Working Paper 290

Fiscal Devaluations

Emmanuel Farhi
Gita Gopinath
Oleg Itskhoki

ISBN 978-81-7791-146-6

Institute for Social and Economic Change (ISEC) is engaged in interdisciplinary research in analytical and applied areas of the social sciences, encompassing diverse aspects of development. ISEC works with central, state and local governments as well as international agencies by undertaking systematic studies of resource potential, identifying factors influencing growth and examining measures for reducing poverty. The thrust areas of research include state and local economic policies, issues relating to sociological and demographic transition, environmental issues and fiscal, administrative and political decentralization and governance. It pursues fruitful contacts with other institutions and scholars devoted to social science research through collaborative research programmes, seminars, etc.

The Working Paper Series provides an opportunity for ISEC faculty, visiting fellows and PhD scholars to discuss their ideas and research work before publication and to get feedback from their peer group. Papers selected for publication in the series present empirical analyses and generally deal with wider issues of public policy at a sectoral, regional or national level. These working papers undergo review but typically do not present final research results, and constitute works in progress.

FISCAL DEVALUATIONS

Emmanuel Farhi, Gita Gopinath and Oleg Itskhoki*

Abstract

*We show that even when the exchange rate cannot be devalued, a **small** set of **conventional** fiscal instruments can robustly replicate the real allocations attained under a nominal exchange rate devaluation in a dynamic New Keynesian open economy environment. We perform the analysis under alternative pricing assumptions—producer or local currency pricing, along with nominal wage stickiness; under arbitrary degrees of asset market completeness and for general stochastic sequences of devaluations. There are two types of fiscal policies equivalent to an exchange rate devaluation—one, a uniform increase in import tariff and export subsidy, and two, a value-added tax increase and a uniform payroll tax reduction. When the devaluations are anticipated, these policies need to be supplemented with a consumption tax reduction and an income tax increase. These policies are revenue neutral. In certain cases equivalence requires, in addition, a partial default on foreign bond holders. We discuss the issues of implementation of these policies, in particular, under the circumstances of a currency union.*

1. Introduction

Exchange rate devaluations have long been proposed as a desirable policy response to macroeconomic shocks that impair a country's competitiveness in the presence of price and wage rigidities. Milton Friedman famously argued for flexible exchange rates on these grounds. Yet countries that wish to or have to maintain a fixed exchange rate (for instance, because they belong to a currency union) cannot resort to exchange rate devaluations. In this paper we show how a country can use unilateral fiscal policy to generate the same real outcomes as those following a nominal exchange rate devaluation, while keeping the nominal exchange rate fixed.

This question about *fiscal devaluations* dates back to the period of the gold standard when countries could not devalue their currencies. At that time, Keynes (1931) had conjectured that a uniform ad valorem tariff on all imports plus a uniform subsidy on all exports would have the same impact as an exchange rate devaluation. Recently, it has also been conjectured that a similar outcome could be achieved by increasing value-added taxes and cutting payroll taxes. Yet these suggestions have largely been treated as theoretical curiosities.

The current crisis in the Euro area has brought fiscal devaluations to the forefront of policy. The Euro has been blamed for the inability of countries like Greece, Portugal, Spain, Italy and even

* Emmanuel Farhi, Gita Gopinath are with Harvard University and Oleg Itskhoki is with Princeton University

We thank Andrew Abel, Philippe Aghion, Alberto Alesina, Pol Antràs, Mark Aguiar, Gianluca Benigno, Raj Chetty, Arnaud Costinot, Michael Devereux, Charles Engel, Francesco Franco, Xavier Gabaix, Etienne Gagnon, Fabio Ghironi, Elhanan Helpman, Olivier Jeanne, Urban Jermann, Mike Golosov, João Gomes, Gene Grossman, John Leahy, Elias Papaioannou, Veronica Rappoport, Ricardo Reis, Richard Rogerson, Martín Uribe, Adrien Verdelhan, Michael Woodford and seminar/conference participants at NES-HSE, ECB, Frankfurt, Princeton, Federal Reserve Board, Columbia, NBER IFM, Wharton, NYU, Harvard, MIT, NY Fed, LSE for their comments, and Eduard Talamas for excellent research assistance.

France to devalue their exchange rates and restore their competitiveness in international markets.[1] Faced with the dramatic alternatives of austerity-ridden internal devaluation and exit from the Euro, countries in the Eurozone are considering the option of fiscal devaluations. Indeed, in early 2012, France has implemented a fiscal devaluation. Previous examples include Denmark in 1988, Sweden in 1993, and Germany in 2006. Fiscal devaluations have clearly become a serious policy option.

Despite discussions in policy circles, there is little formal analysis of the equivalence between fiscal devaluations and exchange rate devaluations.[2] This is an area where the policy debate is ahead of academic knowledge. This paper is intended to bridge this gap, by providing the first formal analysis of fiscal devaluations in a stochastic dynamic general equilibrium New Keynesian open economy environment.

We define a fiscal devaluation of size δ_t at date t to be a set of *unilateral* fiscal polices that implements the same real (consumption, output, labor supply) allocation as under a nominal exchange rate devaluation of size δ_t, but holding the nominal exchange rate fixed. We explore a general path of δ_t, including both expected and unexpected devaluations. Since the nature of price rigidity— whether prices are set in the currency of the producers or in local currency—is central for the real effects of nominal devaluations (see, for example, Lane, 2001; Corsetti, 2008), we allow for both the cases of producer (PCP) and local currency pricing (LCP) and for nominal wage rigidity.[3] Additionally, we allow for a wide range of alternative international asset market structures, including complete markets, and various degrees of incompleteness such as international trade in risk-free nominal bonds only or international trade in equities.

We find that, first, despite the fact that the actual allocations induced by devaluations in New Keynesian environments are sensitive to the details of the environment, there exists a small set of fiscal instruments that can robustly replicate the effects, both on real variables and nominal prices, of nominal exchange rate devaluations across all specifications. The exact details of which instruments need to be used depend on the extent of completeness of asset markets, the currency denomination of bonds and the expected or unexpected nature of devaluations. Second, the required adjustment in taxes is only a function of δ_t, the size of the required devaluation, and is independent of all details of the environment. Third, when all proposed tax instruments are used a fiscal devaluation is government revenue neutral. Otherwise, we show that these policies generate additional government revenue in periods of trade deficits.

We study two types of fiscal policies that generate fiscal devaluations. The first policy involves a uniform increase in import tariffs and export subsidies. The second policy involves a

---

[1] For popular policy writings on the topic see, for example, Feldstein in the *Financial Times* in February 2010 (http://www.nber.org/feldstein/ft02172010.html), Krugman in the *New York Times* in May 2010 (http://krugman.blogs.nytimes.com/2010/05/01/why-devalue/), Roubini in the *Financial Times* in June 2011 (http://www.economonitor.com/nouriel/2011/06/13/the-eurozone-heads-for-break-up/).

[2] For policy discussions, see for example Farhi and Werning (http://web.mit.edu/iwerning/Public/VAT.pdf); Cavallo and Cottani on VoxEU (http://www.voxeu.org/index.php?q=node/4666); IMF Press Release on Portugal (http://www.imf.org/external/np/sec/pr/2011/pr11160.htm) and IMF's September 2011 *Fiscal Monitor* (http://www.imf.org/external/pubs/ft/fm/2011/02/fmindex.htm).

[3] PCP refers to the case when prices are sticky in the currency of the producer (exporter), while LCP is the case when prices are sticky in the currency of the consumer (importer) of the good.

uniform increase in value-added taxes and a reduction in payroll taxes (e.g., social security contributions). The dynamic analysis reveals that both of these policies, in general, need to be accompanied by a uniform reduction in consumption taxes and an increase in income taxes.[4] However, under some circumstances, changes in consumption and income taxes can be dispensed with. When this latter option is possible depends on the extent of completeness of asset markets and whether the exchange rate movements that are being mimicked are anticipated or unanticipated.

To provide intuition for the underlying mechanisms, consider the case of producer currency pricing (PCP). One of the channels through which a nominal devaluation raises relative output at home is through a depreciation of home's terms of trade that makes home goods cheaper relative to foreign goods. This movement in the terms of trade can be mimicked either through an export subsidy or through an increase in the value-added tax (which is re- imbursed to exporters and levied on importers). Additionally, to ensure that prices at home are the same as under a nominal devaluation, the export subsidy must be accompanied by a uniform import tariff, while an increase in the value-added tax needs to be offset with a reduction in the payroll tax. The prices of all goods then respond identically under a fiscal and nominal devaluation.

When is a reduction in consumption taxes and an increase in income taxes required? Without a reduction in consumption taxes, fiscal devaluations result in an appreciated real exchange rate relative to a nominal devaluation. This is because fiscal devaluations, despite having the same effect on the terms of trade, lead to an increase in the relative price of the home consumption bundle—an effect absent under nominal devaluation. This difference is of no consequence for the real allocation when trade is balanced or when the devaluation is unexpected and asset markets are incomplete, as neither risk-sharing nor saving decisions are affected under these circumstances. As a result, precisely in these two cases, we can dispense with the adjustment in consumption taxes.

By contrast, with expected devaluations, in the absence of an adjustment in consumption taxes, the different behavior of the real exchange rate under nominal and fiscal devaluations induces different savings and portfolio decisions. These effects then need to be undone with a reduction in consumption taxes. This allows to fully mimic the behavior of the real exchange rate under a nominal devaluation. When the consumption tax is used, an offsetting increase in income taxes is required so as not to distort the labor supply decision of households.

In the case of incomplete markets we highlight the role of the currency denomination of debt. When bonds are denominated in the foreign currency, no additional instruments are required for a fiscal devaluation. By contrast when international bonds are denominated in the home currency, the proposed set of tax instruments does not suffice. Equivalence then requires a partial default by the home country. Specifically, a nominal devaluation depletes the foreign-currency value of home's external debt if it was denominated in home currency. The proposed limited set of fiscal instruments cannot replicate this effect on home's foreign obligations. This is why a fiscal

[4] Consumption tax is equivalent to a sales tax that is applied only to final goods, and not to intermediate goods. In our setup all goods are final, and hence consumption and sales taxes are always equivalent. Further, under tariff-based policy, an increase in income tax should extend to both wage income and dividend income, while under VAT-based policy dividend-income tax should be left unchanged.

devaluation under these circumstances must be accompanied by a partial default on home-currency debt of the home country.

We emphasize that the proposed fiscal devaluation policies are robust across a number of environments, despite the fact that the actual allocations induced by devaluations are sensitive to the details of the environment. Specifically, for a given asset market structure, fiscal devaluations work robustly independently of the degree of wage and price stickiness, and of the type of pricing—whether local or producer currency.

Importantly, when all four taxes VAT, payroll, consumption and income taxes are used, the policy is revenue-neutral for the government. That is the direct effects of tax changes on the fiscal deficit add up to zero as the revenue earned from the VAT and income tax increases exactly offset the revenue declines that follow the payroll and consumption tax cuts. The indirect effects on revenue that arise from the stimulative effects of a fiscal devaluation on output, however, remain exactly as in the case of an exchange rate devaluation. When only a reduced set of tax instruments are used, such as VAT and payroll, a fiscal devaluation generates positive fiscal revenues in states when the country runs a trade deficit.

We additionally consider a series of extensions that are important for implementation. We first discuss the implementation of fiscal devaluations by individual countries in a currency union. We then consider other extensions: we introduce capital as the second variable input, we allow for labor mobility, and we consider non-symmetric short-run pass-through of VAT and payroll taxes into prices.

In the case of a currency union interest rates and money supply are controlled by a union central bank. Therefore, implementation of a fiscal devaluation by one country within the union may call for an increase in money supply by the union central bank with the seignorage income from this policy transferred to the home country. Equivalently, the union central bank can let the national central bank of the country under consideration print the required money. There are two empirically relevant cases when the fiscal devaluation can be engineered unilaterally without any intervention by the union central bank. This is the case when the devaluing country is small relative to the overall size of the currency union and/or where seigniorage income constitutes a negligible share of a country's GDP. In these cases the increase in money supply and transfer of seigniorage income becomes practically inessential.

In the case where production involves the use of capital as a variable input, additional tax instruments are typically required. In the presence of capital, the VAT-based fiscal devaluation requires an additional capital subsidy to firms, because without it firms will have an incentive to substitute labor for capital, an effect absent under a nominal devaluation. In the case of a one-time unexpected devaluation, where a consumption subsidy is not used, this is the only additional instrument required. As a more general principle, all *variable* production inputs, apart from intermediates, need to be subsidized uniformly under a VAT-based devaluation, while no such subsidies are needed under a tariff-based devaluation.

When labor is mobile and agents can choose in which country to work, equivalence requires differentiating the taxes on income generated by home residents at home and in foreign. A similar

issue arises in the case where agents can choose in which country to consume certain goods equivalence would then require differentiating the taxes on goods consumed by home residents at home and in the foreign country. However, as long as income taxes are source-based and consumption taxes are point-of-purchase-based, the same policies implement fiscal devaluations in these more general environments.

Our baseline analysis assumes symmetric pass-through of VAT and the payroll tax into prices, both when prices are sticky and when they change. Although as we argue this is a natural assumption to make, we consider an extension in which in the short run prices are indexed to VAT and the payroll tax with differential degrees of pass-through. Under these circumstances a fiscal devaluation requires a non-uniform adjustment in the taxes. Specifically, if the short-run pass-through of VAT is larger than that of a payroll tax, then a one-time devaluation can be replicated with the same increase in VAT as in the benchmark model, but with a larger reduction in the payroll tax, with the difference gradually phased out as prices adjust over time.

The outline of the paper is as follows. Section 2 outlines the model. Section 3 presents the main equivalence results. Section 4 analyzes several extensions, such as implementation in the currency union, capital inputs, and asymmetric pass-through of taxes. Section 5 provides a numerical illustration of the equilibrium dynamics under nominal and fiscal devaluations against that under fixed exchange rates and passive fiscal policy. Section 6 concludes.

Related literature Our paper contributes to a long literature, both positive and normative, that analyzes how to replicate the effects of exchange rate devaluations with fiscal instruments. The tariff-cum-export subsidy and the VAT increase-cum-payroll tax reduction are intuitive fiscal policies to replicate the effects of a nominal devaluations on international relative prices, and accordingly have been discussed before in the policy and academic literature. Poterba, Rotemberg, and Summers (1986) emphasize the fact that tax changes that would otherwise be neutral if prices and wages were flexible have short-run macroeconomic effects when prices or wages are sticky. Most recently, Staiger and Sykes (2010) explore the equivalence using import tariffs and export subsidies in a partial equilibrium static environment with sticky or flexible prices, and under balanced trade. While the equivalence between a uniform tariff-cum-subsidy and a devaluation has a long tradition in the literature (as surveyed in Staiger and Sykes, 2010), most of the earlier analysis was conducted in static endowment economies (or with fixed labor supply). Berglas (1974) provides an equivalence argument for nominal devaluations, using VAT and tariff-based policies, in a reduced-form model without micro-foundations, no labor supply and without specifying the nature of asset markets.[5]

Our departure from this literature is to perform a dynamic general equilibrium analysis with varying degrees of price rigidity, alternative asset market assumptions and for expected and unexpected devaluations. In contrast to the earlier literature, we allow for dynamic price setting as in

[5] The VAT policy with border adjustment has been the focus of Grossman (1980) and Feldstein and Krugman (1990), however, in an environment with flexible exchange rates and prices. Calmfors (1998) provides a policy discussion of the potential role of VAT and payroll taxes in impacting allocations in a currency union.

the New Keynesian literature, endogenous labor supply, savings and portfolio choice decisions, as well as interest-elastic money demand. In doing so, we learn that the tariff-cum-subsidy and VAT-cum-payroll fiscal interventions do not generally suffice to attain equivalence. In the general case, additional tax instruments such as consumption taxes, income taxes or partial default are required. Moreover, some of the conclusions regarding which tax instruments suffice (such as import tariff only for local currency pricing as discussed in Staiger and Sykes, 2010) do not carry through in our more general environment. Furthermore, and this is more surprising, despite the different allocations being mimicked under different circumstances and a rich set of endogenous margins of adjustment, the additional instruments required are few in number. In other words, we find that a small number of instruments is all that is required to robustly implement fiscal devaluation under the fairly rich set of specifications we explore.

This paper is complementary to Adao, Correia, and Teles (2009) who show that any equilibrium allocation in the flexible price, flexible exchange rate economy can be implemented with fiscal and monetary policies that induce stable producer prices and constant exchange rates.[6] Since the optimal policy is sensitive to details of the environment the fiscal instruments used will vary across environments and in general will require flexibly time-varying and firm-varying taxes. Our approach is different and closer in focus to the previously discussed papers. We analyze simple fiscal policies that robustly replicate the effects of nominal devaluations across a wide class of environments, regardless of whether or not nominal devaluations exactly replicate flexible price allocations. We perform the analysis in a more general environment, with different types of price and wage stickiness, under a rich array of asset market structures and for expected and unanticipated devaluations. An attractive feature of our findings is that the fiscal adjustments that are necessary to replicate nominal devaluations are to a large extent not dependent on the details of the environment.

Another important difference with Adao, Correia, and Teles (2009) lies in the set of fiscal instruments that we consider. First, their implementation requires time-varying taxes both at Home and in Foreign. By contrast, ours requires only adjusting taxes at Home. This is an important advantage because it can be implemented unilaterally. Second, their implementation relies on income taxes and differential consumption taxes for local versus imported goods. These taxes are less conventional than payroll and value-added taxes—tax instruments that have been proposed as potential candidates in policy circles (e.g., see IMF Staff, 2011).

This paper is also related to Lipińska and von Thadden (2009) and Franco (2011) who quantitatively evaluate the effects of a tax swap from direct (payroll) taxes to indirect taxes (VAT) under a fixed exchange rate.[7] Neither of these studies however explores exact equivalence with a nominal devaluation, as we do in this paper. Lastly, this paper is similar in spirit to Correia, Farhi, Nicolini, and Teles (2011) who, building on the general implementation results of Correia, Nicolini,

[6] Eggertsson (2004) makes a similar observation in a simplified log-linearized model.

[7] Other quantitative analysis includes Boscam, Diaz, Domenech, Ferri, Perez, and Puch (2011) for Spain.

and Teles (2008), use fiscal instruments to replicate the effects of the optimal monetary policy when the zero-lower bound on nominal interest rate is binding.

2. Model

The model economy features two countries, home *H* and foreign *F*. There are three types of agents in each economy: consumers, producers and the government, and we describe each in turn.

2.1. Consumers

The home country is populated with a continuum of symmetric households. Households are indexed by $h \in [0, 1]$, but we often omit the index h to simplify exposition. In each period, each household h chooses consumption C_t, money M_t and holdings of assets B^j_{t+1}, $j \in J_t$. The set of assets J_t available to the households can span an arbitrary set of states and dates, including the extremes of complete markets and one period bonds-only economies. Each household also sets a wage rate $W_t(h)$ and supplies labor $N_t(h)$ in order to satisfy demand at this wage rate.

The household *h* maximizes expected utilityτ

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\,(C_t, N_t, m_t),$$

subject to the flow budget constraint:

$$\frac{P_t C_t}{1+\varsigma_t^c} + M_t + \sum_{j \epsilon J_t} Q_t^j\, B_{t+1}^j \leq \sum_{j \epsilon J_{t-1}} (Q_t^j + D_t^j)\, B_t^j + M_{t-1} + \frac{W_t N_t}{1+\tau_t^n} + \frac{\Pi_t}{1+\tau_t^d} + T_t,$$

Where P_t is the consumer price index before consumption subsidy ς_t^c and $m_t = M_t(1+ \varsigma_t^c)/P_t$ denotes real money balances. Π_t is aggregate profits of the home firms assumed (without loss of generality) to be held by the representative domestic consumer; $\tau_t^n$is the labor-income tax, τ_t^d is the profit (dividend-income) tax, and T_t is the lump-sum transfer from the government. An asset j is characterized by its price Q_t^j and effective payout D_t^j reflecting possible defaults and haircuts on the asset.

For convenience of exposition we adopt the following standard utility specification:

$$U(C_t, N_t, m_t) = \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{k}{1+\varphi} N_t^{1+\varphi} + \frac{x}{1-v} m_t^{1-v}.$$

Consumption C_t is an aggregator of home and foreign goods:

$$C_t = \left[\gamma_H^{\frac{1}{\varsigma}} C_{Ht}^{\frac{1-\varsigma}{\varsigma}} + \gamma_F^{\frac{1}{\varsigma}} C_{Ft}^{\frac{1-\varsigma}{\varsigma}} \right]^{\frac{\varsigma}{\varsigma-1}}, \quad \varsigma > 0,$$

that features a home bias, $\gamma \equiv \gamma_H = 1 - \gamma_F \in (1/2, 1]$. The consumption of both home and foreign goods is given by CES aggregators of individual varieties $i \in [0, 1]$:

$$C_{kt} = \left[\int_0^1 C_{kt}(i)^{\frac{\rho-1}{\rho}} di\right]^{\frac{\rho}{\rho-1}}, \quad k \in \{H, F\}, \quad \rho > 1.$$

We now discuss some of the relevant equilibrium conditions associated with consumers' optimal decisions. Given the CES structure of consumption aggregators, consumer good demand is characterized by:

$$C_{kt}(i) = \left(\frac{P_{kt}(i)}{P_{kt}}\right)^{-\rho} C_{kt}, \quad C_{kt} = \gamma_k \left(\frac{P_{kt}}{P_t}\right)^{-\rho} C_t, \tag{1}$$

where i is the variety of the home or foreign good ($k \in \{H, F\}$). $P_{kt}(i)$, P_{kt} and P_t are respectively the price of variety i of good k, the price index for good k and the overall consumer price index. As is well known, CES price indexes are defined by

$$P_t = \left[\gamma_H P_{Ht}^{1-\varsigma} + \gamma_F P_{Ft}^{1-\varsigma}\right]^{\frac{1}{1-\varsigma}}, \quad P_{kt} = \left[\int_0^1 P_{kt}(i)^{1-\rho} di\right]^{\frac{1}{1-\rho}}, \tag{2}$$

for $k \in \{H, F\}$, and the aggregate consumer expenditure is given by

$$P_t C_t = P_{Ht} C_{Ht} + P_{Ft} C_{Ft}, \qquad P_{kt} C_{kt} = \int_0^1 P_{kt}(i) C_{kt}(i) di.$$

It is useful to define the (nominal) stochastic discount factor of a household:

$$\Theta_{t,s} = \beta^{s-t} \left(\frac{C_{t+s}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+s}} \frac{1 + \varsigma_{t+s}^c}{\varsigma_t^c}, \quad s \geq t, \tag{3}$$

and we use $\Theta_{t+1} \equiv \Theta_{t,\,t+1}$ for brevity. This discount factor must price available assets:

$$Q_t^j = \mathbb{E}_t\{\Theta_{t+1}(Q_{t+1}^j + D_{t+1}^j)\}, \qquad \forall j \in J_t. \tag{4}$$

Finally, money demand is given by

$$\chi C_t^\sigma \left(\frac{M_t(1 + \varsigma_t^c}{P_t}\right)^{-v} = 1 - \mathbb{E}_t \Theta_{t+1}, \tag{5}$$

where the right-hand side is an increasing function of the nominal risk-free interest rate which satisfies $1 + i_{t+1} = 1/\mathbb{E}_t\Theta_{t+1}$

Foreign households face a symmetric problem with the exception that the foreign government imposes no taxes or subsidies and foreign consumers have a home bias towards

foreign-produced goods. We denote foreign variables with an asterisk. For brevity we omit listing all equilibrium conditions for foreign given the symmetry with home. Define J_t^* to be the set of assets available to foreign households and $\Omega_t \subset J_t \cap J_t^*$ to be the set of assets traded internationally by both domestic and foreign households. The equilibrium in the asset market requires $B_t^j + B_t^{*j} = 0$ for all $j \in \Omega_t$ since we assume all assets are in zero net supply.

The foreign-currency nominal stochastic discount factor is given by

$$\Theta_{t,s}^* = \beta^{s-t} \left(\frac{C_s^*}{C_t^*} \right)^{-\sigma} \frac{P_t^*}{P_s^*} \tag{6}$$

Since Euler equations (4) for assets $j \in \Omega_t$ are satisfied for both countries, we can write international risk sharing conditions as:

$$\mathbb{E}_t \left\{ \frac{Q_{t+1}^j + D_{t+1}^j}{Q_t^j} \left[\Theta_{t+1} - \Theta_{t+1}^* \frac{\varepsilon_t}{\varepsilon_{t+1}} \right] \right\} = 0 \qquad \forall j \epsilon \Omega_t, \tag{7}$$

which implicitly assumes that any default or haircut on any asset j is uniform for domestic and foreign holders of the asset. International risk sharing condition (7) states that domestic and foreign stochastic discount factors have to agree in pricing the assets which are traded internationally, a property of optimal risk sharing given the set of available securities. Note that the foreign stochastic discount factor is multiplied by the foreign currency depreciation rate in order to convert home-currency into foreign-currency returns.

2.2. Producers

In each country there is a continuum $i \in [0,1]$ of firms producing different varieties of goods using a technology with labor as the only input. Specifically, firm i produces according to

$$Y_t(i) = A_t Z_t(i) N_t(i)^{\alpha}, \qquad 0 < \alpha \leq 1, \tag{8}$$

where A_t is the aggregate country-wide level of productivity, $Z_t(i)$ is idiosyncratic firm productivity shock, and $N_t(i)$ is the firm's labor input. Productivity A_t, $\{Z_t(i)\}$ and their foreign counterparts follow arbitrary stochastic processes over time.

The firm sells to both the home and foreign market. Specifically, it must satisfy demand (1) for its good in each market given its price $P_{Ht}(i)$ at home and $P_{Ht}^*(i)$ abroad in the foreign currency. Therefore, we can write the market clearing for variety i as:[8]

$$Y_t(i) = C_{Ht}(i) + C_{Ht}^*(i), \tag{9}$$

[8] Note that overall demand for good i results from aggregation of demands across all consumers $h \in [0,1]$ in the home and foreign markets respectively, e.g. $C_{Ht}(i) = \int_0^1 C_{Ht}(i;h)dh$.

where $C^*_{Ht}(i)$ is foreign-market demand for variety i of the home good. The profit of firm i is given by

$$\Pi^i_t = (1-\tau^v_t)P_{Ht}(i)C_{Ht}(i) + (1+\varsigma^x_t)\varepsilon_t P^*_{Ht}(i)C^*_{Ht}(i) - \left(1-\varsigma^p_t\right)W_t N_t(i), \qquad (10)$$

where T^v_t is the value-added tax (VAT) ς^x_t is the export subsidy and ς^p_t is the payroll subsidy. Note that this equation makes it explicit that international sales are not subject to the VAT, or more specifically VAT is rebated back to the firms upon exporting. We define the prices to be inclusive of the VAT and export subsidy but exclusive of the consumption subsidy ς^c_t. Aggregate profits of the home firms are given by $\Pi_t \equiv \int_0^1 \Pi^i_t di$ and labor demand is $N_t = \int_0^1 N_t(i)di$

2.3. Price and wage setting

We now describe the price and wage setting problem of firms and households respectively.

2.3.1. Price setting

Firms set prices subject to a Calvo friction: in any given period, a firm can adjust its prices with probability $1-\theta_p$, and must maintain its previous-period price with probability θ_p. The firm sets prices to maximize the expected net present value of profits conditional on no price change

$$\sum_{s=t}^{\infty} \theta_p^{s-t}\, \mathbb{E}_t \left\{ \Theta_{t,s} \frac{\Pi^i_s}{1+\tau^d_s} \right\},$$

subject to the production technology and demand equations given above, and where τ^d_s is the dividend-income, or profit, tax payed by consumers (stock holders).

We now need to make an assumption regarding the currency of price-setting. We assume that domestic prices are always set in the currency of the consumer and inclusive of the VAT tax. We denote the domestic period t reset price of firm i by $\bar{P}_{Ht}(i)$, so that firm's i current price is given by

$$P_{Ht}(i) = \begin{cases} P_{H,t-1}(i), & w/prob\ \theta_p, \\ \bar{P}_{Ht}(i), & w/prob\ 1-\theta_p. \end{cases} \qquad (11)$$

The foreign price can be set either in the producer currency, often referred to as *producer currency pricing* (PCP) or in the local currency, referred to as *local currency pricing* (LCP).

Producer currency pricing Consistent with the standard definition of PCP we assume that the firm chooses the home-currency reset price $\bar{P}_{Ht}$, while the foreign-market price satisfies the law of one price:

$$P^*_{Ht}(i) = P_{Ht}(i)\frac{1}{\varepsilon_t}\frac{1-\tau^v_t}{1+\varsigma^x_t}, \qquad (12)$$

where $\mathcal{E}_t$ is the nominal exchange rate defined as the price of one unit of foreign currency in terms of units of home currency (increases in $\mathcal{E}_t$ correspond to depreciation of the home currency). In words, the firm sets a common price $\overline{P}_{Ht}(i)$ for both markets, and its foreign-market price equals this price converted into foreign currency and adjusted for border taxes— the export subsidy and the VAT reimbursement. The reset price satisfies the following condition (see the Appendix):

$$\mathbb{E}_t \sum_{s=t}^{\infty} \theta_p^{s-t} \Theta_{t,s} \frac{P_{Hs}^{\rho}(C_{Hs} + C_{Hs}^*)}{1+\tau_s^d} \left[(1-\tau_s^v)\overline{P}_{Ht}(i) - \frac{\rho}{\rho-1} \frac{(1-\varsigma_s^p)W_s}{\alpha A_s Z_s(i) N_s(i)^{\alpha-1}} \right] = 0, \qquad (13)$$

This implies that the preset price $\overline{P}_{Ht}(i)$ is a constant markup over the weighted-average expected future marginal costs during the period for which the price is in effect. Equations (13) and (12), together with the evolution of firm prices, equation (11), and the definition of the price index in (2), describe the dynamics of home firms' prices in the home and foreign markets under PCP.

Local currency pricing Under LCP the firm sets both a home-market price $\overline{P}_{Ht}(i)$ in home currency and a foreign-market price $\overline{P}_{Ht}^*(i)$ in foreign currency. During periods of non-adjustment, the foreign-market price remains constant in foreign currency, therefore movements in the nominal exchange rates and border taxes directly affect the relative price of the firm in the home and foreign markets. As a result, the law of one price (12) is violated in general. Profit maximization with respect to $\overline{P}_{Ht}(i)$ and $\overline{P}_{Ht}^*(i)$ leads now two optimality conditions, one for the home-market price and the other for the foreign-market price (see the Appendix):

$$\mathbb{E}_t \sum_{s=t}^{\infty} \theta_p^{s-t} \Theta_{t,s} \frac{P_{Hs}^{\rho} C_{Hs}}{1+\tau_s^d} \left[(1-\tau_s^v)\overline{P}_{Ht}(i) - \frac{\rho}{\rho-1} \frac{(1-\varsigma_s^p)W_s}{\alpha A_s Z_s(i) N_s(i)^{\alpha-1}} \right] = 0, \qquad (14)$$

$$\mathbb{E}_t \sum_{s=t}^{\infty} \theta_p^{s-t} \Theta_{t,s} \frac{(P_{Hs}^*)^{\rho} C_{Hs}^*)}{1+\tau_s^d} \left[(1-\varsigma_s^x)\varepsilon_s \overline{P}_{Ht}^*(i) - \frac{\rho}{\rho-1} \frac{(1-\varsigma_s^p)W_s}{\alpha A_s Z_s(i) N_s(i)^{\alpha-1}} \right] = 0, \qquad (15)$$

describing the evolution of prices (combined with (11), now for both markets) under LCP.

Foreign firms As for price setting by foreign firms, the reset prices of each foreign variety in the foreign market $\overline{P}_{Ft}^*(i)$ and in the home market $\overline{P}_{Ft}^*(i)$ are characterized in a symmetric manner to that of the home economy, with the exception that all foreign tax rates are kept at zero. Under PCP, the law of one price holds for all foreign varieties, that is,

$$P_{Ft}(i) = P_{Ft}^*(i)\varepsilon_t \frac{1+\tau_t^m}{1-\tau_t^v}, \qquad (16)$$

where τ_t^m is home's import tariff charged at the border together with the home's VAT τ_t^v imposed on the foreign imports. Under LCP, foreign firms set their home-market price in home currency according to:

$$\mathbb{E}_t \sum_{s=t}^{\infty} \theta_p^{s-t} \Theta_{t,s}^* P_{Fs}^{\rho} C_{Fs} \left[\frac{1-\tau_s^v}{1+\tau_s^m} \frac{1}{\varepsilon_s} \overline{P}_{Ft} - \frac{\rho}{\rho-1} \frac{W_s^*}{\alpha A_s^* Z_s^*(i) N_s^*(i)^{\alpha-1}} \right] = 0, \quad (17)$$

2.3.2. Labor demand and wage setting

Labor input N_t is a CES aggregator of the individual varieties supplied by each household:

$$N_t = \left[\int_0^1 N_t(h)^{\frac{\eta-1}{\eta}} dh \right]^{\frac{\eta}{\eta-1}}, \qquad \eta > 1.$$

Therefore, aggregate demand for each variety of labor is given by

$$N_t(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\eta} N_t, \quad (18)$$

Where N_t is aggregate labor demand in the economy, $W_t(h)$ is the wage rate charged by household h for its variety of labor services and

$$W_t = \left[\int_0^1 W_t(h)^{1-\eta} dh \right]^{1/(1-\eta)} \quad (19)$$

is the wage for a unit of aggregate labor input in the home economy. The aggregate wage bill in the economy is given by $W_t N_t = \int_0^1 W_t(h) N_t(h) \, \mathrm{d}h$.

Households are subject to a Calvo friction when setting wages: in any given period, with probability $1-\theta_w$ they can adjust their wage, but with probability θ_w they have to keep their wage unchanged. The optimality condition for wage setting is given by (see the Appendix):[9]

$$\mathbb{E}_t \sum_{s=t}^{\infty} \theta_w^{s-t} \Theta_{t,s} N_s W_s^{\eta(1+\varphi)} \left[\frac{\eta}{\eta-1} \frac{1}{1+\varsigma_s^c} k P_s C_s^{\sigma} N_s^{\varphi} - \frac{1}{1+\tau_s^n} \frac{\overline{W}_t(h)^{1+\eta\varphi}}{W_s^{\eta\varphi}} \right] = 0. \quad (20)$$

This implies that the wage $\overline{W}_t(h)$ is preset as a constant markup over the expected weighted-average between future marginal rates of substitution between labor and consumption and aggregate wage rates, during the duration of the wage. This is a standard result in the New Keynesian literature, as derived, for example, in Galí (2008). Equations (19)-(20), together with the wage evolution equation analogous to (11), characterize equilibrium wage dynamics.

---

[9] The derivation of this equation assumed perfect risk sharing within the country, but not necessarily across countries. When markets are incomplete even within a country, the only change to this condition is that C_s is replaced with C_s^h and $\Theta_{t,s}$ with $\Theta_{t,s}^h$, and all of our results below hold unchanged.

2.4. Government, and Country Budget Constraint

We assume that the government must balance its budget each period, returning all seignior-age and tax revenues in the form of lump-sum transfers to the households (T_t). This is without loss of generality since Ricardian equivalence holds in this model. The government budget constraint in period t is

$$M_t - M_{t-1} + TR_t = T_t, \tag{21}$$

where $M_t - M_{t-1}$ is seigniorage income from money supply. The tax revenues from distortionary taxes TR_t are given by

$$TR_t = \left(\frac{\tau_t^n}{1+\tau_t^n} W_t N_t + \frac{\tau_t^d}{1+\tau_t^d}\Pi_t - \frac{\varsigma_t^c}{1+\varsigma_t^c} P_t C_t\right) \tag{22}$$
$$+ \left(\tau_t^v P_{Ht} C_{Ht} - \varsigma_t^p W_t N_t\right) + \left(\frac{\tau_t^v + \tau_t^m}{1+\tau_t^m} P_{Ft} C_{Ft} - \varsigma_t^x \varepsilon_t P_{Ht}^* C_{Ht}^*\right),$$

where the first bracket contains income taxes levied on and the consumption subsidy paid to home households; the next two terms are the value-added tax paid by and the payroll subsidy received by home firms; the last two terms are the import tariff and the VAT paid by foreign exporters and the export subsidies to domestic firms.

Combining this together with the household budget constraint and aggregate profits, we arrive at the aggregate country budget constraint:

$$\sum_{j\epsilon\Omega_t} Q_t^j B_{t+1}^j - \sum_{j\epsilon\Omega_{t-1}} (Q_t^j + D_t^j) B_t^j = \varepsilon_t P_{Ht}^* C_{Ht}^* - P_{Ft} C_{Ft} \frac{1-\tau_t^v}{1+\tau_t^m}, \tag{23}$$

where as defined above Ω_t is the set of internationally traded assets at t and $B_t^j = \int_0^1 B_t^j(h)dh$ is the aggregate net foreign asset-j position of home households. The right-hand side of (23) is the trade surplus of the home country, while the left-hand side is the change in the international asset position of the home country.

This completes the description of the setup of the model. Given initial conditions and home and foreign government policies—taxes and money supply—the equations above characterize equilibrium price and wage dynamics in the economy. Given prices firms satisfy product demand in domestic and foreign markets, and given wages households satisfy labor demand of firms. Asset prices are such that asset markets are in equilibrium given asset demand by home and foreign households, and consumer money demand equals money supply in both markets.

2.5. Assumptions

Before turning to the results of our analysis, we highlight that several of the assumptions made in the model set-up to ease exposition can be generalized without impacting our results. These include assumptions on:

Functional forms We assume CES consumption aggregators and monopolistic competition, but the results hold under more general environments. For instance, our results generalize to the case of monopolistic competition with non-constant desired markups (e.g., as under Kimball, 1995, demand), as well as to the case of oligopolistic competition with strategic complementarities (e.g., as in Atkeson and Burstein, 2008). Departing from CES consumption aggregators and monopolistic competition substantially increases the notational burden, but leaves the analysis largely unchanged. We can also allow for a general non-separable utility function in consumption and labor without altering conclusions. We have assumed home bias in preferences, but no non-tradable goods or trade costs, yet our results immediately extend to these more general economies. Similarly, we have adopted a money-in-the-utility framework where real money balances are separable from consumption and leisure, but all results are unchanged when money is introduced via a cash-in-advance constraint.

Government policy instruments We formulate our model using money supply as the instrument of monetary policy (money supply rule) in both countries. We could alternatively have performed our analysis using interest rate rules or exchange rate rules without any alterations to our equivalence results.[10] As in the New Keynesian literature, in our environment, the nominal interest rate is the only money market variable relevant for the rest of the allocation. Consequently, we could also focus on the cashless limit and our equivalence results would hold without further proof. We further discuss some of these issue in Section 4.1. For simplicity, we start from a situation where initial taxes are zero and characterize the required changes in taxes, but all the results generalize to a situation where initial taxes are not zero (see footnote 19).

Price setting frictions Our results generalize to departures from Calvo price and wage setting. Any model of time-contingent price adjustment with arbitrary heterogeneity in price adjustment hazard rates would deliver similar results. It can also be generalized to a menu cost model in which the menu cost is given in real units, e.g. in labor, as is commonly assumed, since in this case the decision to adjust prices will depend only on real variables (including relative prices) which stay unchanged across nominal and fiscal devaluations.

3. Fiscal Devaluations

In this section we formally define the concept of a fiscal devaluation and present our main results on the equivalence between nominal and fiscal devaluations, first for complete and then for incomplete asset markets, as well as for the special case of a one-time unanticipated devaluation. We complete the section with the discussion of government revenue neutrality of fiscal devaluations.

Definition Consider an equilibrium path of the model economy described above, along which the nominal exchange rate follows

$$\varepsilon_t = \varepsilon_0(1+\delta_t) \text{ for } t \geq 0,$$

[10] See Benigno, Benigno, and Ghironi (2007) for the design of an interest rate rule to maintain a fixed exchange rate.

for some (stochastic) sequence $\{\delta_t\}$ $t \geq 0$. Here δ_t denotes the percent nominal devaluation of the home currency relative to period 0. We refer to such an equilibrium path as a *nominal* $\{\delta_t\}$-*devaluation*. Denote by $\{M_t\}$ the path of home money supply that is associated with the nominal devaluation. A fiscal $\{\delta_t\}$-*devaluation* is a sequence $\{M_t', \tau_t^m, \varsigma_t^x, \tau_t^v, \varsigma_t^p, \varsigma_t^c, \tau_t^n, \tau_t^d\}$ $t \geq 0$ of money supply and taxes that achieves the same equilibrium allocation of consumption, output and labor supply, but for which the equilibrium exchange rate is fixed, $\varepsilon_t' \equiv \varepsilon_0$ for all $t \geq 0$.

Note that, in general, we do not restrict the path of the exchange rate under a nominal devaluation. For example, one can examine the case of a probabilistic one-time devaluation where δ_t follows a Markov process with two states {0, δ} where δ is an absorbing state, or the case of a deterministic devaluation where $\delta_t = 0$ for $t < T$ and $\delta_t = \delta$ for $t \geq T$. We will also consider an interesting variant, a *one-time unanticipated devaluation*, under which $\delta_t = 0$ for $t < T$ and $\delta_t = \delta > 0$ with probability one for $t \geq T$; in addition $\Pr_t\{\delta_{t+j} = 0\} = 1$ for $t < T$ and $j \geq 0$, that is, agents put a zero probability on the possibility of a devaluation before it happens.

Before formulating and proving our main results, we briefly discuss the strategy behind our analysis. We need to show that a given dynamic allocation satisfies all equilibrium conditions under both a nominal and a fiscal devaluation. It is convenient to first show that given the path of aggregate consumption $\{C_t, C_t^*\}$, all prices are identical under a nominal and a fiscal devaluation. The second step is to show that given unchanged prices, $\{C_t, C_t^*\}$ indeed follows the same equilibrium path under the two policies.

Given prices, the path of aggregate consumption is determined by the country budget constraint (23) and the international risk-sharing condition (7). In order to develop some further intuition, we rewrite these two conditions in the following way. First, divide both sides of (23) by $P_t^* \varepsilon_t$ to obtain

$$\sum_{j \in \Omega_t} q_t^{j*} B_{t+1}^j - \sum_{j \in \Omega_{t-1}} (q_t^{j*} + d_t^{j*}) B_t^j = \frac{P_{Ht}^*}{P_t^*} [C_{Ht}^* - C_{Ft} S_t], \tag{24}$$

Where

$$q_t^{j*} = \frac{Q_t^j}{P_t^* \varepsilon_t} \quad and \quad d_t^{j*} = \frac{D_t^j}{P_t^* \varepsilon_t}$$

are real prices and payouts of assets in units of the foreign final good; and

$$S_t \equiv \frac{P_{Ft}}{P_{Ht}^*} \frac{1}{\varepsilon_t} \frac{1 - \tau_t^v}{1 + \tau_t^m} \tag{25}$$

is the terms of trade of the home country—the ratio of the import price index to the export price index adjusted by border taxes.

Next substitute the definitions of the home and foreign stochastic discount factors (3) and (6) into the international risk sharing conditions (7), and rearrange terms to obtain:

$$\mathbb{E}_t\left\{\frac{q_{t+1}^{j*}+d_{t+1}^{j*}}{q_t^{j*}}\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}-\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\sigma}\right]\right\}=0 \quad \forall j\in\Omega_t, \tag{26}$$

Where

$$\mathcal{Q}_t \equiv \frac{P_t^*\varepsilon_t}{P_t/(1+\varsigma_t^c)} \tag{27}$$

is the (consumer-price) real exchange rate.

Equations (24) and (26) highlights the role of the two relative prices—the terms of trade S_t in shaping the trade balance on the right-hand side of the country budget constraint (24) and the real exchange rate $\mathcal{Q}_t$ in the international risk sharing condition (26). The exact roles of these two relative prices changes as we consider different asset market environments. But a fiscal devaluation will, in general, need to mimic the behavior of these two relative prices to replicate the equilibrium allocation resulting from a nominal devaluation.

3.1. Complete asset markets

In this case we assume that countries have access to a full set of one-period Arrow securities and there is perfect risk sharing across countries.

Proposition 1 *Under complete international asset markets a fiscal $\{\delta_t\}$-devaluation can be achieved by one of the two policies:*

$\tau_r^m = \varsigma_t^x = \varsigma_t^c = \tau_t^n = \tau_t^d = \delta_t$ for $t \geq 0$, *or* (FD')

$\tau_t^v = \varsigma_t^p = \frac{\delta_t}{1+\delta_t}$, $\varsigma_t^c = \tau_t^n = \delta_t$ and $\tau_t^d = 0$ $for\ t \geq 0$, (FD")

as well as a suitable choice of M_t' for $t \geq 0$.

Proof: One can mechanically verify that a nominal devaluation $\{\varepsilon_t$, 0$\}$ and a fiscal devaluation $\{\varepsilon_t', \tau_t^m, \varsigma_t^x, \tau_t^v, \varsigma_t^p, \varsigma_t^c, \tau_t^n, \tau_t^d\}$ have exactly the same effect on the equilibrium system. That is, taxes affect equilibrium conditions in the same way as changes in the exchange rate; and if the exchange rate does not enter some equilibrium conditions, then in those conditions, the proposed taxes cancel each other out.

Conjecture that $\{C_t, C_t^*\}$ and the path of relative prices and wages is unchanged. Then from good demand (1), goods-market clearing (9), production functions (8) and labor demand (18), it follows that the rest of the equilibrium allocation is unchanged. In particular consumption and output of individual varieties as well as labor input of individual households are unchanged. We now verify the above conjecture by exploring the equilibrium conditions for price and wage settings, as well as for aggregate consumption.

First, substitute the expression for stochastic discount factor (3) into the wage-setting equation (20). Given the rest of the allocation, the same path of $\{\overline{W}_t(h)\}$ satisfies this condition when

$$\frac{1+\varsigma_t^c}{1+\tau_t^n} \equiv 1 \quad \Leftrightarrow \quad \varsigma_t^c \equiv \tau_t^n, \tag{28}$$

as implied by both (FD') and (FD'').

Second, consider price setting by home firms for the home market as given by equations (13) under PCP and by (14) under LCP, again after substituting in (3). Given the rest of the allocation, the same path of reset prices $\{\bar{P}_{Ht}(i)\}$ satisfies these conditions when:[11]

$$\frac{(1+\varsigma_t^c)(1-\tau_t^p)}{1+\tau_t^d} \equiv \frac{(1+\varsigma_t^c)(1-\varsigma_t^v)}{1+\tau_t^d} \equiv 1. \tag{29}$$

Both fiscal devaluations policies (FD') and (FD'') satisfy this requirement.

Third, consider international price setting by home firms in the foreign market described by the law of one price (12) under PCP and by equation (15) under LCP respectively. In both cases, $\{\bar{P}_{Ft}^*\}$ stays unchanged provided that:[12]

$$\frac{1}{\varepsilon_t'}\frac{1-\tau_t^v}{1+\varsigma_t^x} \equiv \frac{1}{\varepsilon_t} \quad \Leftrightarrow \quad \frac{1+\varsigma_t^x}{1-\tau_t^v} \equiv 1+\delta_t.$$

This is again satisfied for both policies (FD') and (FD'').

Fourth, consider international price setting by foreign firms in the home market described by the law of one price (16) under PCP and by (17) under LCP. The same path of $\{\bar{P}_{Ft}\}$ satisfies these conditions when

$$\varepsilon_t' \frac{1+\tau_t^m}{1-\tau_t^v} \equiv \varepsilon_t \quad \Leftrightarrow \quad \frac{1+\tau_t^m}{1-\tau_t^v} \equiv 1+\delta_t,$$

which is satisfied under both (FD') and (FD'').

We have therefore verified that relative prices associated with a nominal devaluation, including the terms of trade defined in (25), are mimicked under either of the two proposed fiscal devaluation policies. To additionally mimic the behavior of the real exchange rate in (27), we require $\varepsilon_t'(1+\varsigma_t^c) \equiv \varepsilon_t$, which together with (28) results in

---

[11] To make the argument more transparent, one can rewrite, for example, the expression for the reset price (13) under PCP as

$$\bar{P}_{Ht}(i) = \frac{\rho}{\rho-1}\frac{\mathbb{E}_t \sum_{s\geq t}(\beta\theta_p)^{s-t} C_s^{-\sigma} P_s^{-1} P_{Hs}^{\rho}(C_{Hs}+C_{Hs}^*)\left[\frac{(1+\varsigma_s^c)(1-\varsigma_s^p)}{1+r_s^d}\right]\frac{W_s}{\alpha A_s Z_s(i) N_s(i)^{\alpha-1}}}{\mathbb{E}_t \sum_{s\geq t}(\beta\theta_p)^{s-t} C_s^{-\sigma} P_s^{-1} P_{Hs}^{\rho}(C_{Hs}+C_{Hs}^*)\left[\frac{(1+\varsigma_s^c)(1-\tau_s^v)}{1+\tau_s^d}\right]}$$

For exact equivalence of reset prices under a fiscal devaluation, the terms in the square brackets in both the numerator and denominator should be identically unity state-by-state and period-by-period, as required by condition (29).

[12] This requirement immediately follows from (12) under PCP, but (15) under LCP instead requires

$$\frac{1+\varsigma_t^c}{1+\tau_t^d}(1+\varsigma_t^x)\varepsilon_t' \equiv \varepsilon_t.$$

However, combining it with (29) results in the same condition as under PCP.

$$\varsigma_t^c \equiv \tau_t^n \equiv \delta_t.$$

We now verify that the equilibrium values of $\{C_t, C_t^*\}$ associated with a nominal devaluation are also equilibrium values under our fiscal devaluation policies. Under complete markets, the international risk-sharing condition (26) becomes the familiar Backus-Smith condition:

$$\left(\frac{C_t}{C_t^*}\right)^{\sigma} = \lambda Q_t, \tag{30}$$

where the constant of proportionality λ is recovered from the intertemporal budget constraint of the country, which depends on relative prices and in particular the evolution of the terms of trade.[13] As long as we have equivalence in all relative prices, including the real exchange rate, we obtain equivalence in the relative consumption allocation. The levels of consumption must also be equivalent under nominal and fiscal devaluations, otherwise price and wage setting will be altered due to the curvature in the utility of consumption and disutility of labor. Therefore, we have confirmed that the equilibrium allocations associated with a nominal devaluation and both fiscal devaluations in (FD') and (FD"') coincide.

Finally, under separable utility in money balances, money demand (5) is a side equation, and hence imposes no additional constraints on policy.[14] Switching from nominal to fiscal devaluation in general changes the path of the (shadow) nominal interest rate, and hence requires an adjustment in money supply in order to satisfy the altered money demand. The required path of the money supply under a fiscal devaluation policy $\{M_t'\}$ can be recovered directly from (5) given the rest of the allocation.

The proof follows by evaluating equilibrium conditions and verifying that under the given policies they do hold equivalently across fiscal and nominal devaluations. For a more intuitive narrative, let us consider a particular price setting environment, namely PCP. In this case an exchange rate devaluation at home depreciates its terms of trade. As home's import price rises relative to its export price, there is an expenditure switching effect that reallocates home and foreign demand towards home goods. This is the standard channel through which exchange rate depreciations have expansionary effects on the economy.

---

[13] Integrating forward the country flow budget constraint using the foreign stochastic discount factor as weights, we arrive at the intertemporal budget constraint of the country

$$\frac{B_0}{P_0^* \varepsilon_0} + \mathbb{E}_0 \sum_{t=0}^{\infty} \beta \left(\frac{C_t^*}{C_0^*}\right)^{-\sigma} \frac{P_{Ht}^*}{P_t^*} [C_{Ht}^* - C_{Ft} S_t] = 0,$$

where B_0 is the home-currency initial net foreign asset position of the home country, and the second term is the sum of all future trade surpluses of the home country discounted by state prices. Note from good demand condition (1) that home and foreign consumption of imports, C_{Ft} and C_{Ht}^*, are functions of aggregate consumption C_t and C_t^*, as well as relative price P_{Ft}/P_{Ht} and P_{Ft}^*/P_{Ht}^* respectively.

[14] Separability of real money balances in the utility function is a standard assumption in the literature and implies that holdings of real money balances have no affect on the marginal utility of consumption. Hence our equivalence results do not require replicating the equilibrium path of real money balances. If on the other hand we had non-separable utility, equivalence would require the use of an additional tax on money holdings in order to reduce money demand under a fiscal devaluation. This is because expected nominal devaluations result in an increased nominal interest rate and depressed money demand. Replicating an unexpected devaluation, however, does not require an extra instrument even under non-separable utility.

A fiscal devaluation mimics the same movement in the terms of trade S_t, which we rewrite as

$$S_t \equiv \frac{P_{Ft}}{P_{Ht}^*}\frac{1}{\varepsilon_t}\frac{1-\tau_t^v}{1+\tau_t^m} = \frac{P_{Ft}^*}{P_{Ht}}\varepsilon_t\frac{1+\varsigma_t^x}{1-\tau_t^v},$$

where the second equality follows from the law of one price conditions (12) and (16) that hold under PCP. Given the producer currency prices P_{Ht} and P_{Ft}^*, a fiscal devaluation requires either $\tau_t^v = \delta_t/(1+\delta_t)$ *or* $\varsigma_t^x = \tau_t^m = \delta_t$. That is, an exchange rate depreciation given producer prices raises the relative price of home imports to home exports. A fiscal devaluation generates the same relative price adjustment by means of either an increase in VAT or imposition of an import tariff and export subsidy. The VAT affects international relative prices because it is reimbursed to home exporters and imposed at the border on home importers of foreign goods. An increased VAT must be coupled with a payroll subsidy $\varsigma_t^p = \tau_t^v$ in order to avoid a negative wedge in the price setting and home good supply, absent under a nominal devaluation.

The use of the consumption subsidy ς_t^c is important for replicating the behavior of the real exchange rate that enters the risk-sharing condition. In the absence of the consumption subsidy the real exchange behaves differently across the two kinds of devaluations: it depreciates under a nominal devaluation and appreciates under a fiscal devaluation. In the presence of international risk sharing, the movement in the real exchange rate matters for the relative consumption allocation across countries, and consequently the consumption subsidy is essential. The use of the consumption subsidy however distorts the wage setting and labor supply decision, which needs to be offset using a proportional labor income tax, $\tau_n^t = \varsigma_t^c = \delta_t$.

As is suggested from this analysis, the consumption subsidy is required when agents use international asset markets to share consumption risk across states affected and not affected by a devaluation. This then implies that there are two cases when mimicking the real exchange rate, and hence using the consumption subsidy and income tax, is not essential for the equivalence. The first is the case of financial autarky and balanced trade state-by-state and period-by-period.[15] The second is the case of incomplete international asset markets and a one-time unanticipated devaluation which we study in detail in Section 3.3.

We now highlight some interesting features about our equivalence results. First, a surprising result is that the same policies work under both LCP and PCP, independently of whether the law of one price holds. This is because the policies replicate not only the terms of trade, but also the deviations from the law of one price, whenever they exist under LCP, and all relative prices more

[15] Under financial autarky, the set of internationally traded assets Ω_t is empty, international risk-sharing conditions (26) are absent, and therefore the real exchange rate is inconsequential for the allocation. Instead, the country budget constraint becomes the balanced trade requirement $C_{Ht}^* = C_{Ft}S_t$, which using good demand (1) can be rewritten as

$$\frac{C_t^*}{C_t} = S_t\left(\frac{P_{Ht}^*}{P_t^*}\right)^{\varsigma}\left(\frac{P_{Ft}}{P_t}\right)^{-\varsigma}.$$

Therefore, consumption allocation now depends only on relative prices, and not on the real exchange rate, and consequently a fiscal devaluation can be implemented without the use of the consumption subsidy and income tax. Nonetheless, full policies (FD') and (FD") still implement a fiscal devaluation in this case.

generally. Note however that despite the equivalence result holding independently of pricing assumptions, the allocations under LCP and PCP can be substantially different (as discussed, for example, in Lane, 2001). In particular, under PCP the terms of trade depreciates with a devaluation, while under LCP it appreciates on impact (see Obstfeld and Rogoff, 2000).

Secondly, fiscal devaluations mimic not only real variables and relative prices, but also nominal prices. This is because under the staggered price setting environment replicating the path of nominal prices is essential in order not to distort relative prices, and hence relative output, across firms that do and do not adjust prices. As a consequence, since fiscal devaluations mimic all nominal prices, the standard redistribution concerns associated with inflation are identical across fiscal and nominal devaluations.

Third, the fiscal devaluation policies depend only on $\{\delta_t\}$, the desired devaluation sequence and not directly on the details of the model economy. In this sense, fiscal devaluation policies are *robust*—they are insensitive to the micro structure of the economy and require little information about it. The optimal size of the devaluation, however, depends on model details, as we illustrate in Section 5.

3.2. Incomplete asset markets

We now consider the case of incomplete asset markets. The equivalence result follows closely that of Proposition 1 under complete markets, and in general terms can be stated as follows:

Lemma 1 *Under arbitrary asset markets, both* (FD') *and* (FD") *constitute* $\{\delta_t\}$ *-fiscal devaluation policies as long as the foreign-currency payoffs of all internationally-traded assets* $\{D_t^{j*}\}$ *are unchanged.*

Proof: As we show in the proof of Proposition 1, (FD') and (FD") replicate changes in all relative prices including the terms of trade and the real exchange rate. The same arguments go through in the case of incomplete markets as the relevant equilibrium conditions are the same. The main difference with the complete markets case is that now the general versions of the country budget constraint and international risk sharing conditions (24) and (26) apply. As long as real asset payoffs and prices $\{d_t^{j*}, q_t^{j*}\}$ are unchanged in terms of the foreign final good, conditions (24) and (26) are satisfied under the original allocation $\{C_t, C_t^*\}$ and the original asset demand $\{B_t^j\}$. Since under these policies, $\{P_t^*\}$ is unchanged, it is enough to require that $\{D_t^{j*}, Q_t^{j*}\}$ are unchanged where $D_t^{j*} = d_t^{j*} P_t^*$ is the foreign-currency nominal payoff of an asset. Finally, the fundamental price of the asset satisfies

$$Q_t^{j*} = \sum_{s \geq t} \mathbb{E}_t \left\{ \Theta_{t,s}^* D_s^{j*} \right\} = P_t^* \sum_{s \geq t} \mathbb{E}_t \left\{ \beta^{s-t} \left(\frac{C_s^*}{C_t^*} \right)^{-\sigma} \frac{D_s^{j*}}{P_s^*} \right\}$$

so under no-bubble asset pricing we only require that the path of foreign-currency nominal asset payoffs $\{D_t^{j*}\}$ is unchanged.

Our equivalence results therefore apply to settings with arbitrarily rich, albeit incomplete, financial markets. Solving for international portfolio choice under these settings is notoriously complicated (e.g., see discussion in Devereux and Sutherland, 2008). Nevertheless, our analysis goes through as we do not need to characterize the solution, but merely verify whether an allocation that is an equilibrium outcome under one set of policies remains an equilibrium allocation under another set of policies.

We next can consider a variety of asset market structures in view of Lemma 1. First consider one-period risk-free foreign-currency nominal bond. This bond pays $D_{t+1}^{f*} \equiv 1$ in foreign currency and its foreign-currency price is

$$Q_t^{f*} = \mathbb{E}_t\{\Theta_{t+1}^*\} = \frac{1}{1+i_{t+1}^*},$$

where i_{t+1}^* is the foreign-currency risk-free nominal interest rate. This asset satisfies requirements in Lemma 1, and hence (FD') and (FD") constitute fiscal devaluation policies without additional instruments. The same applies to long-term foreign-currency debt as well.

Next consider one-period home-currency risk-free bond with a payoff of $D_{t+1}^h = 1$ in home currency, and hence $D_{t+1}^{h*} = 1/\varepsilon_{t+1}$ in foreign-currency. This asset does not satisfy Lemma 1, and hence we need to introduce partial default (haircut τ_t^h) to make its foreign-currency payoff the same as under a nominal devaluation. A haircut policy on one-period home-currency debt that is required for equivalence satisfies:

$$1-\tau_{t+1}^h \equiv \frac{\varepsilon_t}{\varepsilon_{t+1}} \quad \Leftrightarrow \quad \tau_{t+1}^h = \frac{\delta_{t+1}-\delta_t}{1+\delta_{t+1}}, \tag{31}$$

i.e., the haircut at $t+1$ equals the incremental percent devaluation in that period. With this haircut, the equilibrium payoff of the home-currency debt under a fiscal devaluation is

$$D_{t+1}^{h*} = \frac{1-\tau_{t+1}^h}{\varepsilon'_{t+1}} = \frac{\varepsilon_t}{\varepsilon_{t+1}},$$

and hence its foreign-currency price becomes

$$Q_t^{h*} = \mathbb{E}_t\left\{\Theta_{t+1}^* \frac{1-\tau_{t+1}^h}{\varepsilon'_{t+1}}\right\} = \varepsilon_t \mathbb{E}_t\left\{\Theta_{t+1}^* \frac{1}{\varepsilon_{t+1}}\right\}.$$

This haircut keeps the returns on the bond (D_{t+1}^{h*}/Q_t^{h*}) unchanged in the foreign currency across nominal and fiscal devaluations, and hence the allocation of consumption across countries, given the same relative prices. Note that the partial default in (31) exactly replicates the valuation effects on home-currency assets associated with exchange rate movements (e.g., see Gourinchas and Rey, 2007).[16]

[16] Under a representative agent economy, it is sufficient to require a partial default (haircut) only on all internationally held home-currency bonds; in a heterogeneous-agent economy exact equivalence requires partial default on all outstanding home-currency debt, including the within-country holdings across agents, otherwise fiscal devaluations will introduce additional distributions effects beyond those under a nominal devaluation. Further

As the last example, we consider international trade in equities, for which:[17]

$$D_t^{he*} = \frac{\Pi_t}{(1+\tau_t^d)\varepsilon_t} \quad and \quad D_t^{fe*} = \Pi_t^*.$$

From equations (10) for profits and its foreign counterpart, we observe that both (FD') and (FD") keep both $\Pi_t/[(1+\tau_t^d)\varepsilon_t]$ and Π_t^* unchanged relative to a nominal devaluation, and hence the conditions of Lemma 1 are satisfied without additional instruments. Indeed, the VAT-cum-payroll subsidy under (FD") reduces the foreign-currency profits of home firms, just like a nominal devaluation. Similarly, the profit (dividend-income) tax does the same under a tariff-based devaluation (FD').

We summarize the results above in:

Proposition 2 *Under trade in foreign-currency risk-free bonds and international trade in equities, a fiscal $\{\delta_t\}$-devaluation can be achieved by the same polices* (FD') *and* (FD") *as under complete markets; with trade in home-currency bonds, (FD') and (FD") need to be complemented with a partial default (haircut) equal to $\tau_t^h = (\delta_t - \delta_{t-1})/(1+\delta_t)$ on all outstanding home-currency debt.*

Full policies (FD') and (FD") robustly engineer fiscal devaluations under both complete and incomplete markets.[18] We next study one special case under which the set of policy instruments needed to implement a fiscal devaluation can be substantially reduced.

3.3. One-time unanticipated devaluation

Consider the case of a one-time unanticipated δ-devaluation at $t = 0$. Under these circumstances, prior to $t = 0$, the devaluation is completely unexpected (i.e., a zero probability event), while at $t = 0$ the exchange rate devalues by δ once and for all future periods and states. As we now show, a fiscal devaluation under these circumstances imposes a substantially weaker requirement on the set of fiscal instruments—in particular, the consumption subsidy and the income tax can be dispensed with—as long as asset markets are incomplete in the sense that they do not allow for international transfers targeted specifically to the zero-probability event of an unanticipated devaluation.

Proposition 3 *Under incomplete markets, a one-time unanticipated fiscal δ-devaluation may be attained with one of the two reduced policies:*

$$\tau_t^m = \varsigma_t^x = \tau_t^d = \delta \quad and \quad \varsigma_t^c = \tau_t^n = 0 \quad for \quad t \geq 0, \text{ or} \qquad (FD'_R)$$

$$\tau_t^v = \varsigma_t^p = \frac{\delta}{1+\delta} \quad and \quad \varsigma_t^c = \tau_t^n = \tau_t^d = 0 \quad for \quad t \geq 0, \qquad (FD''_R)$$

---

note that for long-term home-currency debt, the partial default should also extend to the principal of the debt outstanding.

[17] The value of the equities are given by $Q_t^{he*} = \sum_{s\geq t} \mathbb{E}_t \left\{\Theta_{t,s}^* \frac{\Pi_s}{(1+\tau_t^d)\varepsilon_t}\right\}$ and $Q_t^{fe*} = \sum_{s\geq t} \mathbb{E}_t\{\Theta_{t,s}^* \Pi_s^*\}$.

[18] As Benigno and Kucuk-Tuger (2012) highlight, the real allocations are very sensitive to small changes in the number of assets traded. Despite this, the fiscal equivalence propositions remain the same across arbitrary degrees of asset market completeness.

coupled with a partial default (haircut) $\tau_0^h = \delta/(1+\delta)$ *on home-currency debt and an unchanged money supply* $M_t' = M_t$.

Proof: Following the steps of the proof of Proposition 1, the conditions to mimic the path of prices become simply:

$$\frac{1+\varsigma_t^c}{1+\tau_t^n} \equiv 1, \quad \frac{1+\varsigma_t^x}{1-\tau_t^v} \equiv \frac{1+\tau_t^m}{1-\tau_t^v} \equiv 1+\delta_t,$$

which are satisfied under both (FD'$_R$) and (FD"$_R$). These conditions do not impose a requirement on the use of profit tax τ_t^d, because under a one-time unexpected devaluation policy it no longer affects price setting in (13)–(15). Indeed, for price setting before $t = 0$, no nominal or fiscal policy changed is anticipated, so it does not affect price setting; for $t \geq 0$, the change in either nominal or fiscal regime happens once and for all, and hence all taxes can be moved outside the expectation in (13)–(15) and canceled out.

We still need to use profit tax τ_t^d if domestic equity is traded internationally in order to replicate the effects on the budget constraint (24) and international risk sharing (26), as shown in Lemma 1. In particular, the path of $D_t^{he*} = \Pi_t/[(1+\tau_t^d)\varepsilon_t]$ must be replicated under a fiscal devaluation, which from the equation for profits (10) requires $\tau_t^d \equiv \delta$ for $t \geq 0$ under (FD'$_R$) and $\tau_t^d \equiv 0$ under (FD"$_R$). Whenever a home-currency debt is traded, a partial default (haircut) $\tau_0^h = \delta/(1+\delta)$ is needed in the event (state-period) of a fiscal devaluation in order to replicate the valuation effects in the country budget constraint (24).

Since devaluation is one-time unanticipated, the path of the home nominal risk-free interest rate is unaffected (and in fact, UIP holds in this case as interest parity, $i_{t+1} = i_{t+1}^*$, in every period), and therefore money demand in (5) is not affected. As a result, with $\varsigma_t^c = 0$, the same money supply as under a nominal devaluation would also support the fiscal devaluation ($M_t' = M_t$).

Finally, with $\varsigma_t^c = 0$, the path of the real exchange rate is not exactly mimicked relative to a nominal devaluation, however this does not affect the international risk sharing conditions (26). This is because for $t < 0$ no policy change is anticipated (zero-probability event), and for $t \geq 0$ the policy change is once and for all, therefore leaving saving and portfolio choice decisions unaffected before, after and at $t = 0$.

In the case of a one-time unanticipated devaluation the set of necessary instruments is smaller because we have one less relative price to replicate and that is the real exchange rates; and consumption subsidies are only required if we need to replicate the dynamics of the real exchange rate. The intuition is that the terms of trade is the relative price affecting trade within period-state (in (24)), while the real exchange rate is the relative price affecting trade across periods and states (in (26)). When a devaluation is one-time unanticipated, international risk sharing is not affected by a one-time jump in the real exchange rate in the event of a devaluation, provided that international asset markets are incomplete. As a result, only the path of the terms of trade, but not of the real exchange rate, has to be mimicked under a fiscal devaluation. Therefore, fiscal devaluation policies under a one-time

unanticipated devaluation do not need to use the consumption subsidy, and by consequence the income tax.

Arguably, the reduced policy (FD"$_R$) under a one-time unanticipated devaluation is the most practical from a policy perspective. Indeed, it requires only two tax instruments—an increase in the value-added tax and a payroll subsidy (a reduction in the payroll tax)—possibly complemented with a one-time partial default on outstanding home-currency debt.

It might appear that while the size of a nominal devaluation is unrestricted with $\delta \in (0, +\infty)$, even in theory the size of the tax adjustment is limited as it cannot exceed 100%. This is actually not the case. Theoretically a fiscal devaluation of arbitrary size $\delta \geq 0$ is also possible. For example, under (FD"$_R$), a δ-devaluation requires setting VAT and payroll subsidy at $\delta/(1+\delta) \in (0, 1)$.[19]

3.4. Government revenue neutrality

We now study how fiscal devaluations affect government revenues over and above the effects of a nominal devaluation. We first show that the full fiscal devaluation policies (FD') and (FD") are exactly revenue neutral, state-by-state and period-by-period, that is lead to exactly the same effects on the government budget as a nominal devaluation. We then analyze the one-time unanticipated policies (FD'$_R$) and (FD"$_R$) which do not utilize consumption and income taxes, and show that these policies generate additional tax revenues in periods (and states of the world) when the country runs trade deficits.

It is convenient to introduce the following notation:

$$\tau_t^m = \varsigma_t^x = \tau_t^d = \delta_t^m, \qquad \tau_t^v = \varsigma_t^p = \frac{\delta_t^v}{1+\delta_t^v}, \qquad \varsigma_t^c = \tau_t^n = \epsilon_t.$$

Under (FD'), $\delta_t^m = \epsilon_t = \delta_t$ and $\delta_t^v = 0$; under (FD"), $\delta_t^m = 0$ and $\delta_t^v = \epsilon_t = \delta_t$. The one-time policies, (FD'$_R$) and (FD"$_R$) differ only in that $\epsilon_t = 0$ in both cases (and $\delta_t = \delta$ for t ≥ 0 and zero for $t < 0$ if the one-time unanticipated devaluation happens at $t = 0$).

With this notation, we can rewrite incremental government tax revenues (22) generated from fiscal devaluations as:

$$TR_t = \frac{\epsilon_t}{1+\epsilon_t}(W_t N_t - P_t C_t) + \frac{\delta_t^v}{1+\delta_t^v}(P_{Ft}C_{Ft} + P_{Ht}C_{Ht} - W_t N_t)$$
$$+ \frac{\delta_t^m}{1+\delta_t^m}(P_{Ft}C_{Ft} - (1+\delta_t^m)\varepsilon_0 P_{Ht}^* C_{Ht}^* + \Pi_t),$$

[19] If there were initial non-zero VAT and payroll taxes in place, one can verify that the required new taxes under a fiscal δ-devaluation are:

$$\tau^v = \frac{\bar{\tau}^v + \delta}{1+\delta} \quad and \quad \tau^p = \frac{\bar{\tau}^p - \delta}{1+\delta}$$

where $\bar{\tau}^v$ and $\bar{\tau}^p$ are the pre-devaluation levels of VAT and payroll taxes. Note that for any size of devaluation δ, we still have $\tau^v < 1$ and $\varsigma^p \equiv -\tau^p < 1$. The larger is the initial level of VAT, the smaller is a required further increase in the VAT to achieve a given level of devaluation.

where we have used the fact $\varepsilon_t' = \varepsilon_0$ under a fiscal devaluation. Under the set of fiscal devaluation policies that we consider, this expression can be rewritten as:[20]

$$TR_t = \left[\frac{\delta_t^v}{1+\delta_t^v} + \frac{\delta_t^m}{1+\delta_t^m} - \frac{\epsilon_t}{1+\epsilon_t}\right](P_t C_t - W_t N_t), \tag{32}$$

Given this result, we prove the following:

Proposition 4 (i) *The full fiscal devaluation policies,* (FD') *and* (FD"), *are exactly government revenue neutral state-by-state and in every time period.* (ii) *Under reduced fiscal devaluation policies,* (FD'$_R$) *and* (FD"$_R$), *additional government revenues over and above that from a one-time unanticipated nominal devaluation equal*

$$TR_t = -\frac{\delta_t}{1+\delta_t} NX_t + \frac{\delta_t \Pi_t}{1+\tau_t^d}, \tag{33}$$

where $NX_t = (1+\delta_t)\varepsilon_0 P_{Ht}^* C_{Ht}^* - P_{Ft} C_{Ft}$ *is the trade balance of the country. Furthermore, the net present value of fiscal surpluses equals δ times the sum of net foreign assets and stock market capitalization of the home country at the time of the devaluation.*

Proof: (i) follows immediately from (32) after substituting in $\varepsilon_t = \delta_t^m$ under (FD') and $\varepsilon_t = \delta_t^v$ under (FD").

To prove (ii), note that under both (FD'$_R$) and (FD"$_R$) we can rewrite

$$\begin{aligned} P_t C_t - W_t N_t &= (P_{Ft} C_{Ft} - (1+\delta_t)\varepsilon_0 P_{Ht}^* C_{Ht}^*) + (P_{Ht} C_{Ht} + (1+\delta_t)\varepsilon_0 P_{Ht}^* C_{Ht}^* - W_t N_t) \\ &= -NX_t + (1+\delta_t^v)\Pi_t = -NX_t + (1+\delta_t)\frac{\Pi_t}{1+\tau_t^d} \end{aligned}$$

Note that the second term is firm profits under (FD'), but under (FD") it is firm profits divided by $(1-\tau_t^v) = (1+\delta_t^v)^{-1}$. Multiplying it and dividing it by $(1+\tau_t^d)$ we obtain the last equality after noting that $(1+\delta_t^v)(1+\tau_t^d) = (1+\delta_t^v)(1+\delta_t^m) = (1+\delta_t)$ under both (FD'$_R$) and (FD"$_R$). Finally, substituting this resulting equation into (32), and imposing $\in_t = 0$ and $\delta_t^m = \delta_t$ *or* $\delta_t^v = \delta_t$ under the two reduced fiscal devaluations respectively, we obtain (33).

To prove the final statement of the proposition, we integrate forward the government revenues TR_t in (33), discounting future states by the stochastic discount factor, and then apply the country budget constraint, to obtain

[20] We used the fact that under (FD') and (FD'$_R$), for which $\delta_t^m \neq 0$, the expression for firm profits becomes

$$\Pi_t = P_{Ht} C_{Ht} + (1+\delta_t^m)\varepsilon_0 P_{Ht}^* C_{Ht}^* - W_t N_t,$$

as well as the general expenditure decomposition $P_t C_t = P_{Ht} C_{Ht} + P_{Ft} C_{Ft}$

$$\sum_{t=0}^{\infty} \mathbb{E}_0\{\Theta_{0,t} TR_t\} = \delta\left(B_0 + Q_0^{he}\right),$$

where B_0 is the net foreign asset position of the home country and $Q_0^{he} = \sum_{t=0}^{\infty} \mathbb{E}_0\{\frac{\Theta_{0,t}\Pi_t}{1+\tau_t^d}\}$ is the (shadow) value of the home stock market, both upon devaluation at $t = 0$. The formal details of this part of the proof are provided in the Appendix.

Part (ii) of Proposition 4 implies that as long as aggregate profits in the economy are non-negative, a one-time unanticipated fiscal devaluation policy will generate additional fiscal revenues in the periods and states in which the country runs a trade deficit. This is an appealing feature of the one-time unanticipated fiscal devaluation policies. These policies may generate a deterioration of fiscal balance (relative to that under a nominal devaluation) only in period and states in which the country runs a trade surplus (or if aggregate profits are negative). Finally, the net present value of additional fiscal surpluses is proportional to the size of the devaluation and the sum of the net foreign asset position of the country and its stock market capitalization at the instance of the fiscal devaluation. The net present value of additional fiscal surpluses is non-negative when the country's stock market capitalization exceeds its net foreign liabilities, which is easily satisfied for the majority of developed countries.

4. Extensions

In this section we discuss four extensions to the benchmark environment discussed in previous sections. First, we describe how to engineer a fiscal devaluation in a currency union. Second, we allow for capital as a variable input in production besides labor. Third, we discuss our tax pass-through assumptions and evaluate the case of asymmetric pass-through of VAT and payroll taxes into prices. Fourth, we allow for labor mobility.

4.1. Fiscal devaluations in a currency union

We now consider the implementation of a fiscal devaluation in a monetary union, where the member-countries give up their monetary policy independence and adopt a common currency hence abandoning the possibility of a nominal devaluation.[21] In general, as we discussed above, a nominal devaluation required a change in the home money supply. In a currency union money supply to individual member-countries becomes an endogenous variable, and the relative money supply between the countries adjusts in order to satisfy the fixed nominal value of the currency across member-countries. Instead, the union-wide central bank controls the overall money supply to all country members, or alternatively a union-wide nominal interest rate. We now study whether under

[21] For a recent survey of the literature on currency unions see Silva and Tenreyro (2010).

these circumstances, a fiscal devaluation can be implemented as a unilateral policy or it requires coordination from the union central bank.[22]

We start by characterizing the change in the equilibrium conditions under a currency union between home and foreign. The union central bank collects seigniorage revenues from total money supply $\bar{M}_t$ and transfers them back to individual member-countries:

$$\bar{M}_t - \bar{M}_{t-1} = \Omega_t + \Omega_t^*,$$

where Ω_t and Ω_t^* are transfers from the union central bank to home and foreign governments (e.g., national central banks) respectively. The union-wide money supply equals the sum of money supplies to individual member-countries:

$$\bar{M}_t = M_t + M_t^*,$$

where M_t and M_t^* now adjust endogenously in order to satisfy the equilibrium conditions given a fixed exchange rate

$$\bar{\varepsilon}_t \equiv 1,$$

that is, common currency. Finally, the budget constraint of home government instead of (21) becomes

$$\Omega_t + TR_t = T_t,$$

and for the foreign government it becomes $\Omega_t^* = T_t^*$ respectively. Therefore, the revenues of the government from seigniorage under an independent monetary policy are replaced with the transfers of a share in the union-wide seigniorage revenues. All the other equilibrium conditions remain unchanged.

Given this, we can immediately formulate the following generalization of the fiscal devaluation policies to the currency union setup:

Lemma 2 *The fiscal devaluation policies in Propositions 1-3 still constitute a fiscal* $\{\delta_t\}$*- devaluation in a currency union, provided that the union central bank follows*

$$\bar{M}_t = M_t' + M_t^* \qquad and \qquad \Omega_t = \Delta M_t',$$

Where M_t' *is the money supply under a fiscal devaluation in Propositions 1-3 respectively*.

In words, the union central bank needs to increase the money supply exactly to accommodate the increase in money supply in the two countries under the fiscal devaluation scenario when home has an independent monetary policy. The union central bank does not need to worry about the distribution of this money supply between the two countries, as it will happen endogenously given the fixed

[22] We still stay in the framework of two countries, both of which are now members of the same currency union. A separate question is how to engineer a devaluation against both countries within and outside the currency union, which would require considering three countries at least. This extension, however, is immediate. In general, one can always think of a fiscal devaluation of one member of a currency union against another (e.g., Spain against Germany), while the value of the union-wide currency against third-country currencies (e.g., Euro against the US dollar) being determined by the union-wide monetary policy, as in conventional models.

exchange rate (common currency) between the two countries. This same outcome can be attained with a union-wide interest rate rule, by setting a path for i^*_{t+1}. In this case, the union central bank does not have to make any calculation about $\bar{M}_t$, but merely needs to follow the same i^*_{t+1}-policy the foreign country would have followed in the counterfactual scenario of the two countries with independent monetary policies. This is, of course, a more practical case, which also better fits the reality of monetary policies in the world.[23]

The other requirement on the union central bank's policy is the distribution of additional seigniorage revenues obtained under a fiscal devaluation towards the home country ($\Omega_t = \Delta M'_t$ condition). This requirement is still necessary when the union sets an interest policy (i^*_{t+1}) and money supply adjusts endogenously. Without this transfer, the home country's budget constraint will be different from the case of a counterfactual nominal devaluation or a fiscal devaluation under independent monetary policies of the countries. One situation under which this transfer is not needed is the limiting case of cashless economy, that is when $\chi \to 0$ in the utility function. In fact, this may be the relevant case empirically provided that seigniorage plays a small role as a source of government revenues in most developed countries. Indeed, a large part of the New Keynesian literature focuses entirely on the cashless limit (e.g., see Woodford, 2003). Note that when $\chi \to 0$, demand for money in (5) is indeed negligible independently of consumption and nominal interest rate, and hence seigniorage revenues are also negligible and no transfers are needed in the limit.

To summarize, in general a fiscal devaluation by a member country in a currency union requires a coordinated action from the union central bank, which must both adjust the union- wide money supply and the allocation of seigniorage revenues across the member-countries. However, in a number of relevant cases discussed above, the required coordination by a union central bank is either more limited or not needed at all. We emphasize one such case in the following:

Proposition 5 *Consider a cashless economy ($\chi = 0$), in which a union central bank follows some monetary policy resulting in a given equilibrium path of the nominal interest rate, $\{i^*_{t+1}\}$. Then a member-country of the currency union can attain a fiscal devaluation unilateraly, by means of fiscal policies described in Propositions 1-3.*

4.2. Capital

In this sub-section, we discuss how our characterization of fiscal devaluations change when we introduce capital into the model as an additional variable input in production. With capital, additional tax instruments are required to implement a fiscal devaluation, and we introduce these instruments below. We adopt a formalization where firms frictionlessly rent the services of labor and capital on centralized spot markets, at prices W_t and R_t, and capital is accumulated by households. The full model setup is described in the Appendix, while here we present the two central new equilibrium conditions. Given

[23] In the case when home is a small open economy, in the particular sense that $M_t/M^*_t \to 0$, the changes in M'_t do not affect $\bar{M}_t$, and hence the union central bank does not need to move $\bar{M}_t$ when a small member of the union does a fiscal devaluation. In this case, given $\bar{M}_t$, the money supply will relocate towards home, but it won't affect the rest of the currency union since home is small.

these two conditions, the remaining equilibrium conditions including price setting, country budget constraint and international risk sharing conditions are not affected.

The first of these conditions is the firm's choice of production inputs:

$$MRT_{it}\big(N_t(i), K_t(i)\big) = \frac{(1-\varsigma_t^R)R_t}{(1-\varsigma_t^p)W_t},$$

where $MRT_{it}\big(N_t(i), K_t(i)\big)$ is the marginal rate of transformation of one unit of capital for one unit of labor in the production of firm i, ς_t^p is the payroll subsidy as before, and now ς_t^R is a capital subsidy (or, a subsidy on the firm capital rental expenses). Whenever the payroll subsidy is used (e.g., as in the VAT-payroll subsidy policy (FD")), it has to be complemented with a uniform capital subsidy:

$$\varsigma_t^R \equiv \varsigma_t^p,$$

otherwise firms would have an incentive to substitute labor for capital in production under a fiscal devaluation—an effect absent in a nominal devaluation.

The second new condition is household optimality with respect to capital accumulation (see the Appendix):

$$\mathbb{E}_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+1}}\frac{1+\varsigma_t^I}{1+\varsigma_t^c}\left[R_{t+1}\frac{1+\varsigma_{t+1}^c}{1+\tau_{t+1}^K}+(1-d)\frac{1+\varsigma_{t+1}^c}{1+\varsigma_{t+1}^I}\right]\right\}=1,$$

where d is the capital depreciation rate, ς_t^c is the consumption subsidy as before, and now ς_t^I is the investment subsidy (investment tax credit) and τ_t^K is the capital-income tax. The condition above states that the return on an additional unit of physical capital discounted with the home stochastic discount factor equals one. It is derived under the assumption that, without taxes, one unit of the consumption good can be frictionlessly converted into one unit of the investment good.

As can be seen from this optimality condition, in general, a fiscal devaluation policy will require

$$\tau_t^K \equiv \varsigma_t^I \equiv \varsigma_t^c$$

i.e., a capital-income tax and an investment subsidy both equal to the consumption subsidy involved. If the investment subsidy is not used together with the consumption subsidy, a fiscal devaluation distorts the household's allocation of expenditure in favor of consumption goods and away from investment goods since the relative price of the investment good increases. If the capital-income tax is not used together with the consumption subsidy, a fiscal devaluation distorts the consumption-savings decision in favor of greater capital accumulation due to increased after-tax returns on capital. Importantly, whenever the consumption subsidy is not used as part of a fiscal devaluation policy, the capital-income tax and the investment subsidy will not be used as well.

We now summarize these results in the context of fiscal devaluation policies studied in Section 3:

Proposition 6 *In an economy with capital as a variable input in production,* (i) *full fiscal devaluation policies* (FD') *and* (FD") *of Propositions 1-2 need to be extended with a capital-income tax and investment subsidy,* $\tau_t^K \equiv \varsigma_t^I \equiv \delta_t$, *while* $\tau_t^K \equiv \varsigma_t^I \equiv 0$ *under reduced fiscal devaluation policies* (FD'$_R$) *and* (FD"$_R$) *of Proposition 3;* (ii) *in addition, VAT-based fiscal devaluation policies* (FD") *and* (FD"$_R$) *need to be complemented with a capital subsidy,* $\varsigma_t^R \equiv \delta_t/(1+\delta_t)$, *while tariff-based policies* (FD') *and* (FD'$_R$) *need not*.

If we focus on the reduced VAT-based fiscal devaluation (FD"$_R$) as the most practical policy, the only additional tax instrument required is the capital subsidy to firms. The general principle is that all variable inputs of the firm need to be subsidized at the same rate in order not to distort the equilibrium mix of the factors of production.

4.3. Tax pass-through

We now turn to the discussion of our assumptions on the sensitivity of prices to exchange rate and tax changes, relate it to existing empirical evidence and analytically evaluate a departure from the pass-through assumptions in the main text. For concreteness, we restrict attention to the VAT-based reduced fiscal devaluation policy (FD"$_R$) replicating a one-time unanticipated devaluation (Proposition 3), due to its greater implementability. The propositions on equivalence rely on two sets of assumptions that would be normal to impose in a standard new Keynesian environment: One, foreign firms pass-through of exchange rate and VAT changes into the prices at which they sell to the domestic market is the same, all else equal, that is conditional on the foreign wage. Two, domestic firms pass-through of VAT and payroll tax to domestic prices is the same, conditional on the domestic wage.

In the medium and long-run, when firms adjust their prices, these assumptions are natural. When the exchange rate and tax changes are large the long-run can be attained very quickly since firms will choose to adjust prices immediately. The question then is about the short-run, when as a large body of evidence suggests, prices adjust infrequently and respond sluggishly to shocks.

We now survey what empirical evidence exists on the short-run response of prices to exchange rate and tax policy changes. The first assumption requires symmetry of pass-through of exchange rate shocks and VAT shocks into foreign firms prices to the domestic market. Since existing papers in the literature do not directly address this question, one is necessarily comparing evidence across different data sets and more importantly comparing cases where the tax shocks and exchange rate shocks are not necessarily similarly unanticipated or anticipated. Nevertheless, what evidence exists appears to support the assumption of similar pass-through rates. For instance, Campa, Goldberg, and González-Mínguez (2005) estimate that short-run (one month) pass-through into import prices in the Euro Area is 66% (and 81% in the long-run, after four months). Andrade, Carré, and Bénassy-Quéré (2010) examine data on French exports to the Euro zone over the 1996-2005 period and document that median pass-through of VAT shocks that occurred in eleven EMU12 partner countries over this period is 70-82% at a one year horizon. While they lack higher frequency data they conclude that the evidence is consistent with similar pass-through behavior for exchange rate and VAT shocks over a year. The evidence also appears consistent with producer currency pricing.

Evidence on the second assumption on responses of domestic prices to VAT and payroll is even harder to come by. First, while there exist some studies on VAT pass-through at various horizons there are very few equivalent studies for payroll taxes. Carbonnier (2007) studies two French reforms that involved steep decreases in VAT in 1987 and then in 1999 and finds that the pass-through into domestic prices, almost immediately, was 57% in the new car sales market and 77% in the household repair services market. The extent of pass- through therefore varies by market. There is however no similar evidence for payroll tax changes in these markets. Further, the tax changes were of a very large magnitude and consequently more revealing of long-run pass-through.[24] The one case study that involved both a VAT increase and a payroll tax cut is the German VAT increase of 3 percentage points and a cut in employer and employee payroll contributions by 2.3 percentage points in 2007. Carare and Danninger (2008) examine the effect of these policy changes on core inflation. They find evidence of staggered price adjustment to tax shocks. The tax policies were announced 13 months ahead of actual implementation and, consistent with infrequent price adjustment, they find that prices adjusted upward prior to implementation. They conclude that overall pass-through from VAT was 73% with about half of this occurring in the run-up to implementation and the other half at the time of implementation. This evidence however cannot be directly used to shed light on the symmetry assumption. Firstly, they focus on core inflation and do not distinguish between domestic and foreign price pass- through. Secondly, they provide no evidence on pass-through of the payroll tax. Given that their identification relies on comparing VAT-effected goods with non-VAT goods, they isolate only the VAT pass-through component. This evidence also does not shed light on unanticipated tax changes.

The existing evidence therefore does not shed much light on the second assumption. Consequently, we briefly discuss how the equivalence proposition is impacted in the case of short-run asymmetry in pass-through rates between VAT and payroll tax. Again, for concreteness, we focus on the case of a one-time unanticipated VAT-based δ-devaluation at t = 0, in a PCP economy with international trade in foreign-currency bonds only. We now assume that firms during the period of price non-adjustment mechanically index their price changes to changes in VAT and payroll taxes, with arbitrary index rates.

Formally, the evolution of the firm's price satisfies:

$$P_{Ht}(i) = \begin{cases} \bar{P}_{Ht}(i), if\ adjusts, w/prob\ 1-\theta, \\ \left(\frac{1-\tau_t^v}{1-\tau_{t-1}^v}\right)^{-\xi v}\left(\frac{1-\varsigma_t^p}{1-\varsigma_{t-1}^p}\right)^{\xi p} P_{H,t-1}(i), if\ does\ not\ adjusts, w/prob\ \theta, \end{cases} \qquad 34$$

where $\xi_v, \xi_p \in [0,1]$ are short-run tax pass-through (index) rates. Our baseline analysis of Sections 2-3 was done under the assumption $\xi_v = \xi_p = 0$. However, since our policies always involve a uniform adjustment in VAT and payroll subsidy ($\tau_t^v = \varsigma_t^p$), the baseline results immediately extend to the case of symmetric short-run pass-through, that is $\xi_v = \xi_p \in [0,1]$. We now analyze the asymmetric pass-through

[24] In September 1987, the VAT rate on car sales went down from the luxury-rate of 33.3% to the full-rate of 18.6%. In September 1999, the VAT rate on housing repair services went down from the full-rate of 20.6% to the reduced-rate of 5.5%

case, for concreteness specializing to $0 \leq \xi_p < \xi_v \leq 1$, that is a higher short-run pass-through on VAT changes relative to payroll tax changes.

Under PCP, the law of one price (12) and (16) still holds for international prices, hence requiring that the VAT adjusts exactly as in Proposition 3 ($\tau_t^v \equiv \delta/(1+\delta)\ for\ t \geq 0$).Therefore, we need to choose a suitable dynamic path for the payroll subsidy in order to mimic the behavior of the price index for the home good in the home market, P_{Ht}.[25] In the Appendix, we prove the following:

Proposition 7 *In a PCP economy with international trade in foreign-currency bond and asymmetric short-run pass-through on VAT and payroll tax, a one-time unanticipated δ-devaluation can be first-order implemented with* $\tau_t^v = \delta/(1+\delta)$ *for all t ≥ 0 and the following payroll subsidy:*

$$if\ \xi_p = 0: \quad \varsigma_0^v = 1 - \left(\frac{1}{1+\delta}\right)^{1+\frac{\xi_v}{\lambda}} \quad and \quad \varsigma_t^p = \frac{\delta}{1+\delta} \quad for \quad t > 0,$$

$$if\ \xi_p > 0: \quad \varsigma_t^v = 1 - \left(\frac{1}{1+\delta}\right)^{1+\frac{\xi_v - \xi_p}{\xi_p}\rho^{1+t}} \qquad for\ t \geq 0,$$

Where $\rho \in (0, 1)$ *is the smaller root of* $\beta x^2 - (1 + \beta + \lambda/\xi_p)x + 1 = 0, \lambda = (1-\theta_p)(1-\beta\theta_p)/\theta_p$.

Note a number of differences in Proposition 7 from our results in Section 3. First, a static *δ*-devaluation requires a dynamic fiscal policy to replicate it, with the payroll subsidy overshooting in the short run its long-run level of *δ*. This is required since short-run pass-through on VAT is larger than on the payroll tax, and hence the payroll subsidy should overshoot the level of the VAT in the short run to compensate for this difference. Second, the equivalence is only first-order and not exact. This is because under fiscal devaluations the firms adjusting prices end up with lower prices relative to non-adjusters, as compared with the nominal devaluation; yet, the overall price index follows the same path. Third, implementation relies on information about the micro structure of the economy, in particular the short-run pass-through rates ξ_p and ξ_v, and the measure of price stickiness λ. Finally, this proposition only applies to PCP, but not LCP, economies. Furthermore, in general these two instruments are insufficient to implement a fiscal devaluation in an LCP economy with arbitrary tax pass-through, since in this case we are one instrument short to replicate the dynamics of P_{Ht}^*.

[25] Note that exact equivalence is no longer feasible, since now firms that happen to adjust and that did not adjust after the tax change will have different relative prices as compared to the case of a nominal devaluation. This can be seen from (34), where tax changes affect the evolution of prices when firms do not adjust, while changes in the exchange rate do not. Mimicking, however, the aggregate behavior of the home price index P_{Ht} is sufficient for the first-order equivalence. This is because, given P_{Ht}, all other aggregate relative prices, including the terms of trade, are replicated.

4.4. Labor mobility

Our baseline setup does not allow for labor mobility across countries, however, the analyzed fiscal devaluation policies can be extended to economies with labor mobility. Labor mobility can be introduced into the model in different ways. Consider the case in which the home workers have the option to be employed in the foreign country, but still have their consumption at home.[26] In this case, the no arbitrage condition for workers requires the equalization of nominal payoffs in the two locations:

$$\frac{W_t}{1+\tau_t^n} = \varepsilon_t W_t^*$$

Since as we have discussed, a fiscal devaluation needs to replicate the path of $\{W_t, W_t^*\}$, the use of income tax becomes essential under labor mobility. Indeed, the full policies (FD') and (FD") of Propositions 1 and 2 do satisfy this requirement, and continue to implement fiscal devaluation even with labor mobility of this type.[27] An important qualification in this case is that income taxes need to be based on the source of income rather than the residency of the worker.

5. Optimal Devaluation: Numerical Illustration

So far we have not focused on whether a devaluation is optimal or desirable; we have simply asked whether it is possible to robustly replicate the real allocations that would follow a nominal devaluation, but keeping the nominal exchange rate fixed. This is because while the optimality of a devaluation is model dependent, equivalence, which is the focus of this paper is robust across many environments.

There are cases when a devaluation is optimal going back to the argument Milton Fried-man made in favor of flexible exchange rates in an environment where prices are rigid in the producer's currency (for a recent formal analysis of this argument see Devereux and Engel, 2007).[28] In this section we examine another case where wages are rigid but prices are flexible. In this environment the optimal policy response to a negative productivity shock is a devaluation: nominal or fiscal.[29]

We provide a simple numerical illustration of this case. For simplicity, we consider a small-open economy. The only international asset is a risk-free foreign-currency bond traded at a constant rate r^* such that $\beta(1+r^*) = 1$. We introduce money into the model by way of a cash-in-advance constraint. The relevant parameters are chosen as follows: $\beta = 0.99$, $\theta_w = 0.75$, $\gamma = 2/3$, $\sigma = 4$, $\varphi = 1$, $\kappa = 1$, $\eta =$

[26] An alternative case is when workers can only choose to migrate fully, moving the location of both their employment and consumption. Since fiscal devaluations replicate all real variables and relative prices, the equivalence extends immediately to this case.

[27] In contrast, fiscal implementation of the first best allocation in Adao, Correia, and Teles (2009) requires additional fiscal instruments under labor mobility.

[28] Hevia and Nicolini (2011) propose a New Keynesian small-open-economy model with trade in commodities as intermediate inputs. In this environment, a nominal devaluation can be the constrained optimal response to an exogenous terms-of-trade shock.

[29] Schmitt-Grohé and Uribe (2011) recently considered a similar environment, but with downward nominal wage rigidity, inelastic labor supply and involuntary unemployment. In their environment, the effects of a nominal devaluation can be replicated with a single payroll subsidy, which as we show is in general insufficient for a fiscal devaluation.

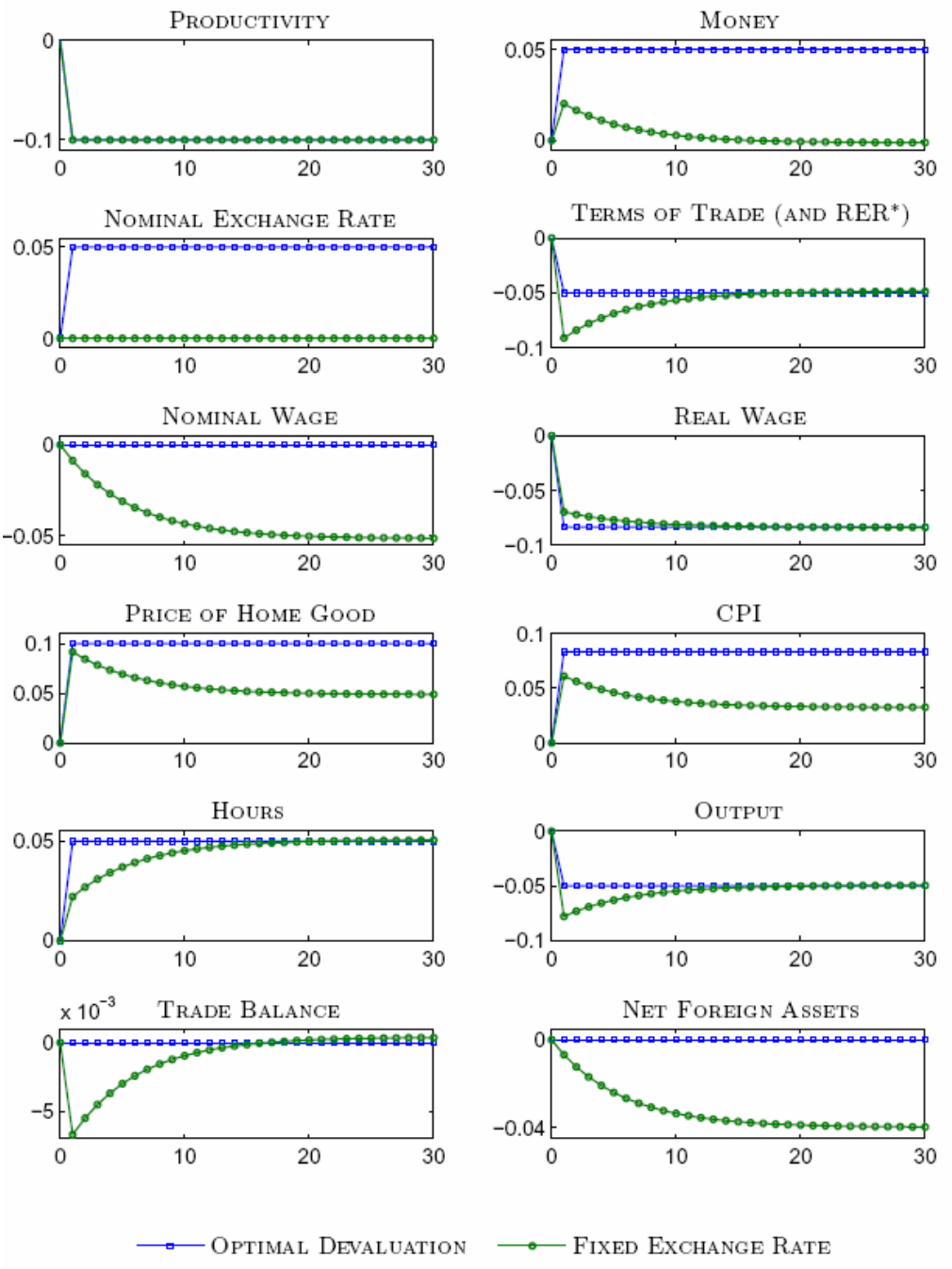
3. Hence, a period corresponds to a quarter and the average wage duration is one year. The choice of the utility parameters does not affect qualitative properties of the dynamics of the small open economy, as long as the relative risk aversion is greater than one ($\sigma > 1$).[30]

We consider the following experiment. The economy starts initially in a non-stochastic steady state with productivity $A_0 = 1$. At $t = 1$, home productivity permanently and unexpectedly drops by 10%.[31] Because home is a small open economy, all the foreign variables remain unchanged. We consider equilibrium dynamic response to this shock under two regimes. First, the economy implements the optimal nominal or fiscal devaluation, and second, the economy maintains a fixed exchange rate and no change in the fiscal policy.

[30] When $\sigma = 1$, productivity does not affect equilibrium nominal wage under fixed exchange rate, and therefore wage stickiness is not a binding constraint in the experiment we consider below. For $\sigma < 1$, under fixed exchange rate nominal wages increase in response to a negative productivity shock.

[31] In our model, this drop in productivity given the nominal wage rate is equivalent to starting the economy at an initial nominal wage which is too high given productivity and price level.

Figure 1: Dynamic path of the economy under optimal devaluation and fixed exchange rate, following a one-time unanticipated 10% fall in productivity



Note: Optimal fiscal devaluation is characterized by the same dynamics with the exception that the nominal exchange rate is constant and taxes adjust instead as described in the text.

* RER is real exchange rate. In this economy, changes in RER are proportional to changes in the terms of trade, $\hat{Q} = \gamma\hat{\delta}$, therefore the dynamics of RER are qualitatively the same as that for the terms of trade, with RER being less volatile since $\gamma < 1$.

Figure 1 describes the dynamic path for the economy under the two regimes. First, consider the regime under which the exchange rate is devalued by 5%. Exactly the same outcome could be achieved through a fiscal devaluation, either by increasing import tariffs and export subsidies by 5 percentage points, or by lowering the payroll tax and increasing the VAT by 5 percentage points (see Proposition 2).

This devaluation replicates the flexible-price, flexible-wage allocation with no wage inflation. This allocation is perfectly constant: consumption drops, hours increase, output drops, the real wage drops, and the terms of trade appreciate. Note that the net foreign asset position remains at zero. Because the shock is permanent and the allocation constant, there are no additional opportunities for consumption smoothing through international borrowing and lending.

One way to understand why a devaluation achieves the flexible-price, flexible-wage outcome is as follows. With the productivity shock, two relative prices need to adjust: the real wage and the terms of trade. The combination of a nominal or fiscal devaluation and a jump in the home price level is sufficient to perfectly and instantly hit both targets, while without a devaluation a jump in prices alone leads to both too high a real wage and over appreciated terms of trade. Alternatively, one can think of the devaluation as a way to achieve the desired real wage adjustment without any nominal wage adjustment. All in all, a devaluation circumvents the sticky wage constraint.[32]

Figure 1 also describes the dynamic path for the economy under fixed exchange rate—that is, an economy with neither nominal, nor fiscal devaluation following the productivity shock. Just like the flexible-price, flexible-wage economy, the sticky wage economy eventually achieves a lower real wage and an appreciated terms of trade. However, the initial adjustment in the home price level cannot alone (without a simultaneous adjustment in the nominal exchange rate) hit the two relative price targets that are the real wage and the terms of trade of the flexible-price, flexible-wage economy. Instead, part of the adjustment now comes in the form of a protracted wage deflation. The initial increase in the home price level results in a decrease in the real wage and appreciation of the terms of trade. But the initial appreciation in the terms of trade overshoots its long run level—the terms of trade appreciates more in the short run—while the real wage undershoots its long term value—the real wage decreases less in the short run. In other words, the resulting short-run wage markup is too high, explaining why wage deflation takes place. This in turn leads to depressed hours and a negative output gap. Finally, that the terms of trade initially appreciate more than in the long run results in trade deficits, followed by trade surpluses. The trade deficits that occur early on can be seen as symptoms of a competitiveness problem.[33]

---

[32] In our economy, flexible-price, flexible-wage allocation is the first best if monopolistic markups in price and wage-setting are offset with appropriate subsidies. We consider optimal coordinated policy for a world planner to shut down the incentives for unilateral terms of trade manipulations.

[33] It is also possible to understand these developments from the perspective of the capital account. While the shock is permanent, the transitional dynamics due to wage stickiness generates a recession in the short run, the effects of which on consumption can be smoothed through international borrowing.

6. Conclusion

In this paper we propose two types of fiscal policies that can robustly implement allocations stemming from a nominal devaluation, but in an economy with a fixed exchange rate. Our proposed fiscal devaluations have a number of appealing features. First, they can be implemented unilaterally by one country using a small set of conventional fiscal instruments. In particular, a one-time unanticipated fiscal devaluation can be implemented adjusting solely the value-added and payroll taxes. Second, they are robust in the sense that they work across a number of economic environments and require virtually no information about the details of the microeconomic environment, in particular about the extent and nature of nominal price and wage rigidity. Third, they are government revenue neutral. Taken together, our results suggest that fiscal devaluations offer a partial but attractive relaxation of Mundell's impossible trinity (for a recent reference, see Obstfeld, Shambaugh, and Taylor, 2010), allowing for essentially the same outcomes as under an active monetary policy while maintaining a fixed exchange rate and free capital flows.

Appendix

A.1 Derivations for Section 2

Price setting Consider first the choice of $\bar{P}_{Ht}(i)$ under the case of PCP. Combine profit equation (10) with the law of one price (12), to arrive at:

$$\Pi_t^i = (1-\tau_t^v)P_{Ht}(i)(C_{Ht}(i)+C_{Ht}(i)^*) - \left(1-\varsigma_t^p\right)W_tN_t(i),$$

Where $C_{Ht}(i)$ and $C_{Ht}^*(i)$ satisfy the demand equations (1) and their counterparts for foreign, so that total output of the firm satisfies

$$Y_t(i) = C_{Ht}(i) + C_{Ht}^*(i) = \left(\frac{\bar{P}_{Ht}(i)}{P_{Ht}}\right)^{-\rho}(C_{Ht}+C_{Ht}^*),$$

where we have used the fact that under price index (2), the law of one price also holds at the aggregate, $\bar{P}_{Ht}^*(i)/P_{Ht}^* = \bar{P}_{Ht}(i)/P_{Ht}$. The output of the firm satisfies the production function (8), which given price $\bar{P}_{Ht}(i)$ determines the demand for labor $N_t(i)$. As explained in the text, the reset price $\bar{P}_{Ht}(i)$ is chosen by maximizing $\sum_{s\geq t}\theta_p^{s-t}\mathbb{E}_t\{\Theta_{t,s}\Pi_s^i/(1+\tau_s^d)\}$ subject to the evolution of price constraint under no adjustment, $P_{Hs}(i) = \bar{P}_{Ht}(i)$. We can therefore rewrite the problem of the firm as:

$$\max_{\bar{P}_{Ht}(i),\{N_s(i)\}} \mathbb{E}_t\sum_{s\geq t}\frac{\theta_p^{s-t}\Theta_{t,s}}{1+\tau_s^d}\left[(1-\tau_s^v)\bar{P}_{Ht}(i)\left(\frac{\bar{P}_{Ht}(i)}{P_{Hs}}\right)^{-\rho}(C_{Hs}+C_{Hs}^*) - \left(1-\varsigma_s^p\right)W_sN_s(i)\right]$$

subject to

$$\left(\frac{\bar{P}_{Ht}(i)}{P_{Hs}}\right)^{-\rho}(C_{Hs}+C_{Hs}^*) = A_sZ_s(i)N_s(i)^{\alpha}, \quad s\geq t.$$

Taking the first order conditions, we obtain the following set of equations:

$$\mathbb{E}_t\sum_{s\geq t}\frac{\theta_p^{s-t}\Theta_{t,s}}{1+\tau_s^d}\left[(1-\tau_s^v)(1-\rho)+\lambda_s\,\rho\frac{1}{\bar{P}_{Ht}(i)}\right]\left(\frac{\bar{P}_{Ht}(i)}{P_{Hs}}\right)^{-\rho}(C_{Hs}+C_{Hs}^*) = 0$$

and

$$\left(1-\varsigma_s^p\right)W_s = \lambda_s\,\alpha A_sZ_s(i)N_s(i)^{\alpha-1}, \quad s\geq t,$$

where $\{\lambda s\}$ are scaled Lagrange multipliers on the constraint. Substituting the second set of FOCs into the first one to express out λ_s, rearranging and multiplying through by $\bar{P}_{Ht}(i)^{1+\rho}/(1-\rho)$, we arrive at the price setting condition (13) in the text.

For the case of LCP, we follow similar steps with the exception that the law of one price no longer holds. We then arrive at the following price-setting problem of the firm:

$$\max_{\bar{P}_{Ht}(i),\bar{P}_{Ht}^*(i)\{N_s(i)\}} \mathbb{E}_t\sum_{s\geq t}\frac{\theta_p^{s-t}\Theta_{t,s}}{1+\tau_s^d}\left[(1-\tau_s^v)\bar{P}_{Ht}(i)\left(\frac{\bar{P}_{Ht}(i)}{P_{Hs}}\right)^{-\rho}C_{Hs}\right.$$
$$\left.+(1+\varsigma_s^x)\varepsilon_s\bar{P}_{Ht}^*(i)\left(\frac{\bar{P}_{Ht}^*(i)}{P_{Hs}^*}\right)^{-\rho}C_{Hs}^* - \left(1-\varsigma_s^p\right)W_sN_s(i)\right]$$

subject to

$$\left(\frac{\bar{P}_{Ht}(i)}{P_{Hs}}\right)^{-\rho} C_{Hs} + \left(\frac{\bar{P}^*_{Ht}(i)}{P^*_{Hs}}\right)^{-\rho} C^*_{Hs} = A_s Z_s(i) N_s(i)^{\alpha}, \quad s \geq t.$$

Similar steps as above result in the two price setting conditions (14)-(15) in the text.

Finally, price setting equation (17) under LCP for foreign firms is the foreign counterpart to (15) with $(1 + \varsigma^x_s)$ replaced with $(1 - \tau^v_s)/[(1 + \tau^m_s)\varepsilon_s]$ and $(1 - \varsigma^p_s)$ absent. Foreign price setting in the foreign markets both under PCP and LCP are direct counterparts to (13) and (14) with all taxes set to zero.

Consumer problem and wage setting The problem of a home household *h* can be described by the following pair of Bellman equations

$$J^h_t = \max_{C^h_t, M^h_t, N^h_t, \{B^{j,h}_{t+1}\}, \bar{W}^h_t} \left\{ U\left(C^h_t, N^h_t, \frac{M^h_t(1+\varsigma^c_t)}{P_t}\right) + \beta\theta_w \mathbb{E}_t \bar{J}^h_{t+1}(W^h_t) + \beta(1-\theta_w)\mathbb{E}_t J^h_{t+1} \right\},$$

$$\bar{J}^h_t(W^h_{t-1}) = \max_{C^h_t, M^h_t, N^h_t, \{B^{j,h}_{t+1}\}} \left\{ U\left(C^h_t, N^h_t, \frac{M^h_t(1+\varsigma^c_t)}{P_t}\right) + \beta\theta_w \mathbb{E}_t \bar{J}^h_{t+1}(W^h_t) + \beta(1-\theta_w)\mathbb{E}_t J^h_{t+1} \right\},$$

where J^h_t denotes the value of the household at *t* upon adjusting its wage, and $\bar{J}^h_t$ is the value of the household which does not adjust its wage at *t*. In this later case, $W^h_t = W^h_{t-1}$, while in case of adjustment $W^h_t = \bar{W}^h_t$. In both cases, the household faces the flow budget constraint

$$\frac{P_t C^h_t}{1+\varsigma^c_t} + M^h_t + \sum\nolimits_j Q^j_t B^{j,h}_{t+1} \leq \sum\nolimits_j (Q^j_t + D^j_t) B^{j,h}_t + M^h_{t-1} + \frac{W^h_t N^h_t}{1+\tau^n_t} + \frac{\Pi_t}{1+\tau^d_t} + T_t.$$

and labor demand

$$N^h_t = \left(W^h_t / W_t\right)^{-\eta} N_t,$$

taking N_t, W_t and other prices as given, and given individual state vector $(\{B^{h,j}_t\}, M^h_{t-1})$.

Substitute labor demand into the utility and the budget constraint, and denote by μ^h_t a Lagrange multiplier on the budget constraint. Note that there exists a separate budget constraint for each state of the world at each date. The description of the state of the world includes whether the household resets its wage rate.[34] The first order condition with respect to C^h_t results in $U^h_{Ct} \equiv (C^h_t)^{-\sigma} = \mu^h_t P_t/(1+\varsigma^c_t)$, and therefore the stochastic discount factor $\Theta^h_{t,s} \equiv \beta^{s-t}\mu^h_s/\mu^h_t$ can be written as in (3). With this, the first order conditions with respect to $B^{j,h}_{t+1}$ and M^h_t result in (4) and (5).

Now consider wage setting and employment choice. Given W^h_t, N^h_t has to satisfy labor demand, and the optimality conditions (FOC and Envelope theorem) for the choice of $\bar{W}^h_t$ are:

$$0 = \eta\kappa\left(\bar{W}^h_t\right)^{-\eta(1+\varphi)-1}\left(W^\eta_t N_t\right)^{1+\varphi} + \frac{\mu^h_t}{1+\tau^n_t}(1-\eta)(\bar{W}^h_t)^{-\eta} W^\eta_t N_t + \beta\theta_w \mathbb{E}_t \frac{\partial \bar{J}^h_{t+1}}{\partial W^h_t},$$

[34] If households have access to a complete set of Arrow bonds, at least traded domestically, the risk is then shared across states when households adjust and do not adjust their wage rates. Since wage-adjustment event is an idiosyncratic risk, Θ^h_{t+1} and μ^h_{t+1} do not depend on whether the household adjusts its wage, and furthermore *h* index can be dropped altogether in this case.

$$\frac{\partial \bar{J}_t^h}{\partial W_{t-1}^h} = \eta\kappa\left(\bar{W}_t^h\right)^{-\eta(1+\varphi)-1}\left(W_t^\eta N_t\right)^{1+\varphi} + \frac{\mu_t^h}{1+\tau_t^n}(1-\eta)(\bar{W}_t^h)^{-\eta}W_t^\eta N_t + \beta\theta_w \mathbb{E}_t \frac{\partial \bar{J}_{t+1}^h}{\partial W_t^h}.$$

Combining these two conditions and solving forward imposing a terminal condition, we obtain the optimality condition for wage setting:

$$\mathbb{E}_t \sum_{s\geq t}(\beta\theta_w)^{s-t}\left[\eta\kappa\left(\bar{W}_t^h\right)^{-\eta(1+\varphi)-1}\left(W_s^\eta N_s\right)^{1+\varphi} + \frac{\mu_s^h}{1+\tau_s^n}(1-\eta)(\bar{W}_t^h)^{-\eta}W_s^\eta N_s\right] = 0.$$

Substituting in μ_s^h and doing standard manipulations results in equation (20) in the text.

A.2 Omitted details in the proof of Proposition 4

To prove the last statement of the proposition, we make use of the budget constraint of the home country (24):

$$\frac{1}{\varepsilon_t}\mathbb{E}_t\{\Theta_{t,t+1}\varepsilon_{t+1}B_{t+1}^*\} - B_t^* = P_{Ht}^* C_{Ht}^* - P_{Ft}C_{Ft}\frac{1}{\varepsilon_t}\frac{1-\tau_t^v}{1+\tau_t^m},$$

where now $B_t^* = \int_{j\epsilon J_{t-1}}(Q_t^{j*} + D_t^{j*})B_t^j dj$ is the foreign-currency equilibrium payoff of the home country international asset portfolio at t (in a given state of the world), or equivalently the foreign-currency net foreign assets (inclusive of period t returns) of the home country in the beginning of period t.[35]

Using the NX_t notation, we can rewrite

$$\frac{1}{\varepsilon_t}\mathbb{E}_t\{\Theta_{t,t+1}\varepsilon_{t+1}B_{t+1}^*\} - B_t^* = \frac{NX_t}{(1+\delta_t)\varepsilon_0},$$

where we have used the fact that $\varepsilon_t(1+\tau_t^m)/(1-\tau_t^v) = \varepsilon_0(1+\delta_t)$ under both nominal and fiscal devaluations. We now specialize to the case of a one-time unanticipated fiscal devaluation under which $\varepsilon_t \equiv \varepsilon_0$and $\delta_t = \delta$ for $t \geq 0$. In this case, solving the above equation forward starting from $t = 0$, we obtain:

$$B_0 = \varepsilon_0 B_0^* = -\sum_{t=0}^{\infty}\mathbb{E}_0\left\{\Theta_{0,t}\frac{NX_t}{1+\delta}\right\},$$

where we have imposed the transversality condition for the country international portfolio. Expressing out $NX_t/(1+\delta)$ from (33) and substituting it into the intertemporal budget constraint, we obtain

$$B_0 = \sum_{t=0}^{\infty}\mathbb{E}_0\left\{\Theta_{0,t}\frac{TR_t}{\delta}\right\} - S_{H0}, \quad where \quad Q_0^{he} = \sum_{t=0}^{\infty}\mathbb{E}_0\left\{\Theta_{0,t}\frac{\Pi_t}{1+\tau_t^d}\right\}$$

is the (shadow) value of the home stock market. Combining and multiplying through by δ results in the expression in the text of the proof.

[35] Note that $\frac{1}{\varepsilon_t}\mathbb{E}_t\{\Theta_{t,t+1}\varepsilon_{t+1}B_{t+1}^*\} = \mathbb{E}_t\{\Theta_{t,t+1}^* B_{t+1}^*\}$ is the period t foreign-currency value of holding a state-contingent net foreign asset position B_{t+1}^* in period $t+1$, where the equality holds in view of the risk sharing conditions (26).

A.3 Model with capital

We adopt a formalization where firms rent the services from labor and capital on centralized markets, at prices W_t and R_t, and capital is accumulated by households according to

$$K_{t+1} = K_t(1 - \delta) + I_t$$

where gross investment I_t combines the different goods in the exact same way as the consumption bundle C_t.

Households face the following sequence of budget constraints:

$$\frac{P_t C_t}{1+\varsigma_t^c} + M_t + \sum_{J\epsilon J_t} Q_t^j B_{t+1}^j + \frac{P_t I_t}{1+\varsigma_t^I} \leq \sum_{J\epsilon J_{t-1}} (Q_t^j + D_t^j) B_t^j + M_{t-1} + \frac{R_t K_t}{1+\tau_t^K} + \frac{W_t N_t}{1+\tau_t^\eta} + \frac{\Pi_t}{1+\tau_t^d} + T_t.$$

where ς_t^I is an investment tax credit and τ_t^K is a tax on capital income.

The households first-order conditions are the same as in the model without capital with the addition of one more first-order condition for capital accumulation:

$$\frac{C_t^{-\sigma}(1+\varsigma_t^c)}{(1+\varsigma_t^I)} = \beta \mathbb{E}_t C_{t+1}^{-\sigma} \left[\frac{R_{t+1}(1+\varsigma_{t+1}^c)}{P_{t+1}(1+\tau_{t+1}^K)} + (1-\delta)\frac{(1+\varsigma_{t+1}^c)}{(1+\varsigma_{t+1}^I)} \right],$$

corresponding to the Euler equation in the text.

On the production side we assume that each firm operates a neoclassical production function, which for concreteness takes a Cobb-Douglas form:

$$Y_t(i) = A_t Z_t(i) N_t(i)^\alpha K_t(i)^{1-\alpha}$$

where $K_t(i)$ is the firm's capital input. Profits are given by:

$$\Pi_t^i = (1-\tau_t^v) P_{Ht}(i) Y_t(i) - \left(1-\varsigma_t^p\right) W_t N_t(i) - (1-\varsigma_t^R) R_t K_t(i),$$

where ς_t^R is the capital subsidy. The pricing equations are symmetric to the ones previously described with the difference that marginal cost is now equal to

$$\left[\frac{\left(\left(1-\varsigma_s^p\right) W_s\right)^\alpha ((1-\varsigma_s^R) R_s)^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} A_s Z_s(i)} \right]$$

instead of $(1-\varsigma_s^p) W_s / [\alpha A_s Z_s(i) N_s(i)^{\alpha-1}]$, and hence price setting imposes exactly the same requirements on fiscal devaluation policies as in the economy without capital.

In addition, the firm's optimal mix of labor and capital use is given by:

$$\frac{N_t}{K_t} = \frac{\alpha}{1-\alpha} \frac{(1-\varsigma_s^R) R_t}{(1-\varsigma_s^p) W_t},$$

which is the special case of the equation in the text under the Cobb-Douglas production function.

A fiscal $\{\delta_t\}$-devaluation in this economy can be engineered exactly as in Proposition 1, Lemma 1 and Proposition 2 supplemented with the following tax adjustments. For (FD') an investment subsidy and a tax on capital income $\varsigma_t^I = \tau_t^K = \varsigma_t^c = \delta_t$ are needed. For (FD"), a subsidy on the rental rate of capital $\varsigma_t^R = \varsigma_t^p = \delta_t/(1+\delta_t)$ is also needed. In the case where the fiscal devaluation is one-time unanticipated, exactly as in Proposition 3, one can dispense with the use of the consumption subsidy and income tax, as well as with the use of the investment subsidy and the tax on capital income ($\varsigma_t^c = \tau_t^n = \varsigma_t^I = \tau_t^K = 0$ for all $t \geq 0$).

A.4 Asymmetric tax pass-through

We specialize right away to the case of a one-time unanticipated devaluation and the VAT-based policy, that is we set $\tau_t^m = \varsigma_t^x = \varsigma_t^c = \tau_t^n = \tau_t^d = 0$ and only allow for non-zero τ_t^v and ς_t^p.

In case of partial indexation to tax changes defined in (34), the price setting problem of the firm under PCP becomes:

$$\max_{\bar{P}_{Ht}(i),\{N_s(i)\}} \mathbb{E}_t \sum_{s\geq t} \theta_p^{s-t} \Theta_{t,s} \left[(1-\tau_s^v) \hat{P}_{Hs}(i) \left(\frac{\hat{P}_{Hs}(i)}{P_{Hs}} \right)^{-\rho} (C_{Hs} + C_{Hs}^*) - \left(1-\varsigma_s^p\right) W_s N_s(i) \right]$$

subject to

$$\left(\frac{\hat{P}_{Hs}(i)}{P_{Hs}} \right)^{-\rho} (C_{Hs} + C_{Hs}^*) = A_s Z_s(i) N_s(i)^{\alpha}, \quad s \geq t,$$

Where

$$\hat{P}_{Hs}(i) = \left(\frac{1-\tau_s^v}{1-\tau_t^v} \right)^{-\xi v} \left(\frac{1-\varsigma_s^p}{1-\varsigma_t^p} \right)^{\xi p} \bar{P}_{Ht}$$

is the price of the firm in period s condition on the last price adjustment of the firm being at $t \leq s$. Following the same steps as in Appendix A.1, we derive the price setting optimality condition:

$$\mathbb{E}_t \sum_{s\geq t} \theta_p^{s-t} \Theta_{t,s} \left[(1-\tau_s^v) \left(\frac{1-\tau_s^v}{1-\tau_t^v} \right)^{-\xi v} \left(\frac{1-\varsigma_s^p}{1-\varsigma_t^p} \right)^{\xi p} \bar{P}_{Ht}(i) - \frac{\frac{\rho}{\rho-1}\left(1-\varsigma_s^p\right) W_s}{\alpha A_s Z_s(i) N_s(i)^{\alpha-1}} \right] \left(\frac{\hat{P}_{Hs}(i)}{P_{Hs}} \right)^{-\rho} (C_{Hs} + C_{Hs}^*) = 0.$$

Using (2) and the Calvo assumption, the evolution of the price index is given by

$$P_{Ht} = \left[\theta_p \left(\left(\frac{1-\tau_t^v}{1-\tau_{t-1}^v} \right)^{-\xi v} \left(\frac{1-\varsigma_t^p}{1-\varsigma_{t-1}^p} \right)^{\xi p} P_{H,t-1} \right)^{1-\rho} + \int_{\theta_p}^{1} \bar{P}_{Ht}(i)^{1-\rho} di \right]^{1/(1-\rho)},$$

where we sorted the firms so that the first θ_p of them do not adjust prices at t.

As discussed in the text, exact fiscal implementation is impossibly with asymmetric pass-through, and therefore we focus on the first-order accurate implementation by which we ensure that the first-order dynamics of all aggregate prices, in particular P_{Ht}, is unchanged under a nominal and a

fiscal devaluation.[36] To this end, we log linearize the price setting and the price index evolution equations above:

$$\bar{p}Ht = (1-\beta\theta)\sum\nolimits_{s\geq t}\left(\beta\theta_p\right)^{s-t}\mathbb{E}_t\{\hat{t}_t^v - \hat{\varsigma}_t^p - \xi_v(\hat{t}_s^v - \hat{t}_t^v) + \xi_p(\hat{\varsigma}_s^p - \hat{\varsigma}_t^p + \widehat{mc}_s\},$$

$$pHt = \theta_p\left(pH, t-1 + \xi_v\Delta\hat{t}_t^v - \xi_p\Delta\hat{\varsigma}_t^p\right) + \left(1-\theta_p\right)\bar{p}Ht,$$

where small letters denote logs of respective variables, $\hat{t}_t^v = -\log(1-\tau_t^v)$, $\hat{\varsigma}_t^p = -\log\left(1-\varsigma_t^p\right)$, $\bar{p}Ht$ is the average reset price across all adjusting firms, $\widehat{mc}_s = \log[\rho/(\rho-1)] + w_s - log\alpha - a_s + (1-\alpha)n_s$ is the average marginal cost in the cross-section of firms (averaging out idiosyncratic productivity shocks) adjusted by markup.

Following the conventional steps in the New Keynesian literature (see Galí, 2008), we can solve this system to obtain a dynamic equation for aggregate price index (an analog to the New Keynesian Phillips curve):

$$\left(\Delta pHt - \xi_v\Delta\hat{t}_t^v + \xi_p\Delta\hat{\varsigma}_t^p\right) = \beta\mathbb{E}_t\{\Delta pH, t+1 - \xi_v\Delta\hat{t}_{t+1}^v + \xi_p\Delta\hat{\varsigma}_{t+1}^p\} + \lambda\left(\hat{t}_t^v - \hat{\varsigma}_t^p + \widehat{mc}_t\right), \tag{35}$$

where $\lambda = (1-\theta_p)(1-\beta\theta_p)/\theta_p$. Under a fiscal devaluation, the dynamics of both pHt and $\widehat{mc}_t$ replicates those under a nominal devaluation, which satisfy (35) with all taxes set to zero. This implies that the path of taxes must satisfy the following difference equation:

$$\left(\xi_v\Delta\hat{t}_t^v - \xi_p\Delta\hat{\varsigma}_t^p\right) - \beta\{\xi_v\Delta\hat{t}_{t+1}^v - \xi_p\Delta\hat{\varsigma}_{t+1}^p\} = \lambda\left(\hat{\varsigma}_t^p - \hat{t}_t^v\right), \tag{36}$$

where we have dropped the expectation as we are looking for a non-stochastic implementation of a one-time fiscal devaluation for $t \geq 0$.

In this PCP economy, the law of one price equations (12)-(16) are satisfied, and therefore a VAT-based fiscal devaluation policy requires $\tau_t^v = \delta/(1+\delta)$, or equivalently $\hat{t}_t^v = \log(1+\delta) \equiv \hat{\delta}$, for $t \geq 0$. This implies that $\Delta\hat{t}_t^v = 0$ for $t \geq 1$ and $\Delta\hat{t}_0^v = \hat{\delta}$. Combining this information with (36), we obtain a dynamic equation for $\hat{\varsigma}_t$:[37]

$$\Delta\hat{\varsigma}_t^p - \beta\Delta\hat{\varsigma}_{t+1}^p = \frac{\xi_v}{\xi_p}\hat{\delta}\mathbb{I}_{\{t=o\}} - \frac{\lambda}{\xi_p}\left(\hat{\varsigma}_t^p - \hat{\delta}\right).$$

The initial condition for this dynamic equation is $\hat{\varsigma}_{-1}^p = 0$, and the stationarity of $\hat{\varsigma}_t$ implies a terminal condition $\lim_{t\to\infty}\hat{\varsigma}_t^p = \hat{\delta}$.

To solve this dynamic equation, rewrite it as:

$$\left(1+\beta+\frac{\lambda}{\xi_p}\right)\left(\hat{\varsigma}_t^p - \hat{\delta}\right) - \left(\hat{\varsigma}_{t-1}^p - \hat{\delta}\right) - \beta\left(\hat{\varsigma}_{t+1}^p - \hat{\delta}\right) = \frac{\xi_v}{\xi_p}\hat{\delta}\mathbb{I}_{\{t=o\}}.$$

Note that it can be further rewritten using lag-operator as:

---

[36] In fact, one could mimic price indexes exactly, but not the whole distribution of individual prices. The policy that exactly replicates the aggregate prices is, however, non-analytic and solves a dynamic non-linear difference equation.

[37] These calculations are done under the assumption $\xi_p > 0$. In the case of $\xi_p = 0$, the solution to (36) is immediately characterized by $\hat{\varsigma}_t^p = \hat{\delta}$ for $t > 0$ and $\hat{\varsigma}_0^p = \hat{\delta}(1+\lambda/\xi_v)$.

$$\rho_2(1-\rho_1 L^{-1})(1-\rho_2^{-1}L)\left(\hat{\varsigma}_t^p-\hat{\delta}\right)=\frac{\xi_v}{\xi_p}\hat{\delta}\mathbb{I}_{\{t=o\}},$$

where $L\hat{\varsigma}_t^p=\hat{\varsigma}_{t-1}^p$ is the lag operator, and $0<\rho 1<1<\rho 2$ are the two roots of $x^2-(1+\beta+\lambda/\xi_p)x-\beta=0$. Inverting the first bracket with the lead operator, we arrive at:

$$\left(\hat{\varsigma}_t^p-\hat{\delta}\right)-\rho_2^{-1}\left(\hat{\varsigma}_{t-1}^p-\hat{\delta}\right)=\rho_2^{-1}\frac{\xi_v}{\xi_p}\hat{\delta}\mathbb{I}_{\{t=o\}},$$

which, taking into account the initial condition, has the solution:

$$\hat{\varsigma}_0^p-\hat{\delta}=\rho_2^{-1}\frac{\xi_v-\xi_p}{\xi_p}\quad and\quad \hat{\varsigma}_t^p-\hat{\delta}=\rho_2^{-1}\left(\hat{\varsigma}_0^p-\hat{\delta}\right).$$

This can be simplified to:

$$\hat{\varsigma}_t^p-\hat{\delta}\left(1+\rho_2^{-(t+1)}\frac{\xi_v-\xi_p}{\xi_p}\right).$$

Finally, note that $\rho=\rho_2^{-1}\epsilon(0,1)$ is also one of the roots of $1-(1+\beta+\lambda/\xi_p)x-\beta x^2=0$. Exponentiating this solution results in the expression in Propostion 7.

Note that under this fiscal devaluation, we first-order replicate the aggregate prices, $\{P_{Ht},P_{Ht}^*,P_{Ft},P_{Ft}^*\}$, and therefore also terms of trade. Given prices, the rest of the allocation is unchanged provided that the relative consumption is the same, which is ensured by the unchanged country budget constraint and risk-sharing condition.

References

ADAO, B., I. CORREIA, AND P. TELES (2009): "On the relevance of exchange rate regimes for stabilization policy," *Journal of Economic Theory*, 144(4), 1468-1488.

ANDRADE, P., M. CARRÉ, AND A. BÉNASSY-QUÉRÉ (2010): Competition and pass-through on international markets: Firm-level evidence from VAT shocks," CEPII.

ATKESON, A., AND A. BURSTEIN (2008): "Pricing-to-Market, Trade Costs, and International Relative Prices," *American Economic Review*, 98(5), 1998-2031.

BENIGNO, G., P. BENIGNO, AND F. GHIRONI (2007): "Interest rate rules for fixed exchange rate regimes," *Journal of Economic Dynamics and Control*, 31(7), 2196-2211.

BENIGNO, G., AND H. KUCUK-TUGER (2012): "Portfolio allocation and International Risk Sharing," *Canadian Journal of Economics*, 45(2), 535-565.

BERGLAS, E. (1974): "Devaluation, Monetary Policy, and Border Tax Adjustment," *Canadian Journal of Economics*, 7(1), 1-11.

BOSCAM, J. E., A. DIAZ, R. DOMENECH, J. FERRI, E. PEREZ, AND L. PUCH (2011): "REMS: A Rational Expectations Model for Simulation and Policy Evaluation of the Spanish Economy," in *The Spanish Economy: A General Equilibrium Perspective*, ed. by J. Bosca, R. Domenech, J. Ferri, and J. Varela. Palgrave Macmillan.

CALMFORS, L. (1998): "Macroeconomic Policy, Wage Setting and Employment-What difference does the EMU make?," *Oxford Review of Economic Policy*, 14(3), 125-151.

CAMPA, J. M., L. S. GOLDBERG, AND J. M. GONZÁLEZ-MÍNGUEZ (2005): "Exchange-Rate Pass-Through to Import Prices in the Euro Area," NBER Working Papers No. 11632.

CARARE, A., AND S. DANNINGER (2008): "Inflation Smoothing and the Modest Effect of VAT in Germany," IMF Working Papers No. 08/175.

CARBONNIER, C. (2007): "Who pays sales taxes? Evidence from French VAT reforms, 1987 1999," *Journal of Public Economics*, 91(5-6), 1219-1229.

CORREIA, I., E. FARHI, J. P. NICOLINI, AND P. TELES (2011): Unconventional Fiscal Policy at the Zero Bound," NBER Working Papers No. 16758.

CORREIA, I., J. P. NICOLINI, AND P. TELES (2008): "Optimal Fiscal and Monetary Policy: Equivalence Results," *Journal of Political Economy*, 116(1), 141-170.

CORSETTI, G. (2008): "New Open Economy Macroeconomics," in *The New Palgrave Dictionary of Economics*, ed. by S. N. Durlauf, and L. E. Blume. Palgrave Macmillan, Basingstoke.

DEVEREUX, M. B., AND C. ENGEL (2007): "Expenditure switching versus real exchange rate stabilization: Competing objectives for exchange rate policy, *Journal of Monetary Economics*, 54(8), 2346-2374.

DEVEREUX, M. B., AND A. SUTHERLAND (2008): "Country Portfolios in Open Economy Macro Models," NBER Working Papers No. 14372.

EGGERTSSON, G. (2004): "Comment on How Do Monetary and Fiscal Policy Interact in the European Monetary Union?, NBER *International Seminar on Macroeconomics*, pp.241-325.

FELDSTEIN, M. S., AND P. R. KRUGMAN (1990): "International Trade Effects of Value-Added Taxation," in *Taxation in the Global Economy*, NBER Chapters, pp. 263-282. National Bureau of Economic Research, Inc.

FRANCO, F. (2011): "Improving competitiveness through fiscal devaluation, the case of Portugal," Universidade Nova de Lisboa.

GALÍ, J. (2008): *Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

GOURINCHAS, P.-O., AND H. REY (2007): From World Banker to World Venture Capi- talist: U.S. External Adjustment and the Exorbitant Privilege, in G7 Current Account Imbalances: Sustainability and Adjustment, NBER Chapters, pp. 11 66. National Bureau of Economic Research, Inc.

GROSSMAN, G. M. (1980): "Border tax adjustments: Do they distort trade?," *Journal of International Economics*, 10(1), 117-128.

HEVIA, C., AND J. P. NICOLINI (2011): "Optimal Devaluations," Federal Reserve Bank of Minneapolis.

IMF STAFF (2011): *Fiscal Monitor: Addressing Fiscal Challenges to Reduce Economic Risks*. International Monetary Fund.

KIMBALL, M. (1995): "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, 27, 1241-77.

LANE, P. R. (2001): "The new open economy macroeconomics: a survey," *Journal of International Economics*, 54(2), 235-266.

LIPIŃSKA, A., AND L. VON THADDEN (2009): "Monetart and Fiscal Policy Aspects of Indirect Tax Changes in a Monetaty Union, ECB Working Papers No. 1097.

OBSTFELD, M., AND K. ROGOFF (2000): "New Directions for Stochastic Open Economy Models," *Journal of International Economics*, 50, 117-153.

OBSTFELD, M., J. C. SHAMBAUGH, AND A. M. Taylor (2010): "Financial Stability, the Trilemma, and International Reserves," *American Economic Journal: Macroeconomics*, 2(2), 57-94.

POTERBA, J. M., J. J. ROTEMBERG, AND L. H. SUMMERS (1986): "A Tax-Based Test for Nominal Rigidities," *American Economic Review*, 76(4), 659-75.

SCHMITT-GROHÉ, S., AND M. URIBE (2011): "Pegs and Pain, Columbia Univeristy.

SILVA, S. J., AND S. TENREYRO (2010): "Currency Unions in Prospect and Retrospect, *Annual Review of Economics*, 2, 51-74.

STAIGER, R. W., and A. O. SYKES (2010): "'Currency manipulation' and world trade," *World Trade Review*, 9(4), 583-627.

WOODFORD, M. (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press.

Recent Working Papers

229 Fiscal Empowerment of Panchayats in India: Real or Rhetoric?
M Devendra Babu

230 Energy Use Efficiency in Indian Cement Industry: Application of Data Envelopment Analysis and Directional Distance Function
Sabuj Kumar Mandal and S Madheswaran

231 Ethnicity, Caste and Community in a Disaster Prone Area of Orissa
Priya Gupta

232 Koodankulam Anti-Nuclear Movement: A Struggle for Alternative Development?
Patibandla Srikant

233 History Revisited: Narratives on Political and Constitutional Changes in Kashmir (1947-1990)
Khalid Wasim Hassan

234 Spatial Heterogeneity and Population Mobility in India
Jajati Keshari Parida and S Madheswaran

235 Measuring Energy Use Efficiency in Presence of Undesirable Output: An Application of Data Envelopment Analysis (DEA) to Indian Cement Industry
Sabuj Kumar Mandal and S Madheswaran

236 Increasing trend in Caesarean Section Delivery in India: Role of Medicalisation of Maternal Health
Sancheetha Ghosh

237 Migration of Kashmiri Pandits: Kashmiriyat Challenged?
Khalid Wasim Hassan

238 Causality Between Energy Consumption and Output Growth in Indian Cement Industry: An Application of Panel Vector Error Correction Model
Sabuj Kumar Mandal and S Madheswaran

239 Conflict Over Worship:A Study of the Sri Guru Dattatreya Swami Bababudhan Dargah in South India
Sudha Sitharaman

240 Living Arrangement Preferences of the Elderly in Orissa, India
Akshaya Kumar Panigrahi

241 Challenges and Pospects in the Measurement of Trade in Services
Krushna Mohan Pattanaik

242 Dalit Movement and Emergence of the Bahujan Samaj Party in Uttar Pradesh: Politics and Priorities
Shyam Singh

243 Globalisation, Democratic Decentralisation and Social Secutiry in India
S N Sangita and T K Jyothi

244 Health, Labour Supply and Wages: A Critical Review of Literature
Amrita Ghatak

245 Is Young Maternal Age A Risk Factor for Sexually Transmitted Diseases and Anemia in India? An Examination in Urban and Rural Areas
Kavitha N

246 Patterns and Determinants of Female Migration in India: Insights from Census
Sandhya Rani Mahapatro

247 Spillover Effects from Multinational Corporations: Evidence From West Bengal Engineering Industries
Rajdeep Singha and K Gayithri

248 Effectiveness of SEZs Over EPZs Structure: The Performance at Aggregate Level
Malini L Tantri

249 Income, Income Inequality and Mortality An empirical investigation of the relationship in India, 1971-2003
K S James and T S Syamala

250 Institutions and their Interactions: An Economic Analysis of Irrigation Institutions in the Malaprabha Dam Project Area, Karnataka, India
Durba Biswas and L Venkatachalam

251 Performance of Indian SEZs: A Disaggregated Level Analysis
Malini L Tantri

252 Banking Sector Reforms and NPA: A study of Indian Commercial Banks
Meenakshi Rajeev and H P Mahesh

253 Government Policy and Performance: A Study of Indian Engineering Industry
Rajdeep Singha and K Gayithri

254 Reproduction of Institutions through People's Practices: Evidences from a Gram Panchayat in Kerala
Rajesh K

255 Survival and Resilience of Two Village Communities in Coastal Orissa: A Comparative Study of Coping with Disasters
Priya Gupta

256 Engineering Industry, Corporate Ownership and Development: Are Indian Firms Catching up with the Global Standard?
Rajdeep Singha and K Gayithri

257 Scheduled Castes, Legitimacy and Local Governance: Continuing Social Exclusion in Panchayats
Anand Inbanathan and N Sivanna

258 Plant-Biodiversity Conservation in Academic Institutions: An Efficient Approach for Conserving Biodiversity Across Ecological Regions in India
Sunil Nautiyal

259 WTO and Agricultural Policy in Karnataka
Malini L Tantri and R S Deshpande

260 Tibetans in Bylakuppe: Political and Legal Status and Settlement Experiences
Tunga Tarodi

261 Trajectories of China's Integration with the World Economy through SEZs: A Study on Shenzhen SEZ
Malnil L Tantri

262 Governance Reforms in Power Sector: Initiatives and Outcomes in Orissa
Bikash Chandra Dash and S N Sangita

263 **Conflicting Truths and Contrasting Realities: Are Official Statistics on Agrarian Change Reliable?**
V Anil Kumar

264 **Food Security in Maharashtra: Regional Dimensions**
Nitin Tagade

265 **Total Factor Productivity Growth and Its Determinants in Karnataka Agriculture**
Elumalai Kannan

266 **Revisiting Home: Tibetan Refugees, Perceptions of Home (Land) and Politics of Return**
Tarodi Tunga

267 **Nature and Dimension of Farmers' Indebtedness in India and Karnataka**
Meenakshi Rajeev and B P Vani

268 **Civil Society Organisations and Elementary Education Delivery in Madhya Pradesh**
Reetika Syal

269 **Burden of Income Loss due to Ailment in India: Evidence from NSS Data**
Amrita Ghatak and S Madheswaran

270 **Progressive Lending as a Dynamic Incentive Mechanism in Microfinance Group Lending Programmes: Empirical Evidence from India**
Naveen Kumar K and Veerashekharappa

271 **Decentralisation and Interventions in Health Sector: A Critical Inquiry into the Experience of Local Self Governments in Keral**
M Benson Thomas and K Rajesh

272 **Determinants of Migration and Remittance in India: Empirical Evidence**
Jajati Keshari Parida and S Madheswaran

273 **Repayment of Short Term Loans in the Formal Credit Market: The Role of Accessibility to Credit from Informal Sources**
Manojit Bhattacharjee and Meenkashi Rajeev

274 **Special Economic Zones in India: Are these Enclaves Efficient?**
Malini L Tantri

275 **An Investigation into the Pattern of Delayed Marriage in India**
Baishali Goswami

276 **Analysis of Trends in India's Agricultural Growth**
Elumalai Kannan and Sujata Sundaram

277 **Climate Change, Agriculture, Poverty and Livelihoods: A Status Report**
K N Ninan and Satyasiba Bedamatta

278 **District Level NRHM Funds Flow and Expenditure: Sub National Evidence from the State of Karnataka**
K Gayithri

279 **In-stream Water Flows: A Perspective from Downstream Environmental Requirements in Tungabhadra River Basin**
K Lenin Babu and B K Harish Kumara

280 **Food Insecurity in Tribal Regions of Maharashtra: Explaining Differentials between the Tribal and Non-Tribal Communities**
Nitin Tagade

281 **Higher Wages, Cost of Separation and Seasonal Migration in India**
Jajati Keshari Parida and S Madheswaran

282 **Pattern of Mortality Changes in Kerala: Are they Moving to the Advanced Stage?**
M Benson Thomas and K S James

283 **Civil Society and Policy Advocacy in India**
V Anil Kumar

284 **Infertility in India: Levels, Trends, Determinants and Consequences**
T S Syamala

285 **Double Burden of Malnutrition in India: An Investigation**
Angan Sengupta and T S Syamala

286 **Vocational Education and Child Labour in Bidar, Karnataka, India**
V Anil Kumar

287 **Politics and Public Policies: Politics of Human Development in Uttar Pradesh, India**
Shyam Singh and V Anil Kumar

288 **Understanding the Fiscal Implications of SEZs in India: An Exploration in Resource Cost Approach**
Malini L Tantri

289 **Does Higher Economic Growth Reduce Poverty and Increase Inequality? Evidence from Urban India**
Sabyasachi Tripati

Price: Rs. 30.00

ISBN 978-81-7791-146-6

INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
Dr V K R V Rao Road, Nagarabhavi P.O., Bangalore - 560 072, India
Phone: 0091-80-23215468, 23215519, 23215592; Fax: 0091-80-23217008
E-mail: lekha@isec.ac.in; Web: www.isec.ac.in