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Exchange Rate Choices with Inflexible Markets and Costly Price Adjustments

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Exchange Rate Choices with Inflexible Markets and Costly Price Adjustments*

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Abstract

This paper analyzes the appropriate choice of an exchange rate regime in agricultural commodity-exporting economies. In an open economy model that incorporates key structural characteristics of agricultural commodity exporters including dual labor markets, the benefits of exchange rate flexibility are shown to depend on the extent of labor and product market development. With developed markets, flexible exchange rates are preferred as they allow for greater relative price fluctuations, which amplify the transmission mechanism of labor re-allocation upon commodity price volatility. When labor and product markets are not well-developed, however, international relative price adjustments exacerbate currency and factor misalignments. A nominal exchange rate peg, by mitigating relative wage and price fluctuations, increases welfare relative to a float. Given the current low level of labor and product market development across most agricultural commodity exporters, the study provides a counterpoint to conventional arguments in favor of flexible exchange rates and a rationale as to why exchange rate targeting is appropriate in agricultural economies.

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"All main commodity price indices are expected to fall in 2016... Low prices for commodities are likely to be with us for some time... Commodity exporters are feeling the pain right away."

-World Bank, Press Release, January 26, 2016

1 Introduction

This paper analyzes the appropriate choice of an exchange rate regime in developing economies that are significantly dependent on labor-intensive agricultural commodity exports.[1] In practice, the majority of such economies target their exchange rates.[2] This poses a puzzle in light of the conventional macroeconomic policy advice since Friedman (1953) that flexible exchange rate have superior stabilization properties. Falling agricultural commodity prices of late (Figure 1), alongside a persistent downward trend and volatility in such prices (World Bank, 2017) have re-ignited discussions across international policy circles on exchange rate choices in commodity exporters (IMF, 2016). The policy recommendations to float have not taken into account the low level of development that influences monetary policy in labor-intensive commodity exporters. This paper seeks to reconcile the exchange rate puzzle in the data and contribute to the ongoing policy debate by providing benchmark theoretical results on the appropriate choice of an exchange rate regime in agricultural commodity-exporting economies.

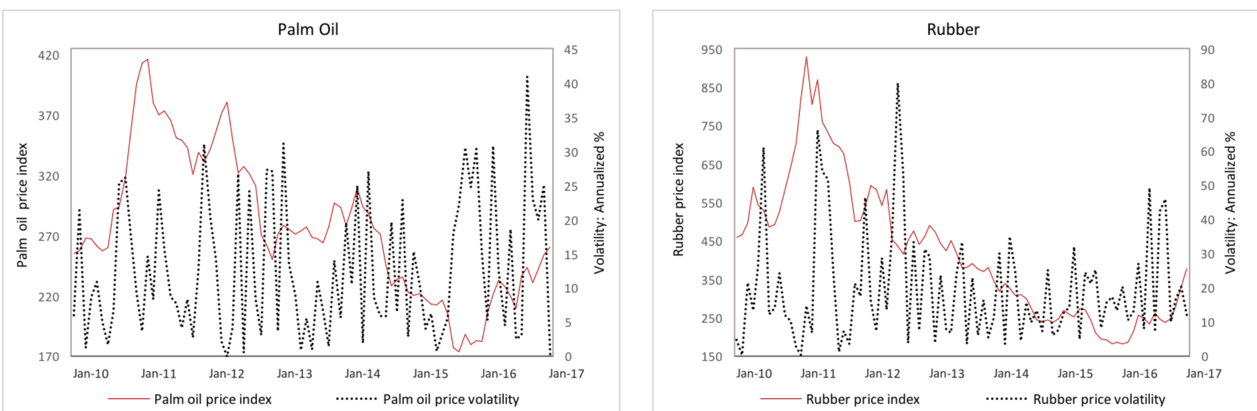

Figure 1: Agricultural Commodity Price Indices (2000=100) and Annualized Volatility Numbers
Source: UNCTAD 2016 Statistics Database (UNCTAD, 2016)

I develop an open economy dynamic stochastic general equilibrium (DSGE) framework that incorporates key structural characteristics of agricultural commodity-exporting economies. The model is able to match stylized facts on the macroeconomic response to commodity export price volatility (discussed further in Section 2). The economy has a heterogeneous production structure with commodity and non-commodity firms. Each sector employs workers to capture the labor-intensive production

[1] Commodity-exporting economies are defined as those economies where commodity export revenues constitute more than 35% of overall export revenues (IMF, 2015a).

[2] See Table 2 in Section 2 for details.

structure in agricultural commodity-exporting economies (UNCTAD, 2013). Labor market rigidity exists in the form of imperfect labor mobility across sectors, implying that wage rates are different across the economy. Both sectors are tradable, with commodities being fully exported and non-commodity goods being supplied to domestic and foreign agents. The commodity sector takes the world price of agricultural goods as given. The non-commodity sector is monopolistic with sticky prices, implying a role for monetary policy. There is limited financial integration with the world and international risk-sharing is imperfect, as representative of developing economies (Kose et al., 2006).

In a novel set of results, I show that the appropriate choice of an exchange rate regime in agricultural commodity exporters depends on the degree of flexibility of domestic labor and product markets. Inflexible labor markets in the model prevent workers from re-allocating hours worked across sectors in response to wage differentials. In developing countries, labor markets are fairly rigid due to sector-specific skills and institutional regulations (Fields, 2009; Artuc et al., 2013). Inflexible product markets in the model are represented by a low Armington (1969) trade elasticity, or the elasticity of substitution between domestic and imported goods. The Armington elasticity is considered low in developing economies as in contrast to industrialized nations, domestic products are typically of poorer quality than foreign goods (Hummels and Klenow, 2005; Henn et al., 2013). With inflexible labor and product markets, a fixed exchange rate leads to higher welfare than a float. Intuitively, with inflexible real markets, and limited financial opportunities to hedge against country-specific risk, relative wage and price fluctuations exacerbate currency and factor misalignments. Instead of allowing for more efficient economic adjustment, price fluctuations in inflexible markets lead to the misallocation of domestic resources. The Central Bank prefers to mitigate international relative price fluctuations, and correspondingly relative wage fluctuations through labor re-allocation, by targeting the exchange rate.

As domestic labor and product markets become more developed, agents can more efficiently respond to wage and price differentials. Flexible labor markets allow households to re-allocate hours worked across sectors worked more efficiently, and thus enjoy higher wages for any given amount of labor effort. Flexible product markets allow households to re-allocate consumption expenditure toward relatively cheaper domestic or foreign goods. In fact, while it is easier said than done in developing economies, when either domestic labor *or* product markets become more flexible, relative price fluctuations become desirable. An exchange rate float leads to higher welfare than a peg in this case. Intuitively, upon a negative shock to the commodity sector, flexible exchange rates allow for greater real depreciation. This increases aggregate demand for tradable non-commodity goods, amplifying the macroeconomic adjustment mechanism of greater wage differentials through labor re-allocation away from the lagging commodity sector. Table 1 summarizes these results, which (i) reconcile the exchange rate puzzle by offering a theory as to why it might be appropriate for less-developed agricultural commodity exporters to target their exchange rates and (ii) these economies should transition to flexible exchange rates, as per conventional wisdom, as they develop over time.

	Rigid Labor Markets	Flexible Labor Markets
Rigid Product Markets	**Peg**	Float
Flexible Product Markets	Float	Float

Table 1: Appropriate Exchange Rate Regime

Related Literature This paper contributes to three strands of literature.

First, several studies have analyzed macroeconomic policy options to deal with commodity revenue volatility. The literature has tended to focus on the design of fiscal frameworks that promote macro-fiscal stability, fiscal sustainability, and the accumulation of precautionary savings (reviewed in Baunsgaard et al., 2012), and a countercyclical fiscal stance (Frankel et al., 2013). Other papers have studied the stabilization properties of various short- and medium-term fiscal rules as an alternative to discretionary fiscal policy (Bi and Kumhof, 2011; C. Garcia and Tanner, 2011; Kumhof and Laxton, 2013; Snudden, 2016). Monetary policy choices have been analyzed in single-sector models with frictionless complete financial markets (Wills, 2013; Ferrero and Seneca, 2015).[3] This does not account for the several distinguishing factors that influence monetary policy in commodity exporters, including factor re-allocation dynamics or that their financial markets are not deep (UNCTAD, 2013; IMF, 2016). I advance the research agenda by incorporating heterogeneous production, factor re-allocation, and financial market incompleteness. In contrast to the previous literature's prescription of inflation targeting that relies on complete markets, I show that exchange rate targeting, instituted in practice by over 70% of commodity exporters, is preferred with inflexible real and financial markets.

My work is also related to the open economy literature on incomplete financial markets. This literature strongly refutes the existence of complete financial markets in the data, and shows that imperfect risk-sharing in open economy models is a minimum requirement to match relative price dynamics (Backus and Smith, 1993; Chari et al., 2002; Corsetti et al., 2008). While the majority of New Keynesian models nevertheless continue to use complete markets, a few studies have analyzed the appropriate choice of monetary policy with imperfect risk-sharing, albeit in single-sector models (Benigno, 2009; De Paoli, 2009; Corsetti et al., 2010). These papers find a case for exchange targeting under certain parameter configurations, as it can redress inefficient cross-country demand imbalances. I take this literature a step ahead by incorporating dual labor markets in an incomplete financial market world, and showing that the desirability of exchange rate targeting is contingent on the efficiency of factor re-allocation. My results are relevant to developing economies with export-intensive structures and inflexible markets. Finally, my paper adds to the burgeoning literature on monetary policy and factor re-allocation, which has previously focused on closed economy models with labor (Petrella and Santoro, 2011) and capital (Bouakez et al., 2009). I advance this research agenda by incorporating an open economy dimension with exchange rates, as well as incomplete financial markets.

[3] The literature on commodity prices and exchange rates includes proposals to target the domestic price of commodities (Frankel, 2011), as well as incorporating commodity prices to improve the forecasting ability of exchange rate models (Cashin et al., 2004) in a separate but related set of questions.

The rest of the paper proceeds as follows. Section 2 provides stylized facts that motivate the theoretical analysis. Section 3 develops an open economy model that incorporates key structural features of agricultural commodity exporters. Section 4 calibrates the framework. Section 5 assesses the role of labor and product market rigidity in influencing the appropriate choice of an exchange rate regime. Section 6 concludes, discusses extensions, and offers policy recommendations.

2 Stylized Facts

Background Commodity exporters, defined as those economies where commodity export revenues constitute 35% or more of total export revenues, are uniquely vulnerable to the high volatility in international commodity prices (IMF, 2015a). Economic progress in these countries is tightly linked to unstable foreign exchange revenues, making it paramount to consider exchange rate regimes that mitigate the resulting domestic macroeconomic volatility (IMF, 2015b). There are around 40 commodity-exporting economies that produce labor-intensive agricultural commodities, a large number of which are in Africa (UNCTAD, 2013). Other commodity exporters extract metals and oil using capital-intensive technology, and the challenges facing those economies are quite different (for an overview, see IMF, 2015a). This paper focuses on the agricultural commodity exporters in Table 2. Most of these are low-income or developing economies, and commodity export employment generally constitutes a high fraction of aggregate employment. Moreover, in contrast to the conventional wisdom on the superiority of flexible exchange rates, over 70% of agricultural commodity exporters have exchange rate anchors.

Structural Features The following key structural characteristics of agricultural commodity exporters are important to take into account in a DSGE model (IMF, 2016; UNCTAD, 2013). Agricultural commodity exporters are typically small and open economies, which take the volatile international price of commodities as given. Production activities are typically heterogeneous, with distinct commodity and non-commodity sectors. These commodities include sugar, rubber, coffee, and rice, and harvesting them is highly labor-intensive with limited machinery. Non-commodity products are typically of lower quality than in advanced economies (Hummels and Klenow, 2005; Henn et al., 2013). Domestic households supply labor, but cannot respond efficiently to inter-sectoral wage differentials as labor markets are fairly rigid in developing economies (Fields, 2009; Artuc et al., 2013).

Asset markets are typically thin and imperfectly integrated with the rest of the world, making it difficult to insure against aggregate risk (Kose et al., 2006). This can be modeled in a DSGE framework through incomplete international financial markets, which implies suboptimal international risk-sharing. Agricultural production is subject to decreasing returns to scale, and export revenues generally accrue to domestic households who account for almost all of commodity production (UNCTAD, 2013). Commodities are also typically almost fully exported. In practice, a very small fraction of agricultural exports is consumed domestically, but for simplicity, all commodities are fully exported in the model.

All the structural characteristics discussed above are explicitly modeled, and allow the framework to replicate key macroeconomic dynamics upon a commodity price fall, as discussed next.

Country	**Agri Exports/ Total Exports**	**% Agri Employment**	**Exchange Rate Regime**
Guinea-Bissau	91%	53%	Exch rate anchor (soft peg)
Rwanda	84%	59%	Exch rate anchor (soft peg)
Malawi	80%	53%	Exch rate float (money target)
Paraguay	76%	17%	Exch rate float (inflation target)
Ethiopia	75%	51%	Exch rate anchor (soft peg)
Nicaragua	70%	10%	Exch rate anchor (soft peg)
Gambia	69%	51%	Exch rate anchor (soft peg)
Djibouti	69%	49%	Exch rate anchor (hard peg)
Burundi	67%	59%	Exch rate float (money target)
Burkina Faso	65%	61%	Exch rate anchor (soft peg)
Afghanistan	65%	40%	Exch rate float (money target)
Belize	62%	16%	Exch rate anchor (soft peg)
Sao Tome and Principe	60%	37%	Exch rate anchor (soft peg)
Vanuatu	60%	20%	Exch rate anchor (soft peg)
Timor-Leste	59%	53%	Exch rate anchor (hard peg)
Somalia	58%	44%	Exch rate float (inflation target)
Kenya	56%	5%	Exch rate float (money target)
Uganda	55%	50%	Exch rate float (inflation target)
Tonga	53%	18%	Exch rate anchor (soft peg)
Côte d'Ivoire	53%	25%	Exch rate anchor (soft peg)
Argentina	52%	5%	Exch rate anchor (soft peg)
New Zealand	52%	5%	Exch rate float (inflation target)
Uruguay	51%	7%	Exch rate float (money target)
Benin	50%	29%	Exch rate anchor (soft peg)
Saint Vincent	50%	13%	Exch rate anchor (hard peg)
Dominican Republic	49%	7%	Exch rate anchor (soft peg)
Eritrea	49%	49%	Exch rate anchor (soft peg)
Samoa	49%	19%	Exch rate anchor (soft peg)
Comoros	48%	47%	Exch rate anchor (soft peg)
Honduras	47%	16%	Exch rate anchor (soft peg)
Fiji	43%	24%	Exch rate anchor (soft peg)
Panama	41%	11%	Exch rate anchor (hard peg)
Guatemala	40%	25%	Exch rate anchor (soft peg)
Liberia	40%	41%	Exch rate anchor (hard peg)
Dominica	39%	14%	Exch rate anchor (hard peg)
Guyana	39%	10%	Exch rate anchor (soft peg)
Moldova	38%	10%	Exch rate float (inflation target)
Average	**57%**	**30%**	**Exch rate anchor = 73%**

Table 2: Exchange Rate Regimes and Employment in Agricultural Commodity Exporters
Sources: FAO 2010 Yearbook (FAO, 2010) and IMF 2014 Exchange Rates Report (IMF, 2014)
Note: Benin, Burkina Faso, Cote de Ivoire, Guinea-Bissau are in the WAEMU monetary union, and Dominica is in the ECCU currency board. *Exchange rate anchor* refers to (i) *soft pegs* (conventional pegs including monetary unions, crawl-like arrangements, stabilized arrangements, horizontal bands) and (ii) *hard pegs* (currency boards, no separate legal tender) as per *IMF (2014)*. I approximate these through a fixed nominal exchange rate in this paper.

A Commodity Price Fall The dual labor markets structure allows the model to replicate certain stylized facts on macroeconomic fluctuations in commodity exporters. Empirical evidence from Kose and Riezman (2001) and IMF (2015a) suggests that most macroeconomic aggregates are procyclical in response to commodity price volatility. Upon a negative shock to agricultural commodity export revenues, aggregate output and consumption fall. Labor tends to move out of the lagging commodity export sector, and aggregate employment falls due to the substitution effect arising from the fall in wages. The real exchange rate depreciates. These features of macroeconomic fluctuations are qualitatively matched by my model, especially with the monetary regime of exchange rate targeting (see Figure 2 in Section 5). Further details on the framework and its calibration are provided in Sections 3 and 4.

3 A Small Open Commodity-Exporting Economy

I develop an open economy framework that incorporates key structural characteristics in agricultural commodity-exporting countries. The economy has a dual production structure, and each of the two sectors employs workers, to capture the labor-intensive nature of agricultural production. Wage rates are different across the economy due to barriers to labor mobility, which deviates from the assumption of homogeneous labor markets in most existing general equilibrium models. Financial markets are not well-developed and international risk-sharing is imperfect. This implies that agents are unable to insure consumption from income fluctuations, as typical of developing countries (Kose et al., 2006).

3.1 Households

There exists a continuum of identical, infinitely-lived households indexed by $l \in [0,1]$ in the domestic small open economy, which is of measure zero compared to the rest of the world. Thus, external conditions are taken as given and domestic policy decisions do not impact foreign agents. Initial net foreign asset positions are symmetrically zero across countries. The representative domestic household derives utility from consumption of domestic non-commodity and imported goods and disutility from labor supplied to the commodity and non-commodity sectors. As more consumption is desirable, but the marginal utility from each additional unit increases at a decreasing rate, it is modeled through an isoelastic functional form which is concave and continuously differentiable. Disutility from labor supply is strictly increasing in hours worked, and is measured by an isoelastic functional form that is convex and continuously differentiable. At each date $t > 0$, a stochastic event, x_t, is realized with probability $\mu(x_t)$. The initial realization, x_0, is given so that $\mu(x_0) = 1$. The history of events until period $t+s$ is given by $x^{t+s} = \{x_t, x_{t+1}, ..., x_{t+s}\}$. Subject to discounting, β^s, over time $t+s$, $s = 0, 1, 2, ...$, expected household utility at time t, U_t, is given by

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{C_{t+s}^{1-\sigma}}{1-\sigma} - \frac{N_{t+s}^{1+\phi}}{1+\phi} \right] \tag{1}$$

where $\sigma > 0$ is the inverse intertemporal elasticity of substitution, $\phi > 0$ is the inverse Frisch elasticity of labor supply, and $E_t(.) = \sum_{x_{t+s+1}} \mu\left(x^{t+s+1}|x^{t+s}\right)$ is the expectations operator over all possible future states of nature conditional on history x^{t+s}. Hours worked, N_t, are supplied to the commodity and non-commodity sectors according to a constant elasticity of substitution (CES) labor supply index

$$N_t = \left[\eta^{-\frac{1}{\lambda}} N_{C,t}^{\frac{1+\lambda}{\lambda}} + (1-\eta)^{-\frac{1}{\lambda}} N_{H,t}^{\frac{1+\lambda}{\lambda}}\right]^{\frac{\lambda}{1+\lambda}} \tag{2}$$

where $\lambda > 0$ is the CES elasticity of substitution in hours worked across sectors and captures the extent of labor market rigidity, $N_{C,t}$ is labor demanded by the commodity sector, $N_{H,t}$ is labor demanded by the non-commodity sector, and η is the share of commodity sector labor in the steady state (ie. $\eta = N_{C,t}/N_t$). Labor market rigidity, which restricts inter-sectoral re-allocation of hours worked in response to relative wage fluctuations, is inversely proportional to λ.

For $\lambda = 0$, labor markets are fully segmented and workers cannot migrate across sectors even in the presence of wage differentials. As $\lambda \to \infty$, labor markets become flexible and workers devote all their time to the sector paying the higher wage. For $\lambda < \infty$, hours worked are imperfect substitutes, and labor is supplied to both sectors. (2) is similar to the CES aggregator used by Petrella and Santoro (2011) in that it allows for a full employment steady state where sectoral employment shares to sum up to 1, consistent with all workers being employed over the business cycle. C_t is a CES consumption index given by

$$C_t = [(1-\alpha)^{\frac{1}{\varepsilon}} C_{H,t}{}^{\frac{\varepsilon-1}{\varepsilon}} + \alpha^{\frac{1}{\varepsilon}} C_{F,t}{}^{\frac{\varepsilon-1}{\varepsilon}}]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3}$$

where $C_{H,t}$ denotes consumption of non-commodity goods produced domestically, $C_{F,t}$ is consumption of goods imported from the rest of the world, $\alpha \in [0,1]$ is the share of imported goods in the consumption basket, C_t (conversely, $1-\alpha$ measures the extent of home bias in consumption), and ε is the Armington (1969) trade elasticity, or the elasticity of substitution between home and foreign goods. The associated price index is

$$P_t = \left[(1-\alpha)P_{H,t}^{\varepsilon} + \alpha P_{F,t}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{4}$$

where P_t is the consumer price index (CPI), $P_{H,t}$ is the price index for domestic goods, and $P_{F,t}$ is the import price index. Minimizing expenditure on the consumption basket (3) gives rise to the following downward-sloping demand functions for domestic and imported goods

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{Pt}\right)^{-\varepsilon} C_t \qquad C_{F,t} = \alpha\left(\frac{P_{F,t}}{Pt}\right)^{-\varepsilon} C_t \tag{5}$$

The subcomponents of the domestic and imported good indices, $C_{H,t}$ and $C_{F,t}$, measure domestic consumption of individual varieties of goods, i, with elasticity of substitution ν between varieties

$$C_{H,t} = \left[\int_0^1 C_{H,t}(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}} \qquad C_{F,t} = \left[\int_0^1 C_{F,t}(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}} \tag{6}$$

where $C_{H,t}(i)$ is the consumption of variety i produced in the domestic small open economy, and $C_{F,t}(i)$ is the consumption of variety i imported from the rest of the world.

Agents across the world have access to a one-period uncontingent risk-free nominal bond, denominated in units of foreign currency. Unlike foreign households, domestic agents face adjustment costs on changing their holdings of this bond away from its steady state level. This assumption ensures that the equilibrium in an open economy with incomplete markets is stationary as the marginal cost of engaging in asset market transactions is increasing in the quantity of bonds purchased. Domestic households also have access to a one-period uncontingent domestic currency risk-free bond. This is in zero net supply as idiosyncratic risk is pooled among domestic households so that, in effect, only foreign currency bonds are traded in equilibrium. At time t, utility, (1), is maximized in a dynamic optimization problem, subject to the following sequence of nominal budget constraints

$$\begin{aligned} &\int_0^1 P_{H,t}(i)C_{H,t}(i)di + \int_0^1 \int_0^1 P_{j,t}(i)C_{j,t}(i)didj + e_t \left[B_{F,t} + \Gamma\left(B_{F,t}\right)\right] + B_{H,t} \\ &\leq e_t \left(1 + i^*_{t-1}\right) B_{F,t-1} + \left(1 + i_{t-1}\right) B_{H,t-1} + W_{C,t}N_{C,t} + W_{H,t}N_{H,t} + \Omega_{C,t} + \Omega_{H,t} \end{aligned} \tag{7}$$

where $P_{H,t}(i)$ is the price of domestic variety i, $P_{j,t}(i)$ is the price of variety i imported from country j, $W_{C,t}$ is the nominal wage rate per unit of hours worked in the commodity sector, $W_{H,t}$ is the nominal wage rate per unit of hours worked in the non-commodity sector, $\Omega_{C,t}$ denotes nominal dividends from ownership of commodity firms, and $\Omega_{H,t}$ denotes nominal dividends from ownership of non-commodity firms. $B_{F,t}$ is a foreign currency bond, with $\Gamma\left(.\right)$ as adjustment costs and e_t as the nominal exchange rate ie. the price of foreign currency in units of domestic currency. The price of the foreign bond is inversely proportional to the gross foreign nominal interest rate, $1 + i^*_t$. $B_{H,t}$ is a domestic currency bond, with its price inversely proportional to the gross domestic nominal interest rate, $1 + i_t$.

Domestic households take the quadratic adjustment cost, $\Gamma\left(B_{F,t}\right) = \frac{\kappa}{2}\left(B_{F,t} - B_{F,0}\right)^2$, as given when choosing optimal holdings of the foreign bond. This cost is not needed for the characterization of incomplete financial markets in a stochastic open economy, but addresses the associated issue of equilibrium non-stationarity as discussed further in, for example, Schmitt-Grohé and Uribe (2003). $\Gamma\left(B_{F,t}\right)$ induces stationarity by linking consumption growth to asset holdings (which are prevented from growing or shrinking explosively over time due to adjustment costs) in the Euler Equation. I impose some restrictions on the function $\Gamma\left(.\right)$. It is differentiable and increasing in the aggregate level of foreign debt, $\Gamma'\left(.\right) > 0$. Furthermore, varying $\kappa \in [0, \infty)$ is a convenient way of accounting for the different degrees of international risk-sharing arising from financial market imperfections, as capital mobility from the domestic small open economy becomes increasingly restricted as $\kappa \to \infty$.

Using the optimal demand functions for the domestic and imported good baskets, (5), as well as the CPI, (4), total consumption expenditures by the domestic household are given by $P_tC_t = P_{H,t}C_{H,t} +$

$P_{F,t}C_{F,t}$. The period budget constraint reduces to

$$\begin{aligned}&P_tC_t + e_t\left[B_{F,t} + \Gamma\left(B_{F,t}\right)\right] + B_{H,t} \\ &\leq e_t\left(1+i^*_{t-1}\right)B_{F,t-1} + \left(1+i_{t-1}\right)B_{H,t-1} + W_{C,t}N_{C,t} + W_{H,t}N_{H,t} + \Omega_{C,t} + \Omega_{H,t}\end{aligned} \tag{8}$$

The budget constraint binds as preferences are locally non-satiated. The first-order conditions on consumption and sector-specific labor supply can be combined to yield the following set of optimal labor supply conditions for the representative domestic household

$$\eta^{-\frac{1}{\lambda}} N_t^{\frac{\phi(1+\lambda)-1}{1+\lambda}} N_{C,t}^{\frac{1}{\lambda}} C_t^{\sigma} = w_{C,t} \tag{9}$$

$$(1-\eta)^{-\frac{1}{\lambda}} N_t^{\frac{\phi(1+\lambda)-1}{1+\lambda}} N_{H,t}^{\frac{1}{\lambda}} C_t^{\sigma} = w_{H,t} \tag{10}$$

where $w_{C,t} = \frac{W_{C,t}}{P_t}$ is the real commodity sector wage, and $w_{H,t} = \frac{W_{H,t}}{P_t}$ is the real non-commodity sector wage. It is useful to note that, due to the dual labor market structure in this framework, compared to the majority of DSGE models which assume a single labor market, there are two optimal labor supply conditions instead of one. This distinction will play a crucial role in some of the results. Hours supplied by workers respond to two different wage rates, with the substitutability of hours worked across sectors governed by λ. The first-order condition on consumption can be combined with the optimal holdings of domestic and foreign bonds respectively, to yield the following set of Euler Equations

$$1 = \left(1+i_t\right)\beta E_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{1}{\Pi_{t+1}}\right\} \tag{11}$$

$$1 = \left(1+i^*_t\right)\left(\frac{1}{1+\kappa b_{F,t}}\right)\beta E_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{Q_{t+1}}{Q_t}\right\} \tag{12}$$

where $Q_t = \frac{e_tP^*}{P_t}$ is the real exchange rate, $b_{F,t} = \frac{B_{F,t}}{P^*}$ are real foreign bond holdings, and P^* is the constant foreign CPI, which is taken as given by the domestic small open economy and normalized to one. I now discuss the risk-sharing and no-arbitrage conditions with incomplete financial markets. To do so, it is useful to consider the problem of the representative foreign household, which faces the following budget constant each period

$$P^*C^*_t + B^*_{F,t} \leq \left(1+i^*_{t-1}\right)B^*_{F,t-1} + W^*_tN^*_t + \Omega^*_t$$

where $C^*_t, W^*_t, N^*_t, \Omega^*_t$ are foreign consumption, wages, labor supply, and profits. $B^*_{F,t}$ denotes foreign holdings of the foreign currency bond. As foreigners have the same functional form for preferences as domestic households, the foreign Euler Equation is

$$1 = \left(1+i^*_t\right)\beta E_t\left\{\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{1}{\Pi^*}\right\} \tag{13}$$

Combining the intertemporal optimality conditions of the domestic and foreign households with respect to foreign bonds, (12) and (13), yields the Backus-Smith (Backus and Smith, 1993) international risk-sharing condition with incomplete financial markets

$$E_t \left\{ \frac{C_{t+1}}{C_t} \right\} \quad = \quad E_t \left\{ \frac{C^*_{t+1}}{C^*_t} \left(\frac{Q_{t+1}}{Q_t} \right)^{\frac{1}{\sigma}} \right\} \left(\frac{1}{1+\kappa b_{F,t}} \right)^{\frac{1}{\sigma}} \tag{14}$$

The risk-sharing condition holds in expected future changes in relative consumption, $E_t\left(\frac{C_{t+1}}{C_t} / \frac{C_{t+1*}}{C^*_t}\right)$, and the real exchange rate, $E_t\left(\frac{Q_{t+1}}{Q_t}\right)$. (14) formalizes the limited scope for sharing risk internationally in a bond only world. Agents cannot hedge against asymmetric shocks, so that consumption can be smoothed only through borrowing and saving across time.

As asset market arbitrage opportunities do not exist, domestic investors are indifferent between holding domestic currency bonds and foreign currency bonds (taking into account adjustment costs on the latter). This makes it possible to derive an equilibrium condition linking the nominal interest and exchange rates by combining (11) and (12) to yield a version of the uncovered interest rate parity (UIP) condition with incomplete financial markets

$$1 + i_t = (1 + i^*_t)\, E_t \left(\frac{e_{t+1}}{e_t} \right) \left(\frac{1}{1+\kappa b_{F,t}} \right) \tag{15}$$

Note that bond adjustment costs drive a wedge between the expected change in nominal exchange rates and the spread in nominal interest rates. (15) implies that the nominal exchange rate is expected to adjust upon shocks to equalize the domestic currency returns on domestic and foreign bonds.

3.2 Relative Prices

Domestic and international prices are defined in relative terms and normalized by the CPI, P_t. Key relative prices are the relative domestic non-commodity price index, $p_{H,t} = \frac{P_{H,t}}{P_t}$, the relative import price index, $p_{F,t} = \frac{P_{F,t}}{P_t}$, and the relative domestic commodity price index, $p_{C,t} = \frac{P_{C,t}}{P_t}$. It is possible to retrieve all relative prices upon determining $S_{H,t}$, the non-commodity terms of trade, defined as the relative price of imported to domestic goods

$$S_{H,t} = \frac{p_{F,t}}{p_{H,t}} \tag{16}$$

Noting that the CPI, (4), can be written as a function of the terms of trade as $P_t^{1-\varepsilon} = P_{H,t}\left[1-\alpha+\alpha S_{H,t}^{1-\varepsilon}\right]$, relative domestic non-commodity and import prices are given by

$$p_{H,t} = \left[1-\alpha+\alpha S_{H,t}^{1-\varepsilon}\right]^{-\frac{1}{1-\varepsilon}} \qquad p_{F,t} = S_{H,t}\left[1-\alpha+\alpha S_{H,t}^{1-\varepsilon}\right]^{-\frac{1}{1-\varepsilon}} \tag{17}$$

The real CPI exchange rate, $Q_t = \frac{e_t P^*}{P_t}$, is defined as the domestic currency price of a foreign basket of consumption, $e_t P^*$, relative to that of a domestic basket of consumption, P_t, where e_t is the nominal exchange rate ie. the price of foreign currency in units of domestic currency and P^* is the constant world CPI. Q_t can be expressed in terms of $S_{H,t}$. Assuming that purchasing power parity holds in the imported goods market, so that $P_{F,t} = e_t P_F^*$, and that from the perspective of the domestic economy, which is small, the world as a whole behaves like a closed economy, so that $P^* = P_F^*$, I derive

$$Q_t = \left[(1-\alpha)S_{H,t}^{\varepsilon-1} + \alpha\right]^{\frac{1}{\varepsilon-1}} \tag{18}$$

As the domestic economy is small, the international price of commodities, $P_{C,t}^*$, is taken as given. Further, purchasing power parity (PPP) holds for commodities traded worldwide, so that the domestic price of commodities, $P_{C,t}$, is related to the exogenous international price as $P_{C,t} = e_t P_{C,t}^*$. Using the definition of the real exchange rate, (18), and the fact that the relative international price, $p_{C,t}^* = \frac{P_{C,t}^*}{P^*}$, is exogenous, the relative domestic price of commodities is given by

$$p_{C,t} = Q_t p_{C,t}^* \tag{19}$$

The commodity terms of trade, $S_{C,t}$, is a ratio of relative prices, $S_{C,t} = \frac{p_{F,t}}{p_{C,t}}$. Noting however that PPP holds for imported and commodity goods, the commodity terms of trade fluctuates exogenously, ie. $S_{C,t} = \frac{p_F^*}{p_{C,t}^*}$, as is approximately the case in small, commodity-exporting economies (Cashin et al., 2004).

3.3 Firms

As commodity exporters rely heavily on commodity exports as primary sources of revenue, the framework incorporates explicit macroeconomic dependence on commodities. Heterogeneous production activities in the economy are undertaken by (i) commodity firms and (ii) non-commodity firms. Both sectors are owned by domestic households. While commodities are fully exported, non-commodity goods are supplied to both domestic and foreign agents. Further, as the economy in question is small and open, the international price of commodities is taken as given. The domestic commodity price, however, is influenced by exchange rate and sectoral dynamics. Non-commodity firms are monopolistic and set prices in a staggered manner, which gives rise to inefficient price dispersion.

3.3.1 Commodity Sector

Commodity firms, $h \in [0,1]$ are perfectly competitive and are subject to an industry-wide decreasing returns to scale technology. Commodity goods, $Y_{C,t}$, produced in this sector are demanded by foreign agents. An individual firm h employs the following production function

$$Y_{C,t}(h) = A_{C,t}\bar{K}N_{C,t}^{1-\psi}(h) \tag{20}$$

where $A_{C,t}$ is overall productivity in the non-commodity sector, $N_{C,t}(h)$ is labor demanded by commodity firm h, $\bar{K}$ is industry-wide available capital and land used in the production of commodities that is fixed, and $\psi \in [0,1]$ measures the extent of deviation from constant returns to scale. $\psi > 0$, common across the sector, implies positive profits for firm h. The cost incurred by commodity firms in hiring workers is the commodity sector wage, $W_{C,t}$. Noting that $P_{C,t}$ is the domestic currency price of commodities, the profit maximization problem faced by firm h is given by

$$\underset{\tilde{P}_{C,t}(h)}{Max}\ \tilde{P}_{C,t}(h) A_{C,t} \bar{K} N_{C,t}^{1-\psi}(h) - W_{C,t} N_{C,t}(h) \tag{21}$$

The aggregate production function in this sector is given by $Y_{C,t} = A_{C,t}\bar{K}N_{C,t}^{1-\psi}$, which is derived by imposing the labor market clearing condition, $N_{C,t} = \int_0^1 N_{C,t}(h)dh$, and the condition that the supply of all individual commodities are met by foreign demand. In a symmetric equilibrium, the same optimal price, $\tilde{P}_{C,t}$, is chosen by all commodity firms, so that aggregate employment in this sector is given by

$$N_{C,t}^{\psi} = (1-\psi)\left(\frac{W_{C,t}}{\tilde{P}_{C,t}(h)}\right)^{-1} \bar{K} A_{C,t} \tag{22}$$

Commodity sector profits are correspondingly

$$\Omega_{C,t} = \psi \tilde{P}_{C,t} Y_{C,t} \tag{23}$$

3.3.2 Non-Commodity Sector

Non-commodity goods are supplied to domestic and foreign consumers. Firms, $i \in [0,1]$, are monopolistic and set prices in a staggered fashion according to the Calvo pricing scheme. In any given period and independent of time elapsed since last reset, a fraction $(1-\theta)$ of (randomly selected) firms can re-optimize prices. Fraction θ of firms cannot re-optimize and instead adjust labor demand to meet changes in output demand upon shocks. Firms that do reset prices upon shocks take into account that the probability of keeping this period's price k periods ahead is given by θ^k.

With production function $Y_{H,t}(i) = A_{H,t}N_{H,t}(i)$, each reoptimizing firm i sets its optimal reset price as a markup over current and expected future marginal costs, where $MC_{H,t}(i) = W_{H,t}/A_{H,t}P_{H,t}(i)$, giving rise to domestic inflation. Noting that a firm that reoptimizes in period t will choose the price $\tilde{P}_{H,t}(i)$ that maximizes current and future discounted profits until period $t+k$ while this price remains effective, so that $\tilde{P}_{H,t+k}(i) = \tilde{P}_{H,t}(i)$ for $k = 0, ..., \infty$, the optimal reset price at time t solves

$$\underset{\tilde{P}_{H,t}(i)}{Max}\ E_t \sum_{k=0}^{\infty} \theta^k Z_{t,t+k} \left\{ \tilde{P}_{H,t}(i) Y_{H,t+k}(i) - W_{H,t+k} N_{H,t+k}(i) \right\}$$

$$s.t.\ \ Y_{H,t+k}(i) = \left(\frac{\tilde{P}_{H,t}(i)}{P_{H,t}}\right)^{-\nu} \left(C_{H,t+k}(i) + C^*_{H,t+k}(i)\right) \tag{24}$$

where $Y_{H,t+k}(i)$ and $W_{H,t+k}N_{H,t+k}(i)$ are respectively the output and total cost in period $t+k$ for a firm that last reset its price in period t, $E_t Z_{t,t+k} = (1+i_t)^{-1}$ is the price of the domestic currency bond, and $C_{H,t+k}(i)$ and $C^*_{H,t+k}(i)$ represent demand for good i in period $t+k$ respectively by domestic and foreign consumers. In a symmetric equilibrium, the same price is chosen by all firms that can re-optimize so that $\tilde{P}_{H,t}(i) = \tilde{P}_{H,t} \forall i$. The first-order condition is

$$E_t \sum_{k=0}^{\infty} \theta^k Z_{t,t+k} Y_{H,t+k}(i) \left[\tilde{P}_{H,t} - \frac{\nu}{\nu - 1} \frac{W_{H,t+k}}{A_{H,t+k}} \right] = 0 \tag{25}$$

Using (24), the labor-market clearing condition $N_{H,t} = \int_0^1 N_{H,t}(i) di$, the price index associated with the demand for monopolistic goods $P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\nu} di \right]^{\frac{1}{1-\nu}}$, and the definition of price dispersion, $\Delta_t \equiv \int_0^1 \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\nu} di$, which follows law of motion

$$\Delta_t^{\frac{\nu-1}{\nu}} = \rho \Pi_{H,t}{}^{\nu-1} \Delta_{t-1} + (1-\theta) \frac{1 - \theta \Pi_{H,t}{}^{\nu-1}}{1-\theta} \tag{26}$$

it is possible to derive (27), which resembles an aggregate production function, but takes into account the technological restrictions and distributional inefficiencies associated with price dispersion

$$Y_{H,t} \Delta_t = A_{H,t} N_{H,t} \tag{27}$$

Using the price index and definition of price dispersion, the optimal reset price relates to the domestic inflation rate, $\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$, as follows

$$\frac{\tilde{P}_{H,t}}{P_{H,t}} = \left(\frac{1 - \theta \Pi_{H,t}{}^{\nu-1}}{1-\theta} \right)^{\frac{1}{1-\nu}}$$

From the first-order condition, (25), the optimal reset price is written as a function of aggregate variables only as

$$\frac{\tilde{P}_{H,t}}{P_{H,t}} = \frac{F_t}{K_t} \tag{28}$$

where F_t is the present discounted value of total costs in real terms

$$F_t = \frac{\nu}{\nu-1} \frac{Y_{H,t}}{C_t^{\sigma}} \frac{MC_{H,t}}{S_{H,t}^{\alpha}} + \beta\theta E_t \left(\Pi_{H,t+1}{}^{\nu} F_{t+1} \right) \tag{29}$$

and K_t is the present discounted value of total revenues in real terms

$$K_t = \frac{Y_{H,t} S_{H,t}{}^{-\alpha}}{C_t^{\sigma}} + \beta\theta E_t \left(\Pi_{H,t+1}{}^{\nu-1} K_{t+1} \right) \tag{30}$$

Equations (28) to (30) summarize the recursive representation of the non-linear Phillips Curve. [4]

[4]The corresponding linearized version of the Phillips curve takes the familiar form: $\pi_{H,t} = \beta \pi_{H,t+1} + \xi mc_{H,t}$, where $\xi = \frac{(1-\beta\theta)(1-\theta)}{\theta}$.

3.4 Central Bank

The Central Bank follows a monetary policy rule of the following form

$$\left(\frac{1+i_t}{1+r_0}\right) = \left(\frac{1+\pi_{H,t}}{1+\pi_{H,0}}\right)^{\phi_\pi} \left(\frac{e_t}{e_0}\right)^{\phi_e} \tag{31}$$

where r_0 is the steady state real interest rate, and $\pi_{H,0}$ and e_0 are the steady state inflation rate and nominal exchange rate respectively. In the model simulations, exchange rate targeting will be represented by $\phi_e > 1, \phi_\pi = 0$, and flexible exchange rates will be represented by $\phi_e = 0, \phi_\pi > 1$.

3.5 Market-Clearing and Accounting

3.5.1 Goods, Labor, National Accounts

The demand for each non-commodity good $i \in [0,1]$, ie. $Y_{H,t}(i)$, is

$$Y_{H,t}(i) = C_{H,t}(i) + C^*_{H,t}(i) \tag{32}$$

The demand for commodities exported by the domestic economy, $Y_{C,t}$, is fully met internationally so that $Y_{C,t}(h) = Y^*_{C,t}(h)$ for each individual variety, $h \in [0,1]$. Hours worked by domestic households are demanded by the commodity and non-commodity sectors as follows

$$N_{C,t} = \int_0^1 N_{C,t}(h)dh \qquad N_{H,t} = \int_0^1 N_{H,t}(i)di \tag{33}$$

Real gross domestic product (GDP), adjusted by the CPI, is

$$GDP_t = p_{C,t}Y_{C,t} + p_{H,t}Y_{H,t} \tag{34}$$

which can also be written as the sum of domestic consumption, C_t, and net exports, NX_t, so that $GDP_t = C_t + NX_t$, where net exports are defined as the imbalance between domestic production and consumption. Adjusted by the CPI, real net exports are

$$NX_t = p_{C,t}Y_{C,t} + p_{H,t}Y_{H,t} - C_t \tag{35}$$

3.5.2 Assets

Domestic currency bonds, $B_{H,t}$, are in zero net supply domestically, and the market for foreign currency bonds clears internationally so that

$$B_{F,t} + B^*_{F,t} = 0 \tag{36}$$

The evolution of net foreign assets held by the domestic economy is required to characterize equilibrium as adjustment costs, $\Gamma(.)$, depend on the level of foreign bond holdings and affect the ability of domestic households to smooth consumption through the risk-sharing condition, (14). The evolution of foreign bonds, adjusted by the foreign CPI, is derived from the representative domestic household's budget constraint (7) by replacing in for profits, to yield

$$Q_t \left[b_{F,t} + \Gamma\left(b_{F,t}\right)\right] = NX_t + \frac{1}{\beta} Q_t b_{F,t-1} \tag{37}$$

where $b_{F,t} = \frac{B_{F,t}}{P^*}$ with $P^* = 1$ and $\beta = \frac{1}{1+i_t^*}$.

3.6 Equilibrium

I define an equilibrium from the perspective of the domestic small open economy, assuming that the no-Ponzi and transversality conditions are satisfied, and that initial net foreign asset positions are symmetrically zero across the world. For any specification of monetary policy, (31), which determines the nominal interest rate, i_t, the equilibrium is a sequence of prices

$$\{S_{H,t}, S_{C,t}, Z_{t,t+1}, \Pi_t, \Pi_{H,t}, P_{C,t}, W_{H,t}, W_{C,t}, \Delta_t, e_t\}_{t=0}^{\infty}$$

and quantities

$$\{C_t, C_{H,t}, C_{F,t}, N_t, N_{H,t}, N_{C,t}, Y_{H,t}, F_t, K_t, Y_{C,t}, B_{F,t}\}_{t=0}^{\infty}$$

such that

- Households optimize labor supply: (9) and (10)
- Households optimize consumption: (12)
- Consumer optimization of domestic and foreign goods yields: (4), (5), and (6)
- International-risk sharing is imperfect: (14)
- Firms, $j \in [0, 1]$, optimize: (22), (27), (28), (29), and (30)
- Goods, (32), labor, (33), and asset, (36), markets clear
- Net foreign assets evolve according to (37)

taking as given exogenous processes for technology and foreign variables $\left\{p_{C,t}^*, A_t, X_t, C_t^*, i_t^*\right\}_{t=0}^{\infty}$.[5] $S_{H,t}$, given by (16), is the only relative price required for the characterization of equilibrium.

4 Calibration

I analyze equilibrium dynamics based on a calibrated version of the framework for a representative agricultural commodity-exporting economy. The degree of labor market flexibility, or the elasticity of

[5]The exogenous variables are determined according to stationary autoregressive processes of the following functional form: $B_t = B_0^{1-\rho_B} B_{t-1}^{\rho_B} \exp\{\epsilon_B\}$, where $B_t \equiv \left\{p_{C,t}^*, A_t, X_t, C_t^*, i_t^*\right\}$, B_0 is the steady state value of B_t, and ϵ_B is a shock.

substitution in hours worked across sectors, λ, is calibrated at 0.8. I set λ to be lower than the estimate of 1 for a developed economy (the United States) from Horvath (2000), as a specific value for λ is not available for developing countries where labor markets are typically far more rigid (Fields, 2009; Artuc et al., 2013). The degree of product market flexibility, or the Armington (1969) trade elasticity of substitution between domestic non-commodity goods and imports, ε, is calibrated at 0.8. While a specific estimate of ε is also not available for developing economies, this parameter has been estimated to be a bit over 1 on average for advanced economies in a range of studies summarized by Feenstra et al. (2014). It is likely that ε is much lower in developing countries where domestically produced goods are typically of much lower quality than imports, implying that home and imported products are poor substitutes (Hummels and Klenow, 2005; Henn et al., 2013).

I pair the baseline calibration of λ and ε with extensive sensitivity analysis to assess the implications of rigid versus flexible markets for the appropriate choice of an exchange rate regime. The rest of the baseline parameterization is as follows. Following Kose et al. (2006), limited financial integration captured by the parameter on the adjustment costs for the household's holding of foreign bonds, κ, is set at 0.1, which is 10 times higher than the analogous calibration used for developed countries (Benigno, 2009). Calibration of the other structural parameters is a challenging task, as the required micro-level data is scarce for small, commodity-exporting economies. I thus select parameters from the existing open economy literature with respect to developing countries, and pair this with sensitivity analysis. Consistent with the estimates in Berg et al. (2013), the intertemporal elasticity, σ, equals 2. The degree of openness to trade, α, is set at 0.5 and the inverse Frisch elasticity, ϕ, equals 5, implying fairly inelastic labor supply. I calibrate returns to scale in the commodity sector, ψ, at 0.1, consistent with the micro-level evidence on diminishing returns to agricultural production (FAO, 2001).

The steady state share of employment in the commodity sector, η, is set at 0.3, which is the average value across the agricultural commodity exporters reported in Table 2. This value for the steady state is supported by the choice of calibration of the structural parameters. I consider strict exchange rate and inflation targeting (sufficiently high weights on ϕ_e and ϕ_π respectively in the monetary rule, (31)), and pair this with sensitivity on the weights. Following standard values in the literature and pairing these with sensitivity analysis, the fraction of randomly chosen monopolistic producers that can reset prices, θ, is set at 0.75, implying an average period of around one year between price adjustments. The household discount factor β equals 0.99, implying a steady state real interest rate of around four percent. The elasticity of substitution between differentiated monopolistic goods, ν, is calibrated at 4, which implies a steady state markup of around 30%. The persistence of shocks, ie. ρ_b in the stationary autoregressive process $b_t = \rho_b b_{t-1} + \epsilon_{b,t}$, where $b_t \equiv \{\hat{p}^*_{C,t}, a_t, x_t, c^*_t, i^*_t\}$, is set at 0.9, consistent with the evidence for developing economies provided in Aguiar and Gopinath (2007).

5 Exchange Rate Choices in Inflexible Markets

This section assesses whether fixed or flexible exchange rates are more appropriate in agricultural commodity exporters. Section 5.1 describes how the economy responds to a negative shock to the commodity export price, differentiating between peg versus float (domestic inflation targeting). Sensitivity analysis confirms that the dynamics hold robust with alternative calibration schemes. Sections 5.2 and 5.3 discuss how the macroeconomic response through relative price and wage adjustments is affected by labor and product market rigidity. Sections 5.4 and 5.5 assess the welfare implications of fixed versus flexible exchange rate regimes, contingent on the degree of flexibility of domestic markets.

5.1 Dynamics under Alternate Exchange Rate Regimes

Figure 2 simulates the economy with a 5% unexpected fall in the international price of agricultural commodities. I solve for the equilibrium dynamics in Section 3 using second-order perturbation techniques, and calibrate the parameters based on the discussion in Section 4. I contrast dynamics with an exchange rate peg versus float. As commodity export revenues fall, labor demand in the commodity sector contracts and wages fall. Consumption falls with the decline in income, as households cannot hedge against the adverse shock due to the lack of financial deepening and asset market insurance. Due to the fall in consumption demand for non-commodity goods, non-commodity labor demand decreases and wages fall. Correspondingly, non-commodity prices decline, and real depreciation ensues.

The key difference between fixed versus flexible exchange rates lies in the extent of real depreciation. While non-commodity production falls under fixed exchange rates due to the decrease in domestic demand, it increases under a float as greater real depreciation allows the impact of relatively higher foreign purchasing power to carry through. Correspondingly, non-commodity wages do not fall by as much under a float. Commodity output declines further, however, as labor re-allocates to the non-commodity sector driven by the relative increase in marginal product there. Commodity sector wages also decline by less with flexible exchange rates due to the outflow of workers. Consumption is more stable under a float due to the higher wage income compared to a peg.

The welfare properties of peg versus float with underdeveloped markets, discussed in the upcoming Section 5.4, depend on how these regimes affect *relative* price and relative wage fluctuations. Result 1 discusses the relative price and wage effects of exchange rate flexibility.

Result 1. *Exchange rate flexibility amplifies relative wage and price fluctuations.*

Flexible exchange rates allow for a greater fall in the price of domestic non-commodity goods relative to imports. This increases the international price differential, acting as a "shock absorber" by allowing for more real depreciation in the face of restricted domestic price adjustment. The wage differential, which measures the value of commodity wages relative to non-commodity wages, also increases. Commodity wages initially fall by more than non-commodity wages, as they are directly affected by the negative shock to commodity export revenues. As the greater foreign purchasing power under a float incentivizes non-commodity production compared to a peg, there is a further relative increase in the marginal product of non-commodity labor. This increases the wage differential.

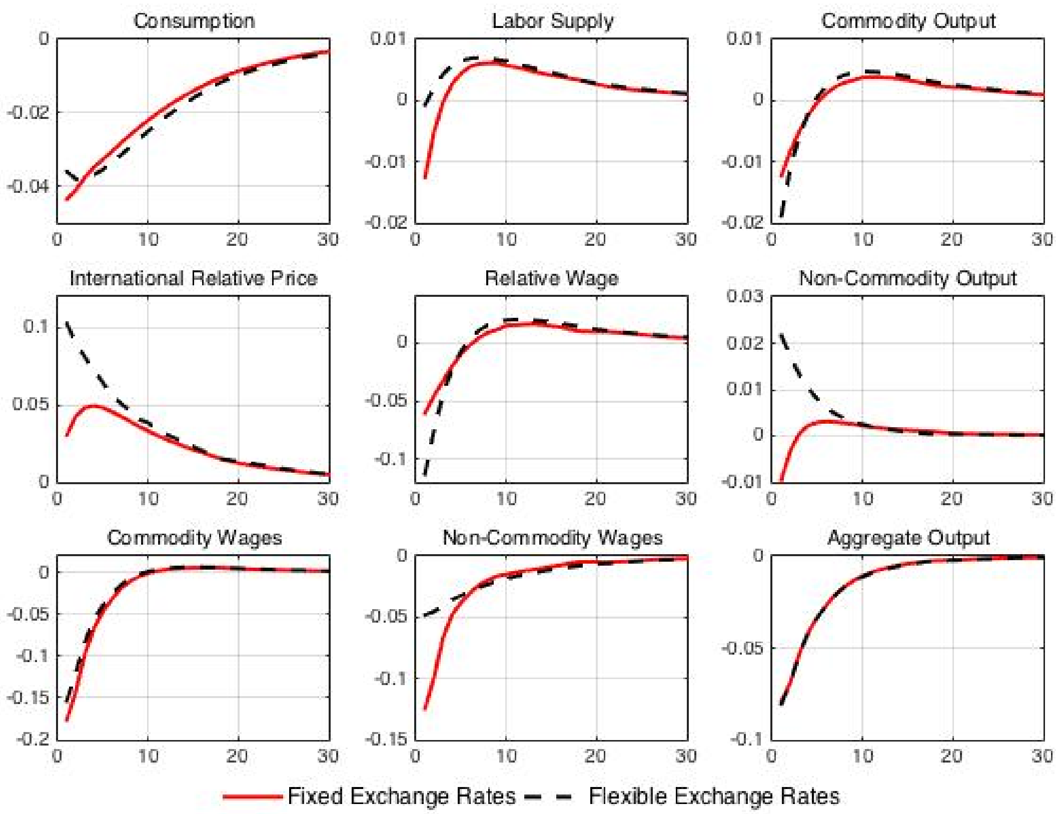

Figure 2: Impulse Responses to a 5% Negative Shock to the International Price of Commodities

Sensitivity The equilibrium response to a negative commodity price shock is analyzed for the following empirically relevant range of parameters: trade openness, $\alpha \in [0.2, 0.8]$, bond adjustment costs, $\kappa \in [0.01, 100]$, price stickiness, $\theta \in [0.4, 0.8]$, inverse elasticity of intertemporal substitution, $\sigma \in [0.5, 5]$, inverse elasticity of labor supply, $\phi \in [1, 10]$, decreasing returns to scale, $\psi \in [0.1, 0.6]$, elasticity of substitution between individual varieties, $\nu \in [4, 8]$, shock persistence, $\rho_b \in [0.5, 0.9]$, monetary rule flexibility, $\phi_e, \phi_\pi \in [1.5, \infty]$, elasticity of labor supply between sectors, $\lambda \in [0.5, \infty]$, and elasticity of substitution between domestic and foreign aggregates, $\varepsilon \in [0.5, 5]$. The dynamics do not differ in terms of direction, or in relative terms between the exchange rate regimes; however, the following changes in parametrization affect quantitative magnitudes in interesting ways.

An increase in α implies that households consume a higher fraction of relatively more expensive imports compared to domestic non-commodity goods. For any given change in the international relative price, consumption thus declines by more. Non-commodity output is higher as greater openness increases the consequences of greater foreign purchasing power upon the shock, and commodity output is lower as labor re-allocates away. The wage differential increases due to higher non-commodity wages. An increase in bond holding costs, κ, implies that there is less international financial integration and dynamics become more volatile. For any given change in the international relative price, consumption decreases more, and non-commodity output follows suit. Commodity output falls by less due to labor re-allocation, and the wage differential decreases due to the fall in non-commodity output. As $\theta \to 0$ (prices become more flexible), the dynamics under peg and float converge.

A decrease in ϕ (more elastic labor supply) implies that labor supplied by households is allowed to fall by more upon the shock. In response, output across the economy falls but aggregate wages are pulled up due to the shortfall in labor supply. This smooths consumption, leading to lower real depreciation. As σ decreases (more elastic response of consumption), consumption falls by more, and non-commodity output follows suit. This eases the downward pressure on non-commodity prices, leading to less real depreciation. The lower depreciation results in a greater fall in commodity output. Note that the above sensitivity analysis holds for both peg and float. Small adjustments to the commodity returns to scale, the elasticity of substitution between varieties, or monetary rule flexibility, do not produce significant changes in dynamics. The roles of greater labor and product market flexibility, reflected in higher values of λ and ε, are the focus of this paper and highlighted next.

5.2 Labor Market Rigidity

The baseline calibration, with $\lambda = 0.8$, reflects the under-developed labor markets in agricultural commodity exporters. An increase in labor market flexibility, ie. as $\lambda \to \infty$, implies that for any given wage differential, $\frac{w_{C,t}}{w_{H,t}}$, relative hours supplied, $\frac{N_{C,t}}{N_{H,t}}$, adjust by more. This has opposing effects on household consumption and the monetary transmission mechanism. On the one hand, workers are freer to migrate to the sector with relatively higher wages, which leads to relatively *higher* consumption for any given amount of labor effort. On the other hand, there is a greater outflow of workers from the lagging commodity sector toward the non-commodity sector. This puts additional downward pressure on non-commodity wages, contributing to relatively *lower* consumption for any given amount of labor effort. The first effect generally dominates so that consumption is smoother, and regardless of exchange rate regime, labor market flexibility has the following impact on relative wages and prices.

Result 2. *Labor market flexibility stabilizes relative wages but increases price differentials.*

Unlike the case of exchange rate flexibility, which amplifies relative wage and price fluctuations, labor market flexibility serves to narrow the wage differential between sectors. As labor becomes more mobile, sectoral output dynamics are amplified with more workers migrating away from the lagging commodity sector toward the non-commodity sector. The influx of labor in the non-commodity sector and corresponding surge in production puts downward pressure on non-commodity prices, increasing the international price differential. However, the outflow of workers from the commodity sector in search of a higher marginal product puts downward pressure on non-commodity wages while easing the fall in commodity wages. This stabilizes relative wages.

5.3 Product Market Rigidity

The baseline calibration, with $\varepsilon = 0.8$, reflects the limited ability of agents to substitute domestic goods for better-quality imports in agricultural commodity exporters. An increase in product market flexibility increases opportunities to smooth consumption by re-allocating expenditure toward relatively cheaper goods. Consumption remains more stabilized with higher ε upon the commodity price shock, with either peg or float and regardless of the degree of labor market flexibility.

Result 3. *Product market flexibility stabilizes relative prices but increases wage differentials.*

While labor market flexibility narrows the wage differential between sectors while exacerbating relative price fluctuations, product market flexibility does the opposite. An increase in ε allows agents to consume more, which mitigates real depreciation and narrows the international price differential. Recall that non-commodity wages decrease *more* with flexible labor markets, as workers face a lower cost of labor re-allocation and can thus be compensated less. However, non-commodity wages decrease *less* with flexible product markets as the non-commodity sector can afford to pay higher wages due to higher consumption demand. This increases the wage differential.

5.4 Welfare

Table 3 reports whether fixed or flexible exchange rates are preferred for different degrees of labor and product market flexibility The corresponding loss numbers are also provided. The losses are measured in consumption equivalent units, Γ. The consumption equivalent is a useful measure of welfare costs as utility, (1), is not cardinal. Γ defines the constant fraction of consumption households have to give up each period starting from the steady state, to equate the present discounted value of welfare under a peg with the present discounted value of welfare under a float. Γ solves

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{[(1-\Gamma)C_{t,e}]^{1-\sigma}}{1-\sigma} - \frac{N_{t,e}^{1+\phi}}{1+\phi} \right] \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{C_{t,\pi}^{1-\sigma}}{1-\sigma} - \frac{N_{t,\pi}^{1+\phi}}{1+\phi} \right] \right\} \tag{38}$$

where $C_{t,e}$ and $N_{t,e}$ are consumption and labor supply under a peg, and $C_{t,\pi}$ and $N_{t,\pi}$ are consumption and labor supply under a float. Note that $\Gamma > 0$ when labor and product markets are rigid (implying that "Peg" is appropriate), but the consumption equivalent becomes negative as markets becomes more flexible (implying that "Float" is appropriate). This brings us to a key insight of this study in Result 4 (robust to sensitivity analysis), which draws upon Results 1-3 that greater flexibility in exchange rates and markets amplifies relative wage and/or relative price fluctuations.

Welfare Ranking of Fixed vs Flexible Regimes						
	Product Markets					
Labor Markets		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
	$\lambda = 0.4$	**Fixed**	**Fixed**	**Fixed**	Flex	Flex
	$\lambda = 0.6$	**Fixed**	**Fixed**	**Fixed**	Flex	Flex
	$\lambda = 0.8$	**Fixed**	**Fixed**	**Fixed**	Flex	Flex
	$\lambda = 1.0$	**Fixed**	**Fixed**	**Fixed**	Flex	Flex
	$\lambda = 1.6$	**Fixed**	**Fixed**	Flex	Flex	Flex

Welfare Loss (% Consumption Equivalent)						
	Product Markets					
Labor Markets		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
	$\lambda = 0.4$	**8.21**	**2.35**	**0.29**	-0.06	-0.15
	$\lambda = 0.6$	**6.07**	**1.37**	**0.19**	-0.10	-0.19
	$\lambda = 0.8$	**3.81**	**0.91**	**0.11**	-0.13	-0.23
	$\lambda = 1.0$	**2.35**	**0.65**	**0.06**	-0.16	-0.26
	$\lambda = 1.6$	**0.93**	**0.28**	-0.06	-0.23	-0.35

Table 3: Welfare Rankings (in terms of Γ) with a 5% Commodity Price Fall

Result 4. *Exchange rate targeting leads to higher welfare than a float in agricultural commodity exporters.*

As agricultural commodity exporters tend to be developing economies, their labor and product markets are typically more rigid (Hummels and Klenow, 2005; Fields, 2009; Artuc et al., 2013; Henn et al., 2013). With inflexible real markets, and limited financial opportunities to insure against country-specific risk, relative wage and price fluctuations exacerbate currency and factor misalignments. Instead of allowing for more efficient economic adjustment, price fluctuations in inflexible markets lead to the misallocation of consumption and employment. The Central Bank prefers to mitigate international relative price fluctuations, and correspondingly relative wage fluctuations through labor re-allocation, by targeting the nominal exchange rate. As real markets become more flexible, agents are better able to respond to relative wage and price fluctuations. In this case, flexible exchange rates are preferred as they increase international price and wage differentials, which amplifies the adjustment mechanism. This result provides a novel rationale as to why over 70% of agricultural commodity exporters have exchange rate anchors, in contrast to conventional arguments in favor of flexible exchange rates.

5.5 Robustness

I find that Result 4 is robust to alternative calibration schemes. To assess how the welfare properties of fixed versus flexible exchange rates are affected with a range of parameters, I vary the calibration as described in the sensitivity analysis in Section 5.1. There are some interesting findings. The welfare rankings of peg versus float in Table 3 are robust to changes in calibration of most parameters. However, varying the degree of trade openness, α, and the degree of international capital mobility, κ, makes a significant difference. These results are reported in Tables 4 and 5. Greater trade openness and more limited international financial integration, characteristic of developing commodity-exporting economies, *increase* the case for fixed exchange rates, thus strengthening the results.

The Central Bank faces a trade-off between mitigating the price dispersion distortion (increasing the case for inflation targeting and flexible exchange rates) and mitigating costly real exchange rate misalignments due to the incomplete financial market distortion (increasing the case for exchange rate targeting). In a more open economy ($\alpha = 0.8$), more imported products are consumed relative to domestic goods. This implies that real exchange rate misalignments lead to a greater misallocation of domestic resources. To mitigate this, a peg is preferred even with flexible labor and product markets. With low international financial integration ($\kappa = 100$), real exchange rate misalignments are also more costly. This is because agents are restricted from efficiently responding to shocks through adjustments in their asset portfolios. Greater flexibility in labor and product markets cannot fully overcome the limited ability to share risk internationally, increasing the case for exchange rate targeting.

Welfare Ranking of Fixed vs Flexible Regimes: Higher Openness ($\alpha = 0.8$)						
		Product Markets				
		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
Labor Markets	$\lambda = 0.4$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	**Fixed**
	$\lambda = 0.6$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	**Fixed**
	$\lambda = 0.8$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	**Fixed**
	$\lambda = 1.0$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	**Fixed**
	$\lambda = 1.6$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	**Fixed**

Welfare Loss (% Consumption Equivalent)						
		Product Markets				
		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
Labor Markets	$\lambda = 0.4$	**15.23**	**13.20**	**4.10**	**1.46**	**0.29**
	$\lambda = 0.6$	**9.18**	**8.17**	**3.11**	**1.38**	**0.25**
	$\lambda = 0.8$	**6.54**	**5.14**	**2.48**	**1.26**	**0.23**
	$\lambda = 1.0$	**5.91**	**3.74**	**2.07**	**1.15**	**0.22**
	$\lambda = 1.6$	**3.05**	**2.13**	**1.42**	**0.91**	**0.21**

Table 4: Welfare Properties (in terms of Γ) with a 5% Commodity Price Fall

Welfare Ranking of Fixed vs Flexible Regimes: Lower financial integration ($\kappa = 100$)						
	Product Markets					
Labor Markets		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
	$\lambda = 0.4$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	Flex
	$\lambda = 0.6$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	Flex
	$\lambda = 0.8$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	Flex
	$\lambda = 1.0$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	Flex
	$\lambda = 1.6$	**Fixed**	**Fixed**	**Fixed**	**Fixed**	Flex

Welfare Loss (% Consumption Equivalent)						
	Product Markets					
Labor Markets		$\varepsilon = 0.4$	$\varepsilon = 0.6$	$\varepsilon = 0.8$	$\varepsilon = 1.0$	$\varepsilon = 1.6$
	$\lambda = 0.4$	**9.40**	**7.62**	**1.41**	**0.05**	-0.47
	$\lambda = 0.6$	**6.31**	**4.28**	**1.05**	**0.05**	-0.46
	$\lambda = 0.8$	**3.22**	**2.88**	**0.84**	**0.04**	-0.44
	$\lambda = 1.0$	**2.82**	**2.14**	**0.70**	**0.03**	-0.43
	$\lambda = 1.6$	**2.02**	**1.41**	**0.48**	**0.02**	-0.32

Table 5: Welfare Properties (in terms of Γ) with a 5% Commodity Price Fall

6 Conclusion

In light of the significant economic dependence of agricultural commodity-exporting economies on volatile and downward-trending commodity prices, this study sought to further understanding on the appropriate choice of an exchange rate regime. A small open economy framework incorporating structural characteristics of agricultural commodity exporters was developed, and the roles of labor and product market flexibility were analyzed in influencing exchange rate choices. The results provide novel insights into whether exchange rate targeting, as adopted by over 70% of agricultural commodity exporters in practice, might be appropriate. In a counterpoint to the conventional wisdom since Friedman (1953) on the optimality of flexible exchange rates, it is shown that fixed exchange rates are desirable in underdeveloped markets as they mitigate costly relative price and wage adjustments.

The results from this study suggest that the exchange rate anchors adopted by the majority of agricultural commodity-exporting economies are appropriate given their current low stages of development. The analysis further indicates, however, that these countries should transition to flexible exchange rates and inflation targeting as their economies mature and become more flexible over time. The study complements recent empirical evidence that inflation targeting could lead to higher macroeconomic volatility in developing economies (Samarina et al., 2014), and cautions against recommending exchange rate flexibility to countries without taking into account the degree of rigidity of their labor and product markets. In future work, it would be useful to extend the analysis in this paper to oil and metal commodity-exporting economies with capital-intensive production.

References

Aguiar, M. and Gopinath, G. (2007). Emerging Market Business Cycles: The Cycle is the Trend. *Journal of Political Economy*, 115(1):69–102.

Armington, P. (1969). A Theory of Demand for Products Distinguished by Place of Production. *IMF Staff Papers*.

Artuc, E., Lederman, D., and Porto, G. G. (2013). A Mapping of Labor Mobility Costs in Developing Countries. *World Bank Policy Research Working Paper 6556*.

Backus, D. K. and Smith, G. W. (1993). Consumption and Real Exchange Rates in Dynamic Economies with Non-Traded Goods. *Journal of International Economics*, 35(3):297–316.

Baunsgaard, M. T., Poplawski-Ribeiro, M., Richmond, C. J., and Villafuerte, M. M. (2012). Fiscal Frameworks for Resource Rich Developing Countries. *International Monetary Fund, Staff Report*.

Benigno, P. (2009). Price Stability With Imperfect Financial Integration. *Journal of Money, Credit and Banking*, 41(s1):121–149.

Berg, A., Portillo, R., Yang, S.-C. S., and Zanna, L.-F. (2013). Public Investment in Resource-Abundant Developing Countries. *IMF Economic Review*, 61(1):92–129.

Bi, H. and Kumhof, M. (2011). Jointly Optimal Monetary and Fiscal Policy Rules Under Liquidity Constraints. *Journal of Macroeconomics*, 33(3):373–389.

Bouakez, H., Cardia, E., and Ruge-Murcia, F. J. (2009). The Transmission of Monetary Policy in a Multi-Sector Economy. *International Economic Review*, 50(4):1243–1266.

C. Garcia, J. R. and Tanner, E. (2011). Fiscal Rules in a Volatile World: A Welfare-Based Approach. *Journal of Policy Modeling*, 33(4):649–676.

Cashin, P., Céspedes, L. F., and Sahay, R. (2004). Commodity Currencies and the Real Exchange Rate. *Journal of Development Economics*, 75(1):239–268.

Chari, V., Kehoe, P., and McGrattan, E. (2002). Can Sticky Prices Generate Volatile and Persistent Real Exchange Rates? *Review of Economic Studies*, 69:633–63.

Corsetti, G., Dedola, L., and Leduc, S. (2008). International Risk Sharing and the Transmission of Productivity Shocks. *Review of Economic Studies*, 75:443–73.

Corsetti, G., Dedola, L., and Leduc, S. (2010). Optimal Monetary Policy in Open Economies. *Handbook of Macroeconomics*, 3.

De Paoli, B. (2009). Monetary Policy Under Alternative Asset Market Structures: The Case of a Small Open Economy. *Journal of Money, Credit and Banking*, 41(7):1301–1330.

FAO (2001). Agricultural Investment and Productivity in Developing Countries. *Food and Agriculture Organization of the United Nations, Economic and Social Development Paper*.

FAO (2010). *FAO Statistical Yearbook 2010*. Food and Agricultural Organization of the United Nations.

Feenstra, R. C., Luck, P. A., Obstfeld, M., and Russ, K. N. (2014). In Search of the Armington elasticity. *NBER Working Paper 20063*.

Ferrero, A. and Seneca, M. (2015). Notes on the Underground: Monetary Policy in Resource-Rich Economies. *OxCarre Working Papers 158*.

Fields, G. (2009). *Segmented Labor Market Models in Developing Countries*. The Oxford Handbook of Philosophy of Economics. Oxford: Oxford University Press.

Frankel, J. (2011). A Comparison of Product Price Targeting and Other Monetary Anchor Options for Commodity Exporters in Latin America. *Economia*, 12(1):1–57.

Frankel, J., Vegh, C., and Vuletin, G. (2013). On Graduation from Fiscal Procyclicality. *Journal of Development Economics*, 100(1):21–47.

Friedman, M. (1953). *The Case for Flexible Exchange Rates*. Essays in Positive Economics. Chicago: University of Chicago Press.

Henn, C., Papageorgiou, C., and Spatafora, N. (2013). Export Quality in Developing Countries. *IMF Working Paper 13/108*.

Horvath, M. (2000). Sectoral Shocks and Aggregate Fluctuations. *Journal of Monetary Economics*, 45(1):69–106.

Hummels, D. and Klenow, P. J. (2005). The Variety and Quality of a Nation's Exports. *American Economic Review*, 95(3):704–723.

IMF (2014). Annual Report on Exchange Rate Restrictions. *International Monetary Fund, 2014 Annual Report*.

IMF (2015a). Adjusting To Lower Commodity Prices. *International Monetary Fund, World Economic Outlook (WEO), October 2015*.

IMF (2015b). Evolving Monetary Policy Frameworks in Low-Income and Other Developing Countries. *International Monetary Fund, Staff Report*.

IMF (2016). Adjusting To Lower Commodity Prices. *International Monetary Fund, World Economic Outlook (WEO) Update, January 2016*.

Kose, M. A., Prasad, E. S., and Terrones, M. E. (2006). How Does Financial Globalization Affect Risk Sharing? Patterns and Channels. *International Monetary Fund, 7th Jacques Polak Research Conference*.

Kose, M. A. and Riezman, R. (2001). Trade Shocks and Macroeconomic Fluctuations in Africa. *Journal of Development Economics*, 65(1):55–80.

Kumhof, M. and Laxton, D. (2013). Simple Fiscal Policy Rules for Small Open Economies. *Journal of International Economics*, 91(1):113–127.

Petrella, I. and Santoro, E. (2011). Input-Output Interactions and Optimal Monetary Policy. *Journal of Economic Dynamics and Control*, 35(11):1817–1830.

Samarina, A., Terpstra, M., and De Haan, J. (2014). Inflation Targeting and Inflation Performance: A Comparative Analysis. *Applied Economics*, 46(1).

Schmitt-Grohé, S. and Uribe, M. (2003). Closing Small Open Economy Models. *Journal of international Economics*, 61(1):163–185.

Snudden, S. (2016). Cyclical Fiscal Rules for Oil-Exporting Countries. *Economic Modelling*, 59:473–483.

UNCTAD (2013). Shared Harvests: Agriculture, Trade, and Employment. *United Nations Conference on Trade and Development*.

UNCTAD (2016). *UNCTADStat 2016 Statistical Database*. United Nations Conference on Trade and Development.

Wills, S. (2013). Optimal Monetary Responses to News of an Oil Discovery. *OxCarre Working Papers 121*.

World Bank (2016). World Bank Lowers 2016 Forecasts for 37 of 46 Commodity Prices, Including Oil. In *http://www.worldbank.org/en/news/press-release/2016/01/26/world-bank-lowers-2016-forecasts-for-37-of-46-commodity-prices-including-oil*.

World Bank (2017). Commodity Market Outlook: Investment Weakness in Commodity Exporters. *World Bank Quarterly Report, January 2017*.