms of trade are completely fixed under DCP and are independent from the local monetary policy.

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[12]Proposition 2 therefore extends the results from Mukhin (2018) to a fully non-cooperative case. It also contrasts with the inward-looking policy derived by Casas, Díez, Gopinath, and Gourinchas (2017) in a model with no intermediate goods.

3.2.2   U.S.

Consider next the planner's problem in the U.S.:

$$\max_{C_i,L_i,C^*} \frac{C_i^{1-\sigma}}{1-\sigma} - \frac{L_i^{1+\phi}}{1+\phi}$$

$$\text{s.t.}\quad (15),\ (17),\ (19),\ (22),\ (25),$$

where $C^* \equiv \int Q_j^{-\theta}\left(C_j + \frac{\alpha}{1-\alpha}C_j^\sigma L_j^{1+\phi}\right) \mathrm{d}j$. As in other economies, the planner is subject to the market clearing condition (19) and the budget constraint (17). The terms of trade are predetermined and cannot be changed by the monetary policy. Moreover, because both the international transfers and the prices of exports and imports are denominated in dollars, the monetary policy cannot use exchange rate to manipulate the value of foreign debt relative to the net exports.

The key difference, on the other hand, is that U.S. policy can generate expenditure switching on the export side instead of the import one. More formally, the law of one price holds for domestic and export prices in case of the U.S. and hence, there is an additional constraint (22). Given that the terms of trade are also predetermined, it follows that the policymaker cannot change the relative price between domestic and imported goods. At the same time, the planner is free to choose the foreign demand for U.S. exports C^*, which plays the key role in the analysis below. Suppose that the U.S. has an easy monetary policy. The effect on exports depends then on the policy in other economies. On the one hand, if it remains passive and does not respond to the shock, the dollar depreciates and generates expenditure switching towards the U.S. goods. On the other hand, if monetary authorities in other countries peg their exchange rates to the dollar and do not allow for the expenditure switching, they need to ease their policy as well. This stimulates aggregate demand and increases U.S. exports. Thus, in both cases U.S. exports go up — either because of the expenditure switching effect or due to a shift in global demand — and the U.S. planner can choose C^* independently from the response of other economies.

This implies that the optimal policy in non-U.S. countries (25) can be dropped from the planner's problem. The irrelevance of the best response function of other economies also means that the Nash equilibrium coincides with the Stackelberg equilibrium in this model: the optimal policy of the U.S. does not depend whether it takes as given $\{C_j\}$ or $\{C_j(C^*)\}$, $\{Q_j\}$ or $\{Q_j(C^*)\}$.

Proposition 3 (U.S.) *Assume $\Psi_0 = 1$. The optimal non-cooperative discretionary policy in the U.S. stabilizes marginal costs. The resulting allocation is not efficient.*

To understand the optimal policy, consider again a monetary policy that increases labor supply by one unit. In contrast to the non-U.S. case, the additional A_i units of output are split between local and foreign consumers. When $\Psi_0 = 1$, domestic and export prices coincide and the value of the additional production is $A_i P_{ii}$, which can be used to increase consumption by $A_i \frac{P_{ii}}{P_i}$ units. Thus, the marginal

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rate of transformation between consumption and labor is the same for the U.S. as for other economies. Given that all countries have the same utility and, as a result, the same marginal rate of substitution between C_i and L_i, the optimal policy in the U.S. also stabilizes the local firms' marginal costs. In contrast to other economies, however, this result relies on $\Psi_0 = 1$: the export tax drives a wedge between domestic and foreign prices, which means that the revenue from selling one additional unit of output is different from P_{ii}. A higher value means it is optimal to produce more, which generates an inflationary bias. Given that there are no costs of inflation under fully sticky prices, the planner always raises demand more than expected, and there can be no rational expectation equilibrium (see Section 4 for an extension with partially adjusting prices).

A more important differences between the U.S. and other countries under DCP, however, is the asymmetry of the international spillovers and the optimal response to them. On the one hand, the U.S. monetary shocks affect the import prices in all other economies making them optimally "lean against the wind" and partially peg their exchange rates to the dollar. On the other hand, DCP insulates the U.S. economy from foreign shocks allowing it to have a free floating exchange rate and to set policy independent from other countries. Therefore, the wide use of the dollar in the international trade contributes to the fact that the U.S. retains its dominant position in the global monetary system despite the end of the Bretton Woods System. The growing empirical literature supports these predictions of the model: most countries in the world experience a "fear of floating" and use the dollar as an anchor currency in their monetary policy (see Calvo and Reinhart 2002, Ilzetzki, Reinhart, and Rogoff 2017). Moreover, both the spillover effects and the tightness of the peg increase in the share of DCP in country's trade (see Boz, Gopinath, and Plagborg-Møller 2017, Zhang 2018).[13]

3.3 Commitment

3.3.1 Capital controls

In light of the negative spillovers from the U.S. on other economies discussed above, it is natural to ask whether additional fiscal instruments such as capital controls can be used to improve the allocation and increase country's welfare. The modern conventional wisdom among both policymakers and scholars is that "[the use of capital controls by emerging economies] allows advanced economies to use monetary policy to increase domestic demand, while shielding emerging economies of the undesirable exchange rate effects" (Blanchard 2017). In other words, the U.S. can focus on its domestic objectives when setting the monetary policy, while other countries can insulate their economies from the arising spillovers by using the capital controls. Although this argument is usually made for the spillovers arising from the international financial markets, it might be equally important in a context of DCP in global trade.

To answer this question, we next allow the planner in a non-U.S. economy to choose optimally

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[13]While the mechanism is similar to the one described by Zhang (2018), we do not assume that countries stabilize CPI and instead derive the asymmetric spillovers as an endogenous outcome under the optimal non-cooperative policy.

both the monetary policy and a state-contingent tax on capital flows between countries. The latter instrument corresponds to capital controls and effectively allows the planner to choose any risk-sharing subject to ex-ante budget constraint. The policymaker can credibly commit to the monetary and capital tax policies, but takes the preset prices as given. The latter assumption guarantees that the planner does not use its instruments to exploit the terms-of-trade externality. The results, however, would be unchanged if instead we assumed an optimal export tax $\Psi_i = \frac{\theta}{\theta-1}$, which would eliminate the terms-of-trade externality. To summarize, the planner's problem in a representative non-U.S. country is

$$
\max_{\{C_i, L_i, \Phi_i, B_i^h\}} \mathbb{E} \left[\frac{C_i^{1-\sigma}}{1-\sigma} - \frac{L_i^{1+\phi}}{1+\phi} \right]
$$

$$
\text{s.t.} \quad (15), (17), (18), (19).
$$

Proposition 4 (Capital controls) *Capital controls do not insulate economies from U.S. spillovers and are not used by the planner, i.e. the optimal allocation is the same with and without capital controls.*

At a first glance, this may look as a surprising result: after all, the general principle in economics is that the planner usually finds it optimal to decrease distortions in one market by distorting other margins in the economy. In our case, that would correspond to distorting intertemporal asset markets to improve the allocation in static goods markets. Proposition 4 is especially surprising given the result from Farhi and Werning (2016) that the laissez-faire risk sharing is *generically* inefficient when monetary policy cannot implement the first-best allocation. Yet, it turns out that capital controls are completely redundant and are not used by the planner in our setting.[14] The international spillovers arising from DCP are therefore very different from the ones arising from the pecuniary externality and cannot be eliminated with macroprudential policy.

To see the intuition behind this result, note that the reason the risk sharing might be inefficient under sticky prices is the aggregate demand externality: individual agents do not internalize the fact that an international wealth transfer increases aggregate demand, stimulates production and decreases the labor wedge. The optimal monetary policy, however, fully eliminates the labor wedge in our model by stabilizing marginal costs, which removes the aggregate demand externality and closes the gap between private and social value of insurance. This contrasts with the case when monetary policy is constrained by the zero lower bound or fixed nominal exchange rates and cannot close this wedge (*cf.* e.g. Farhi and Werning 2017). Thus, even though the monetary policy cannot implement the first-best allocation under dollar pricing, it is still powerful enough to eliminate the aggregate demand externality and implement the optimal risk sharing between countries. Importantly, this result does not rely on the assumption that asset markets are complete and remains true for arbitrary structure of the international financial markets as long as the pay-off of assets is independent from the monetary policy.

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[14]In contrast to the "approximate efficiency" of the risk sharing in Fanelli (2017), the laissez-faire portfolio choice is exactly optimal in our setting.

3.3.2 Gains from cooperation

Can countries increase the global welfare by choosing cooperatively the monetary policy? If so, does such policy lead to a Pareto improvement or gains are unequally distributed across countries? Proposition 1 shows that under PCP, the key source of disagreement between economies comes from the terms-of-trade externality. The situation is quite different under dollar pricing: the terms of trade are predetermined in this case and are taken as given by the discretionary monetary policy. Instead, the conflict of interest arises from the asymmetric spillovers of the U.S. policy on other economies. The U.S. has an infinitely small weight in the objective function of the global planner, but its monetary policy affects all international prices. It follows that the optimal cooperative solution is to use the U.S. policy to bring export prices of all countries closer to the optimal level rather than to target the local U.S. producers. In other words, the U.S. monetary instruments are only used in response to global shocks instead of idiosyncratic ones.[15] At the same time, the optimal policy in other countries does not change relative to the non-cooperative case, which together with a change in the U.S. policy implies a higher welfare under the cooperative policy.

Proposition 5 (Cooperation) *Assume $\theta = \frac{1}{\sigma} > \frac{1}{2}$, $\alpha = \phi = 0$, $\Psi_i = 1$ for all i and $\{A_i\}$ have a joint log-normal distribution symmetric across i. Then under the optimal discretionary cooperative policy*

1. *monetary authorities in non-U.S. economies stabilize local marginal costs, while the U.S. stabilizes the average marginal costs of exporters from all countries,*

2. *non-U.S. countries enjoy higher welfare than the U.S. and than w/o cooperation,*

3. *the U.S. has a lower welfare than w/o cooperation if γ is small and a higher one if γ is large.*

More surprisingly, the U.S. can either loose or win from the cooperation. It clearly looses if one keeps predetermined variables Λ_0 and S_0 at their values under no cooperation as the U.S. policy now targets global shocks instead of local ones. At the same time, as discussed above, the non-cooperative policy makes importers from other countries charge a higher markup, which depreciates the U.S. terms of trade and decreases its welfare. The cooperative policy, on the other hand, stabilizes the average marginal costs of foreign exporters and destabilizes the marginal costs of U.S. exporters relative to the non-cooperative case. Both U.S. and foreign exporters are now subject only to symmetric idiosyncratic shocks and, hence, in equilibrium $S_0 = \Lambda_0 = 1$. Thus, the cooperative policy can increase the U.S. welfare by bringing the optimal discretion policy closer to the one under commitment.

Lastly, note that countries' interests are perfectly aligned in response to global shocks: the U.S. does not have to choose between local and international shocks to respond to, and the stabilization of marginal costs in all countries achieves the optimal allocation in this case. This prediction is consistent

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[15]This is, of course, an extreme result that is due to the assumption that the U.S. is small economy. Under a more realistic assumption that the U.S. account for a significant fraction of global GDP, the U.S. optimal policy under cooperation targets a weighted average of local and global shocks.

with the high level of cooperation between central bankers around the world during the global financial crisis of $2008 - 2009$. The model also explains why it is much harder to sustain the global cooperation after the crisis ends in the U.S., but other countries have not fully recovered yet.

3.4 Welfare implications

3.4.1 Gain and losses for the U.S.

Are there welfare gains for the U.S. from the global use of the dollar? To answer this question, one needs to solve not only for the optimal policy in each country described in the previous sections, but also for the global equilibrium. This is a complicated problem and we impose additional assumptions to get analytical results. In particular, we focus on the Faia and Monacelli (2008) case with the equal intertemporal and intratemporal elasticities $\theta = \frac{1}{\sigma}$, no intermediate goods $\alpha = 0$ and a linear disutility from labor $\phi = 0$. Given results from Proposition 3, we also assume that countries do not use export taxes $\Psi_i = 1$. While clearly restrictive, these assumptions are widely used in the normative open economy literature. Because all countries other than the U.S. are ex ante symmetric, one can show that the equilibrium terms of trade and the risk-sharing constant are $S_i = \Lambda_i = 1$ for all $i \neq 0$. Using this result, we can express the expected utility in the U.S. and other countries under DCP and, for comparison, under PCP as follows:

$$\mathbb{W}^{US} = (1 - \gamma)\frac{1}{\theta - 1}\mathbb{E}A_0^{\theta - 1} + \gamma \left[\frac{\theta}{\theta - 1}S_0^{1 - \theta} - \Lambda_0^{\theta}\right]\mathbb{E}A_0^{\theta - 1},$$

$$\mathbb{W}^{ROW} = (1 - \gamma)\frac{1}{\theta - 1}\mathbb{E}A_0^{\theta - 1} + \gamma \left[\frac{\theta}{\theta - 1}\left(\frac{S_0}{\Lambda_0}\right)^{1 - \theta} - \left(\frac{\Lambda_0}{S_0}\right)^{\theta}\frac{\mathbb{E}A_0^{\theta}A_i^{-1}}{\mathbb{E}A_0^{\theta - 1}}\right]\mathbb{E}A_0^{\theta - 1}, \qquad (26)$$

$$\mathbb{W}^{PCP} = (1 - \gamma)\frac{1}{\theta - 1}\mathbb{E}A_0^{\theta - 1} + \gamma \left[\frac{\theta}{\theta - 1} - 1\right]\mathbb{E}A_0^{\theta - 1}.$$

The first term in each expression corresponds to consumption and production of local goods, while the second one is the difference between utility from imported goods and disutility from working in the export sector. Equations (26) have several important implications. To start with, note that the first term coincides in all three cases: the monetary policy that stabilizes marginal costs implies the same level of output in the domestic sector across countries and the currency regimes. This result might be surprising given that under DCP, the U.S. monetary policy is less efficient in generating expenditure switching between imported and domestic goods. Instead, there is a larger response of the aggregate consumption C_i that ensures that demand for domestic goods is the same in the U.S. as in other countries. Thus, the import adjustment does not generate per se any benefits to non-U.S. countries relative to the U.S.

The welfare from imports and exports is, on the other hand, markedly different across countries. If countries were completely symmetric ex ante, i.e. $S_0 = \Lambda_0 = 1$, the U.S. expected utility would coincide with the one under PCP, while the welfare of the rest of the world would be lower because of a higher
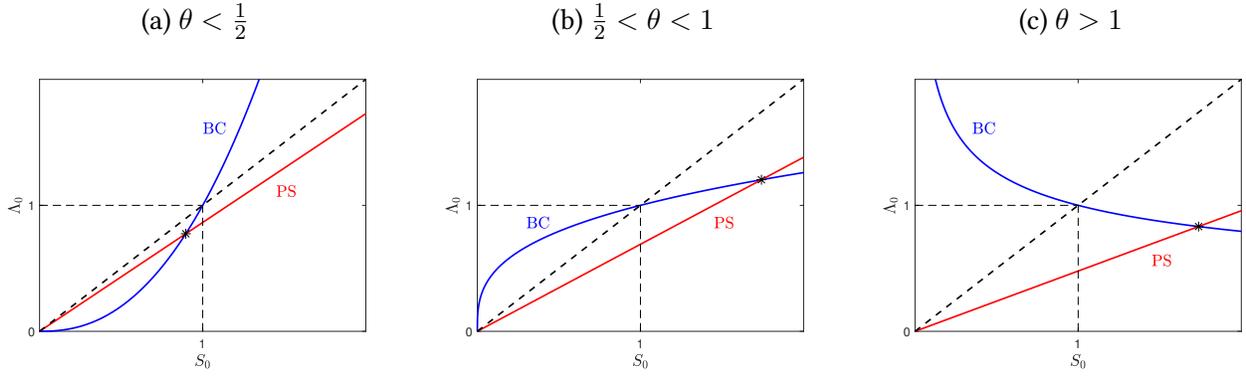
Figure 1: Equilibrium S_0 and Λ_0

Note: the blue line (BC) shows the values of S_0 and Λ_0 such that the U.S. budget constraint is satisfied, while the red line (PS) shows the values, which satisfy the optimal price setting of exporters.

disutility from working in the export sector. The intuition for this result is straightforward: in contrast to the U.S., other economies cannot use their monetary policy to generate expenditure switching on the export side. The suboptimal response of exports to local productivity shocks in these countries relative to the U.S. is summarized by $\mathbb{E}A_0^\theta A_i^{-1} > \mathbb{E}A_0^{\theta-1}$.

Finally, consider the predetermined S_0 and Λ_0. Under DCP, the ex-post asymmetry between the U.S. and other countries affects the ex-ante price setting and risk-sharing between countries. Using the optimal policy, the export price setting in non-U.S. economies (21) and the U.S. budget constraint (18) can be rewritten as

$$\left(\frac{S_0}{\Lambda_0}\right)^\theta = \frac{\mathbb{E}A_0^\theta A_i^{-1}}{\mathbb{E}A_0^{\theta-1}}, \tag{27}$$

$$\Lambda_0^\theta = S_0^{1-\theta}. \tag{28}$$

Intuitively, while the U.S. monetary policy ensures that the prices of local exporters are always proportional to their marginal costs, the prices of exporters from other countries deviate from the optimal level as the monetary policy does not stabilize their marginal costs in dollars. Given that the profit function is concave, exporters from the rest of the world charge a higher markup than the ones from the U.S. to compensate them for the additional risk.[16] As a result, the import prices in the U.S. are higher than the export ones and the terms of trade are depreciated relative to other countries, $S_0 > 1$. Without an export tax, the terms of trade are inefficiently high from a perspective of an individual economy and hence, the U.S. looses from $S_0 > 1$. These costs are smaller when $\theta > 1$: the U.S. still exports less and imports more ($\Lambda_0 < 1$) relative to other economies thanks to a better reallocation of resources across states with high and low productivity. On the other hand, when $\theta < 1$ having depreciated terms of

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[16]This mechanism was first described by Devereux and Engel (1998) in a context of PCP and LCP.

trade becomes too costly and the U.S. suffers from lower imports and higher exports ($\Lambda_0 > 1$).[17] The next proposition summarizes the welfare implications of DCP (see Figure 1 for the illustration).[18]

Proposition 6 (Welfare) *Assume* $\theta = \frac{1}{\sigma} > \frac{1}{2}$, $\alpha = \phi = 0$, $\Psi_i = 1$ *for all* i *and* $\{A_i\}$ *have a joint log-normal distribution symmetric across i. Then under the optimal non-cooperative discretionary policy,*

1. $\mathbb{W}^{ROW} < \mathbb{W}^{US} < \mathbb{W}^{PCP}$ *if* $\theta > 1$,

2. $\mathbb{W}^{US} < \mathbb{W}^{ROW} < \mathbb{W}^{PCP}$ *if* $\theta < 1$,

3. $\mathbb{W}^{US} = \mathbb{W}^{ROW} = \mathbb{W}^{PCP}$ *if* $\theta = 1$ *or if shocks are perfectly correlated across countries.*

The empirical evidence suggests that the short-run elasticity of substitution across goods lies between 1.5 and 2.5 (see Feenstra, Luck, Obstfeld, and Russ 2014), so that $\theta > 1$ is our preferred parametrization. In this case, under DCP, the U.S. policy generates more effective expenditure switching and enjoys a higher welfare relative to other countries. However, despite this advantage over the rest of the world, DCP does not generate welfare gains for the U.S. relative to the PCP case because of the unfavorable terms of trade. Therefore, switching from dollar pricing to PCP would be a Pareto improvement. The social benefits from the currency regime, however, may not coincide with the private benefits of individual exporters and the discretionary policy cannot affect the exporters' ex-ante currency choice (see Mukhin 2018).

3.4.2 Currency union

Our model has also important implications for the optimal currency area (Mundell 1961). While there is much debate about the costs of having a common currency, the benefits of currency unions are less well understood. The new insight that emerges from Proposition 6 is that forming a currency union such as the Eurozone can improve the welfare of its members if it helps to promote the common currency in the international trade.[19] Indeed, a similar model with endogenous currency choice from Mukhin (2018) implies that exporters within the union are more likely use the local currency instead of the dollar as the currency of producer and buyer coincide in this case.[20] Moreover, because of strategic complementarities in currency choice, the trade flows between the union and other countries are more likely to switch to the common currency as well. Thus, if the Euro manages to replace the dollar at the

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[17]In the extreme case when $\theta < \frac{1}{2}$ and the Marshall-Lerner condition is not satisfied, we have $S_0, \Lambda_0 < 1$. Such low elasticity of substitution between goods is hardly realistic and we exclude this case from the analysis.

[18]There are two reasons why our results contrast with the conclusion of Devereux, Shi, and Xu (2007) that the U.S. has always lower welfare than the rest of the world under DCP: (i) the planner is subject to the country's budget constraint rather "naive complete markets" in our setting, (ii) we assume that all countries are small and abstract from strategic interactions between countries that arise in their model with two countries.

[19]See Chari, Dovis, and Kehoe (2013) for other benefits of a currency union arising from a higher level of commitment.

[20]Cavallo, Neiman, and Rigobon (2014) provide supporting evidence that the deviations from the law of one price are smaller for countries with a common currency.

global stage, the Eurozone monetary policy becomes more efficient in generating the optimal expenditure switching towards the exported goods. These new gains from trading with countries outside of the union can potentially outweigh the costs of less efficient stabilization within the union.

A more empirically relevant question, however, is whether the union gains from a common currency when it is used for invoicing of the Eurozone's imports and exports, but does not replace the dollar as a vehicle currency in trade between third countries.[21] Interestingly, the next proposition shows that the Eurozone can achieve the same level of welfare in this case as the U.S. (see Appendix for the details).

Proposition 7 (Eurozone) *Assume that the Eurozone is a small economy with imports and exports invoiced in euros and all other international trade is in dollars. Then the planner's problem for the Eurozone is isomorphic to the U.S. problem and, under the assumptions of Proposition 6, achieves the same welfare.*

Intuitively, the Eurozone is similar to the U.S. with its imports, domestic prices and exports all set in its own currency. As a result, the efficiency of monetary policy in generating expenditure switching on the import and export side is the same as in the U.S. The main difference is, of course, that depreciation of the Euro has no global effects: since a zero measure of imports and exports of other countries are invoiced in euros, the international spillovers of the Eurozone monetary policy are trivial and there is no peg to the Euro. As Section 3.2.2 shows, the response of other economies, however, is irrelevant for the planner's problem in the U.S. Therefore, the optimal policy in the Eurozone coincides with the one in the U.S. and stabilizes local marginal costs. This, in turn, implies that export prices are optimal, while firms exporting from other countries to the union see their prices deviate from the optimal level and charge a higher markup. The resulting terms of trade for the Eurozone are above one and the welfare is exactly the same as in the U.S. The important corollary is that under discretion, the use of the dollar as a vehicle currency does not generate any additional gains for the U.S. and only decreases the welfare of other economies.

4   Dynamic Model

[TO BE COMPLETED]

5   Conclusion

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[21]Gopinath (2016) shows that the share of the Euro in global trade is close to the trade share of the Eurozone.

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