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Bretton Woods and the Reconstruction of Europe

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Abstract

The Bretton Woods international financial system, which was in place from roughly 1949 to 1973, is the most significant modern policy experiment to attempt to simultaneously manage international payments, international capital flows, and international currency values. This paper uses an international macroeconomic accounting methodology to study the Bretton Woods system and finds that it: (1) significantly distorted both international and domestic capital markets and hence the accumulation and allocation of capital; (2) significantly slowed the reconstruction of Europe, albeit while limiting the indebtedness of European countries. Our results also provide support for the utility of the accounting methodology in that it finds a sharp change in the behavior of domestic and international capital market wedges that coincides with the breakdown of the system.

Keywords: Bretton Woods, International Payments, Capital Flows.

JEL Codes: E21, F21, F41, J20.

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1 Introduction

The Bretton Woods international financial system, which was in place from roughly 1949-1973, is the most significant modern policy experiment to attempt to simultaneously manage international payments, international capital flows, and international currency values. Because of the uniqueness of Bretton Woods, there are thousands of studies of this system, with almost all focusing on why the system ultimately failed in 1973, and the consequences of the shift from fixed to flexible exchange rates. In contrast, this paper studies the impact of the Bretton Woods system on the reconstruction of Europe, with a particular focus on the system's constraints on the operation of both domestic and international capital markets. We find these constraints acted to significantly slow the reconstruction of Europe, albeit with the benefit that Europe emerged from reconstruction significantly less indebted.

Studies of the effect of the Bretton Woods system on the international economy, and evaluations of the success of the system in achieving its aims, are challenging for a number of reasons. One reason is that the Bretton Woods system had multidimensional objectives, involving the management of real variables, such as international capital flows and international trade in goods, and also of nominal variables, such as exchange rates. This in turn affected many different types of policies within a country, ranging from monetary policies to capital market policies, as well as possible interrelationships between these policies. Another reason is that many different global economic changes occurred during the Bretton Woods period that obscure its effects. These range from the very rapid economic growth of Western Europe and Japan, to U.S. fiscal and monetary pressures generated by the escalation of the Vietnam War and the Cold War, to growing economic openness and globalization facilitated by GATT.

In light of these challenges, this paper employs an open economy, general equilibrium capital flows accounting framework developed in (Ohanian, Restrepo-Echavarria, and Wright (2018)) to measure the effects of these multidimensional policies on the different dimensions of the international economy. This approach is well-suited to study the consequences of Bretton Wood precisely because of its multi-dimensional policies and objectives. To conduct the analysis, we divide the world economy into three regions: the two major regions within the Bretton Woods agreement, (1) the U.S., and (2) western and northern Europe, and (3) the Rest of the World. The framework accounts completely for observed levels of consumption, labor, investment, output, and capital flows in each of these three regions with a relatively small number of identified wedges. These include the efficiency, labor, capital, and government wedges as developed in Chari, Kehoe, and McGrattan (2006) and Cole and Ohanian (2002), as well as the international wedge that affects the cost of international financial transactions between regions, which in turn affects region-specific capital flows and net exports. This latter wedge is of particular interest since the Bretton Woods system required that countries regulate international capital flows, which was accomplished using a variety of policy variables, including capital controls. These wedges are used to analyze the quantitative importance of various factors and hypotheses that have been suggested within the literature.

An important feature of this capital flow accounting method is that it facilitates the testing of specific hypotheses about how the wedges change over time, and the implementation of general equilibrium counterfactual analyses. We conduct a number of counterfactuals to assess how world economic activity would have been different had countries not operated within the Bretton Woods system after the war. This is very easy to do by fixing the wedges to alternative values that prevailed at the end of the war.

We emphasize three main findings. First, we find a highly statistically significant break in the joint stochastic process generating the international capital market wedges in 1973 using a Markov Switching framework. We consider this a validation of the wedges methodology as it clearly isolates a policy change that is known to have occurred at approximately that date. Second, the methodology focuses attention on the changes in the wedges that are consistent with important changes in capital controls as well as other policies that affected the international accumulation and allocation of private capital. Similarly large changes in policies affecting domestic capital markets are also identified. Interestingly, the international wedge is much more volatile before the breakdown of Bretton Woods than afterwards, suggesting that much of the literature's focus on the increase in nominal and real exchange rate volatility is misplaced. Third, we conduct a counterfactual experiment in which distortions to international capital flows are removed starting in 1950. This experiment indicates that, absent Bretton Woods controls on capital flows, the reconstruction of Europe would have been significantly faster, although it would also have been associated with a significant rise in European indebtedness.

The paper is organized as follows. Section 2 summarizes the capital flow accounting framework. Section 3 discusses the implementation. Section 4 presents the wedges and counterfactual exercises, and Section 5 concludes.

2 Capital Flow Accounting

We use the capital flow accounting framework developed in Ohanian, Restrepo-Echavarria and Wright (2018). Our method is a direct descendant of the closed economy business cycle accounting approaches of Cole and Ohanian (2002) and Chari, Kehoe, and McGrattan (2007) extended to the general equilibrium of a world economy. Unlike this earlier literature, which focuses on business cycle fluctuations in macroeconomic variables, we are also interested in medium- and long-term frequencies that play a large role in determining capital flows and hence pay particular attention to long-run trends in variables.

We start with a variant on the class of models typically used to analyze international capital flows (for example, Mendoza (1991) and Baxter and Crucini (1993, 1995)). We refer to this as our benchmark model and augment it with wedges so that it is able to exactly replicate the data on macroeconomic outcomes including capital flows. These wedges are described as taxes that distort the marginal conditions determining optimal labor supply, domestic investment, and foreign investment but stand in for a wider range of departures from our benchmark accounting framework.

2.1 Households

Consider a world economy composed of three "countries" indexed by j, where $j = U$ stands for "United States," $j = E$ stands for "Europe," and $j = R$ stands for the "rest of the world." Time evolves discretely and is indexed by $t = 0, 1, ...$, so that N_{jt} denotes the population of country j at time t. The decisions of each country are made by a representative agent with preferences over consumption C_{jt} and per capita hours worked h_{jt} ordered by

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left\{ \ln \left(\frac{C_{jt}}{N_{jt}} \right) - \frac{\varphi}{1+\gamma} h_{jt}^{1+\gamma} \right\} N_{jt} \right].$$

The parameters governing preferences—the discount factor β, the preference for leisure φ, and the Frisch elasticity of labor supply $1/\gamma$—are assumed common across countries; therefore, any cross-country differences in core preferences will hence be attributed to the wedges that we introduce next.

The problem of the representative agent of country j is to choose a state-contingent stream of consumption levels C_{jt}, hours worked h_{jt}, purchases of capital to be rented out next period K_{jt+1}, and a portfolio of state-contingent international bond holdings B_{jt+1} subject to a sequence of flow budget constraints for each state and date:

$$\begin{aligned} C_{jt} + P_{jt}^K K_{jt+1} + E_t \left[q_{t+1} B_{jt+1} \right] \quad \leq \quad & \left(1 - \tau_{jt}^h \right) W_{jt} h_{jt} N_{jt} + \left(1 - \tau_{jt}^B \right) B_{jt} + T_{jt} \\ & + \left(1 - \tau_{jt}^K \right) \left(r_{jt}^K + P_{jt}^{*K} \right) K_{jt} + \Pi_{jt}, \end{aligned}$$

with initial capital K_{j0} and bonds B_{j0} given. Here W_{jt} is the wage per hour worked, r_{jt}^K the rental rate of capital, P_{jt}^K the price of new capital goods, and P_{jt}^{*K} the price of old capital goods, which will differ from the price of new capital goods due to the presence of adjustment costs in capital. In this complete markets environment, the prices of state-contingent international bonds at time t that pay off in one state at $t+1$ are composed of a risk-adjusted world price q_{t+1} multiplied by the probability of the state occurring, which allows us to write the expected value of the risk-adjusted expenditures on bonds on the left-hand side of the flow budget constraint. Households also receive profits Π_{jt} from their ownership of domestic firms.

The τ represent taxes or "wedges" on factor payments and investment income. Specifically, τ^h is a tax on wage income (the labor wedge), τ^B is a tax on income derived from international assets or, equivalently, a subsidy on the cost of paying for international liabilities (the international wedge), while τ^K is a tax on income from domestic capital (the capital wedge). Any revenue from these taxes net of the level of government spending G_{jt} are assumed to be transferred in lump-sum fashion to or from households each period as T_{jt},

$$T_{jt} = \tau_{jt}^h W_{jt} h_{jt} N_{jt} + \tau_{jt}^B B_{jt} + \tau_{jt}^K \left(r_{jt}^K + P_{jt}^{*K}\right) K_{jt} - G_{jt}. \tag{1}$$

This implies that there is no government borrowing. As Ricardian equivalence holds in our model, this is without loss of generality. However, some authors (for example, Alfaro, Kalemli-Ozcan, and Volosovych (2014)) have argued that an understanding of government borrowing is necessary to rationalize observed capital flows.

The first-order conditions for the household can be rearranged to find the optimal condition governing the labor supply,

$$\left(1 - \tau_{jt}^h\right) W_{jt} \frac{N_{jt}}{C_{jt}} = \varphi h_{jt}^{\gamma}, \tag{2}$$

the Euler equation for domestic capital,

$$1 = E_t \left[\beta \frac{C_{jt}/N_{jt}}{C_{jt+1}/N_{jt+1}} \left(1 - \tau_{jt+1}^K\right) \frac{r_{jt+1}^K + P_{jt+1}^{*K}}{P_{jt}^K} \right], \tag{3}$$

and the Euler equation for state-contingent international assets,

$$\frac{C_{jt+1}/N_{jt+1}}{C_{jt}/N_{jt}} = \frac{\beta}{q} \left(1 - \tau_{jt+1}^B\right). \tag{4}$$

2.2 Firms

Each country is populated by two types of firms. The first type of firm hires labor and capital to produce the consumption good using a standard Cobb-Douglas technology of the form $A_{jt} K_{jt}^{\alpha} \left(h_{jt} N_{jt}\right)^{1-\alpha}$, where A_{jt} is the level of aggregate productivity in the economy and α is the output elasticity of capital. This yields expressions for the equilibrium wage rate per hour and the rental rate on capital:

$$W_{jt} = (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}}, \text{ and } r_{jt}^K = \alpha \frac{Y_{jt}}{K_{jt}}. \tag{5}$$

The second type of firm produces new capital goods K_{jt+1} using X_{jt} units of investment (deferred consumption) and K_{jt} units of the old capital good. Their objective is to maximize profits

$P^K_{jt}K_{jt+1} - X_{jt} - P^{*K}_{jt}K_{jt}$ subject to the capital production function (or capital accumulation equation) with convex adjustment costs ϕ of the form

$$K_{jt+1} = (1-\delta)K_{jt} + X_{jt} - \phi\left(\frac{X_{jt}}{K_{jt}}\right)K_{jt}.$$

Note that, although the capital good K_{jt+1} is to be used for production in period $t+1$, it is produced and sold in period t at price P^K_{jt}. This gives rise to first-order conditions:

$$P^K_{jt} = \frac{1}{1-\phi'\left(\frac{X_{jt}}{K_{jt}}\right)}, \tag{6}$$

$$P^{*K}_{jt} = P^K_{jt}\left(1-\delta-\phi\left(\frac{X_{jt}}{K_{jt}}\right)+\phi'\left(\frac{X_{jt}}{K_{jt}}\right)\frac{X_{jt}}{K_{jt}}\right). \tag{7}$$

We assume that adjustment costs are of the quadratic form:

$$\phi\left(\frac{X_{jt}}{K_{jt}}\right) = \frac{\nu}{2}\left(\frac{X_{jt}}{K_{jt}}-\kappa\right)^2.$$

All production parameters—the output elasticity of capital α, the depreciation rate δ, and those governing adjustment costs ν and κ—are assumed constant across countries.

2.3 Growth and Uncertainty

The world economy has grown substantially over the period under study. But this growth is not well represented by movements around a deterministic trend with a constant growth rate. Moreover, expectations of future growth in income drive a household's desire to save and invest and hence play a large role (in many cases, the dominant role) in determining capital flows. Hence, it is not appropriate to simply apply the Hodrick-Prescott filter to the data and proceed with a detrended model, as might be done for a business cycle accounting analysis. As a consequence, we adopt a specification for the growth of the population and productivity level in each country that allows the data to speak to us about these expectations of future trends.

We assume that there is a stochastic world trend for both population and productivity and associate this with growth in the United States (for similar approaches, see Canova (1998), Fernandez-Villaverde and Rubio-Ramirez (2007), and Cheremukhin and Restrepo-Echavarria (2014)). Specifically, we assume that the United States productivity and population evolve according to

$$\begin{aligned}\ln A_{Ut+1} &= \ln A_{Ut} + \ln\pi_{ss} + \sigma^A_U\varepsilon^A_{Ut},\\ \ln N_{Ut+1} &= \ln N_{Ut} + \ln\eta_{ss} + \sigma^N_U\varepsilon^N_{Ut},\end{aligned}$$

where π_{ss} and η_{ss} are the growth rates in U.S. productivity and population that would occur in the deterministic steady-state of our model, such that $\pi_t = \frac{A_{Ut+1}}{A_{Ut}} = \pi_{ss} \exp\left(\sigma_U^A \varepsilon_{Ut}^A\right)$ and $\eta_t = \frac{N_{Ut+1}}{N_{Ut}} = \eta_{ss} \exp\left(\sigma_U^N \varepsilon_{Ut}^N\right)$. In order to make our model of the world economy stationary, we scale by the level of effective labor in the rest of the world $Z_t = A_{Ut}^{1/(1-\alpha)} N_{Ut}$. Note that our specification nests a constant growth rate as a special case.

Population and productivity levels in Europe and the Rest of the World are assumed to evolve relative to the U.S. trend in such a way that a non-degenerate long-run distribution of economic activity across countries is preserved. Specifically, for Europe and the Rest of the World we define relative productivity $a_{jt} = A_{jt}/A_{Ut}$ and relative population $n_{jt} = N_{jt}/N_{Ut}$ and assume that both a_{jt} and n_{jt} follow first-order autoregressive processes of the form

$$\begin{aligned} \ln a_{jt+1} &= \left(1-\rho_j^a\right) \ln a_{jss} + \rho_j^a \ln a_{jt} + \sigma_j^a \varepsilon_{jt+1}^a, \\ \ln n_{jt+1} &= \left(1-\rho_j^n\right) \ln n_{jss} + \rho_j^n \ln n_{jt} + \sigma_j^n \varepsilon_{jt+1}^n. \end{aligned}$$

This allows for long-lasting deviations from the world trend. We place no further restrictions on these processes, preferring to allow the data to speak by estimating their parameters directly.

The labor, capital, and international wedges (indexed by $m = h, K$, and B) for each country are also assumed to follow univariate first-order autoregressive processes of the form

$$\ln\left(1-\tau_{jt+1}^m\right) = \left(1-\rho_j^m\right) \ln\left(1-\tau_{jss}^m\right) + \rho_j^m \ln\left(1-\tau_{jt}^m\right) + \sigma_j^m \varepsilon_{jt+1}^m, \tag{8}$$

where τ_{jss}^m is the level the wedge would take on in the deterministic steady-state of our model and ρ_j^m governs the rate of mean reversion. The evolution of the level of government spending in each country G_{jt} is assumed to be such that the ratio of government spending to national income $g_{jt} = G_{jt}/Y_{jt}$ also follows a first-order autoregressive process:

$$\ln g_{jt+1} = \left(1-\rho_j^g\right) \ln g_{jss} + \rho_j^g \ln g_{jt} + \sigma_j^g \varepsilon_{jt+1}^g.$$

The parameters of all of these processes, with the exception of the steady-state international wedge to be discussed next, are estimated from, or calibrated to, match the data.

2.4 Model Solution

Our benchmark assumes that the world economy has complete markets. Complete markets are a natural benchmark, as there are many ways in which markets can be incomplete. It is also the natural approach to modeling a world economy with very rich and complex asset trades—certainly more assets than can be accommodated in a tractable incomplete markets model. However, given our continuous state space, this means that each country has an infinite dimensional portfolio decision to make each period. In a contribution that may be of independent interest, we establish that the solution to a particular pseudo social planner's problem corresponds to the equilibrium of our complete markets economy and work directly on the pseudo social planner's problem. Appendix A describes in detail the mapping between the competitive equilibrium problem and the pseudo social planner's problem. As noted earlier, to obtain stationarity, we scale by the stochastic world trend Z_{t-1} to obtain an intensive form version of the model.

The large number of state variables (23) leads us to use perturbation methods. To do so, we make additional assumptions to ensure that the model has a unique non-degenerate deterministic steady-state (which serves as the point about which the approximation is taken). To see the need for these assumptions, note that we can take equation (4) and rearrange to obtain the first equality in

$$\frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}} = \frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}} \frac{1-\tau^B_{jt+1}}{1-\tau^B_{Rt+1}} = \frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}} \left(1-\tau^B_{jt+1}\right). \tag{9}$$

This means we cannot separately identify each country's international wedge τ^B_j, and so we normalize the rest of the world international wedge to zero, $\tau^B_{Rt+1} = 0$, yielding the second equality. It also means that, if the steady-state international wedge, τ^B_{jss}, is not equal to zero, there is a long-run trend in relative consumption levels so that the deterministic steady-state distribution of consumption is degenerate (one country's share of consumption must converge to zero). Moreover, simply assuming that $\tau^B_{jss} = 0$ for all j does not pin down a *unique* steady-state relative consumption level. Intuitively, the level of the international wedge out of steady-state affects the accumulation of international assets, which in turn affects long-run consumption levels. In terms of equation (9), the *growth rate* of relative consumption is a first-order autoregressive process that converges to zero in the deterministic steady-state; the long-run *level* of relative consumption depends upon the entire sequence of realizations of the international wedge.

Analogous issues arise in multi-agent models with heterogeneous rates of time preference (see the conjecture of Ramsey (1928), the proof of Becker (1980), and the resolution of Uzawa (1968)) and in small open economy incomplete markets models. In the latter context, a suite of alternative resolutions of this issue have been proposed (see Schmitt-Grohe and Uribe (2003) for a survey and discussion). We use a variant of the portfolio adjustment cost approach, adapted to our general equilibrium complete markets setting. Specifically, for Europe and the United States, we assume that their international wedges can be decomposed into a pure tax on international investment income τ^{*B}_{jt} and another term Ψ_{jt}, both of which the country takes as given:

$$1-\tau^B_{jt} = 1-\tau^{*B}_{jt} + \Psi_{jt}.$$

We refer to τ^{*B} as the international wedge from now on (typically suppressing the asterisk) and assume that it follows a first-order autoregressive process with the steady-state assumed to be zero:

$$\ln\left(1-\tau_{jt+1}^{*B}\right)=\rho_j^B \ln\left(1-\tau_{jt}^{*B}\right)+\sigma_j^B \varepsilon_{jt+1}^B. \tag{10}$$

The other term takes the form of a portfolio tax that is assumed, in equilibrium, to satisfy

$$\Psi_{jt}=\left(1-\tau_{jt}^{*B}\right)\left[\left(\frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}}\frac{1}{\psi_{j0}}\right)^{-\psi_{j1}}-1\right]. \tag{11}$$

This ensures that, in the deterministic steady-state, relative consumption levels are pinned down by ψ_{j0}, with mean reversion in relative consumption levels controlled by ψ_{jt} as

$$\ln\frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}}=\frac{\psi_{j1}}{1+\psi_{j1}}\ln\psi_{j0}+\frac{1}{1+\psi_{j1}}\ln\frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}}+\frac{1}{1+\psi_{j1}}\ln\left(1-\tau_{jt+1}^{*B}\right). \tag{12}$$

We refer to this as a portfolio tax because in steady-state, relative consumption levels map one-for-one into net foreign asset positions. Once again, these parameters are identified from the data, meaning that we allow the data to estimate the long-run net foreign asset position of each country.

Under these assumptions on the portfolio tax, there exists a unique non-degenerate deterministic steady-state. We proceed by taking a first-order log-linear approximation of the pseudo social planner's problem around this point.

3 Implementation

The multi-country dynamic stochastic general equilibrium model of the world economy augmented with wedges described above has been designed to exactly replicate data on the national income and product account expenditure aggregates. In this sense, the model can be used as an accounting framework for observed data. In this section, we describe how the model uses these data to identify the wedges. We then briefly describe our data sources, with a more detailed discussion available in Appendix B. To recover realizations of the capital wedge, we must compute the equilibrium of the model in order to determine expectations of future returns to capital, and so we also describe our solution method. A small number of structural parameters governing preferences and production are calibrated. Some wedges can be recovered, and the parameters governing their evolution estimated, without solving the model. The remaining parameters of the model are estimated using maximum likelihood estimation.

3.1 Using the Data to Measure the Wedges

Realizations of the labor, capital, and international wedges can all be measured by feeding data on the national income and accounting expenditure aggregates through the optimality conditions of households and firms combined with the equilibrium conditions of the model. Realizations of the labor and international wedges can be computed directly from first-order conditions without knowing the solution of the model. The capital wedge, on the other hand, requires the computation of expectations about future capital returns and hence requires both estimating and solving the model.

To see this, note that under our assumption of complete markets, the composite international wedge and portfolio tax τ^{B}_{jt+1} can be recovered from data on the growth in relative consumption levels, as shown in equation (9). Estimation of equation (12) serves to both decompose the composite into the international wedge τ^{*B}_{jt+1} and the portfolio tax Ψ_{jt+1} and estimate the parameters governing the evolution of the international wedge and the portfolio tax. Note that under the assumptions of our model, the residual in this equation—the international wedge—follows an autoregressive process; relative consumption does not follow a simple first-order autoregressive process. Nonetheless, all that is needed to estimate the process governing the international wedge and the parameters of the portfolio tax is data on the growth in relative consumption levels. This can be done without solving the entire model.

The labor wedge can also be recovered, and its evolution process estimated, outside of the model. Specifically, using the optimal labor supply condition for the household (2) and the optimal employment decision of the firm (5), we obtain

$$1-\tau^{h}_{jt}=\frac{\varphi}{1-\alpha}h^{\gamma}_{jt}\frac{h_{jt}N_{jt}}{Y_{jt}}\frac{C_{jt}}{N_{jt}}. \tag{13}$$

That is, using data on consumption, population, hours worked, and output, and given values for the production and preference parameters, we can recover realizations of the labor wedge without solving the model. This can then be used to estimate the process governing the evolution of the labor wedge. Note that it is not possible to separately identify the level of the labor wedge from the preference for leisure parameter φ, which in principle could also vary across countries. Hence, in what follows, we normalize the leisure parameter to 1 for all countries, and we focus on changes in the levels of these wedges over time, and not on cross-country differences in their levels.

Lastly, the capital wedge is determined from the Euler equation for the household (3), the optimal capital decision of the consumer good firm (5), and the optimality conditions of the capital good firm (6) and (7). Denoting by $x_{jt+1}=X_{jt+1}/K_{jt+1}$ the ratio of investment to the capital stock, we obtain the capital wedge from

$$1 = E_t \left[\beta \frac{C_{jt+1}/N_{jt+1}}{C_{jt}/N_{jt}} \left(1 - \tau^K_{jt+1}\right) \frac{\alpha \frac{Y_{jt+1}}{K_{jt+1}} + \frac{1-\delta-\phi\left(x_{jt+1}\right)+\phi'\left(x_{jt+1}\right)x_{jt+1}}{1-\phi'\left(x_{jt+1}\right)}}{\frac{1}{1-\phi'\left(x_{jt}\right)}} \right]. \tag{14}$$

Note that it is impossible to separately identify the level of the capital wedge from the level of the discount factor, and hence we focus on changes in the levels of these wedges, and not the levels themselves, below. Unlike the labor and international wedges, this requires computing an expectation, which in turn requires the solution of the model and estimation of the processes governing the evolution of all exogenous variables. Moreover, it also requires a value for the initial capital stock from which data on investment can be used to derive the entire sequence of capital stocks, which we estimate along with all other parameters in the model. We describe the solution and estimation of the model after we describe our data sources.

3.2 Data Sources and Methods

As discussed in the previous subsection, to recover our wedges we need data on the main national accounts expenditure aggregates—output Y_{jt}, consumption C_{jt}, investment X_{jt}, and net exports NX_{jt}—along with data on population N_{jt} and hours worked h_{jt}, for each of our three "countries."

Data were obtained from a number of sources. Briefly, where available, data from the Organization for Economic Co-operation and Development were used for its member countries. For other countries, data from the World Bank's *World Development Indicators* were our primary source. Data prior to 1960 were typically taken from the World Bank's *World Tables of Economic and Social Indicators*. The Groningen Growth and Development Center was a valuable source of hours worked data. Gaps in the resulting database were filled using a number of other sources as detailed in the appendix. A small number of missing observations are replaced using data extrapolated or interpolated from other countries in the relevant country aggregate. For the purpose of comparing our model-generated estimates of the level of productivity and capital stocks to the data, we use the estimate of capital stocks in 1950 from Nehru and Dhareshwar (1993) combined with the perpetual inventory method to construct a reference series for the capital stock and the implied level of productivity. Appendix B provides a detailed country-by-country description of data sources.

All national accounts data were transformed to constant 2000 USD prices. Data were aggregated by summation for each region. Net exports for the rest of the world were constructed to ensure that the world's trade balance with itself was zero, and any statistical discrepancy for a region was added to government spending.

3.3 Calibration and Estimation

As noted above, we solve the model numerically by taking a first-order log-linear approximation of the model around its deterministic steady-state, which is well defined under our assumptions on the portfolio tax. After imposing symmetry in the preference and production parameters across countries, we must assign values to 68 parameters. In this subsection, we describe how some parameters are calibrated to standard values and others are estimated outside the model, while the remainder are estimated by maximum likelihood using the Kalman filter.

The parameters governing preferences and production are assumed constant across countries, so that any differences across countries are attributed to the wedges. Of these common parameters (collected in Table 1), six are calibrated to standard values, while a seventh is a normalization. Specifically, we set the output elasticity of capital in the Cobb-Douglas production function α to 0.36, the discount factor β to 0.96, and the depreciation rate δ to 7 percent per year. These are all standard values. The curvature for the disutility of labor γ is set to 1.5, which implies a Frisch elasticity of labor supply of two-thirds. This is within the range typically estimated using micro data on the labor supply intensive margin, a little higher than estimates using micro data on the extensive margin, but smaller than estimates typically found using macro data (see the surveys by Pencavel (1987), Keane (2011), and Reichling and Whalen (2012)). As is evident from equation (13), we cannot separately identify the household's preference for leisure φ from the long-run labor wedge τ^h_{jss}, so we normalize φ to 1; this means that we are cautious in interpreting the estimated level of the labor wedge and only conduct experiments in which this wedge is set to its sample mean.

In the investment adjustment cost function, the parameter κ is set such that adjustment costs are zero in steady-state, or $\kappa = (\delta + z_{ss} - 1)$. The adjustment cost scale parameter ν is chosen to generate a particular value for the elasticity of the price of capital with respect to the investment-capital ratio, which is equal to $\nu\kappa$. Bernanke, Gertler, and Gilchrist (1999) use a value of 0.25 for this elasticity for the United States and argue the range of plausible values is from 0 to 0.5. We use 0.5 as our benchmark.

The remaining parameters govern the evolution of population, productivity, government spending; the labor, capital, and international wedges; the portfolio tax; and the initial levels of capital in each country. As noted above, some can be estimated without knowing the solution of the model, which helps reduce the number of parameters that are estimated within the model. The processes for the evolution of population, government spending, and the international wedges, as well as the parameters for the portfolio tax, are estimated outside of the model. We impose the assumption that the world economy grows at 2 percent per year in the long run, or $z_{ss} = \pi_{ss}^{1/(1-\alpha)} \eta_{ss} = 1.02$.

As our model is non-stationary, it is estimated using the *growth rates* of our data. To ensure that our estimated model produces *levels* of hours worked, capital, and productivity that are consistent

Table 1: Common Parameter Values

Parameter	Notation	Value
Preferences		
Discount Factor	β	0.96
Frisch Elasticity of Labor Supply	$1/\gamma$	2/3
Preference for Leisure	φ	1
Production		
Output Elasticity of Capital	α	0.36
Depreciation Rate	δ	0.07
Adjustment Cost Size	ν	5.5
Adjustment Cost Reference Level	κ	0.09

with the data, we set the steady-state labor wedge to match the sample average level of hours worked, set the steady-state capital wedge to match capital-to-output ratios from our benchmark capital series, and estimate the steady-states and persistence of the productivity processes from our benchmark productivity series.

All other parameters are then estimated using maximum likelihood (see An and Schorfheide (2007)). Details are available in Appendix C along with the plots of the prior and posterior distributions, which show how priors are not restrictive with the estimated parameters reflecting the information contained in the data.

The linearized equations of the model combined with the linearized measurement equations form a state-space representation of the model. We apply the Kalman filter to compute the likelihood of the data given the model and to obtain the paths of the wedges. We combine the likelihood function $L\left(Y^{Data}|p\right)$, where p is the parameter vector, with a set of priors $\pi_0\left(p\right)$ to obtain the posterior distribution of the parameters $\pi\left(p|Y^{Data}\right) = L\left(Y^{Data}|p\right)\pi_0\left(p\right)$. We use the random-walk Metropolis-Hastings implementation of the MCMC algorithm to compute the posterior distribution.

4 Results

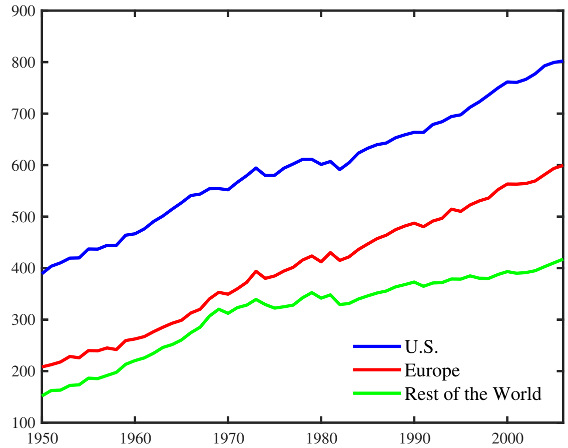
In this section, we report the recovered values of productivity and of the labor, capital, and international wedges. We first examine productivity in order to ascertain where capital should have flowed in the absence of wedges. We then examine each wedge in turn with a view to accounting for actual capital flows.

As noted above, although we introduced the wedges as though they are tax distortions, they may in fact stand in for non-tax distortions, other equilibrium frictions (that are efficient and hence

Process	Region	Steady State	Persistence	Standard Deviation
Population	United States	η_{ss} =1.01	ρ_U^n =1**	σ_U^n =0.003
	Europe	n_{Ess} =0.89	ρ_E^n =0.99	σ_E^n =0.002
	Rest of World	n_{Rss} =2.94	ρ_R^n =0.98	σ_R^N =0.003
Productivity	United States	π_{ss} =1.01**	ρ_π =1 **	σ_π =0.02*
	Europe	a_{Ess} =0.82*	ρ_E^a =0.99*	σ_E^a =0.02*
	Rest of World	a_{Rss} =0.56*	ρ_R^a =0.99*	σ_R^a =0.02*
Government Wedge	United States	g_{Uss} =0.18	ρ_U^g =0.94	σ_U^g =0.03
	Europe	g_{Ess} =0.20	ρ_E^g =0.88	σ_E^g =0.03
	Rest of World	g_{Rss} =0.13	ρ_R^g =0.93	σ_R^g =0.10
Labor Wedge	United States	τ_{Uss}^h =0.47	ρ_U^h =0.98*	σ_U^h =0.04*
	Europe	τ_{Ess}^h =0.49	ρ_E^h =0.99*	σ_E^h =0.03 *
	Rest of World	τ_{Rss}^h =0.44	ρ_R^h =0.96*	σ_R^h =0.03*
Capital Wedge	United States	τ_{Uss}^k =0.95	ρ_U^K =0.85*	σ_U^K =0.01*
	Europe	τ_{Ess}^k =0.97	ρ_U^h =0.97*	σ_U^K =0.01*
	Rest of World	τ_{Rss}^k =0.98	ρ_R^h =0.89*	σ_R^K =0.02*
International Wedge	United States	τ_{Uss}^B =2.95**	ρ_U^B =0.93	σ_U^B =0.02
	Europe	τ_{Ess}^B =1.46**	ρ_E^B =0.93	σ_E^B =0.01
Portfolio Tax	United States	ψ_{U0} = -0.08	$1-\psi_{U1}$ =0.94	—
	Europe	ψ_{E0} = -0.04	$1-\psi_{E1}$ =0.97	—

Notes: * denotes parameter is estimated inside the model; ** denotes the parameter is set by assumption; all other parameters are estimated, or calibrated to match some feature of the data, outside the model; "—" denotes "Not Applicable". Appendix C contains more details on the estimation procedures.

Figure 1: The Efficiency Wedge



non-distortionary), other forms of model misspecification, or some combination of the above. In other words, the recovered wedges may be reduced-form representations of diverse structural phenomena, rather than true primitives of the model. Moreover, a structural distortion in one factor market may be recovered as a reduced-form wedge affecting another factor market or even the level of productivity. We view this as a virtue of the approach, as it pinpoints the precise margins—the allocation of time between market and non-market activities, or the allocation of resources between consumption and investment at home and abroad—that drive observed capital flows in a way that can be informative about large classes of structural models.

4.1 The Evolution of Wedges

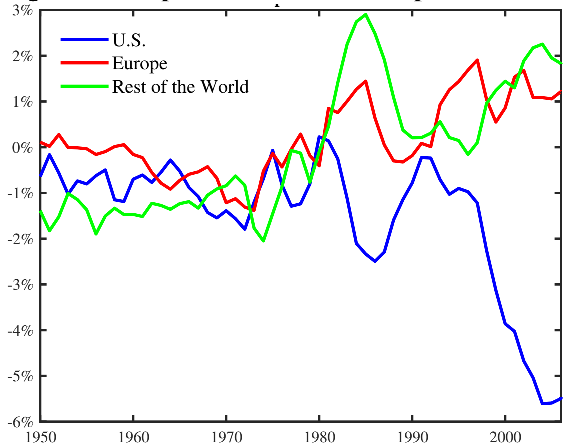
4.1.1 The Efficiency Wedge

Our estimates of total factor productivity across the three regions (A_{jt}) are depicted in Figure 1. This figure shows that unlike what was expected, the world economy grew substantially during this period. Specifically, we can see that during the Bretton Woods era productivity in the United States grew 1.84%, in Europe it grew 2.7% and in the rest of the world it grew 3.6%. At the same time, if we look at output growth we can see that it was 3.7% for the United States, 4.6% for Europe and 7.4% for the rest of the world.

This tells us that prior to 1973, capital should have flown in larger quantities to the rest of the world, then to Europe and finally to the United States. However, Figure 2 shows that during this period capital flows were very small, and that if anything, capital flew in larger quantities to the United States rather than into Europe.

In order to account for this discrepancy, there must exist offsetting incentives in either domestic or international capital markets, or in domestic labor markets. We turn to our estimates of these

Figure 2: Capital Flows (Net-Exports %GDP)



incentives in the next subsections.

4.1.2 The International Wedge

The evolution of the international wedge τ^B is depicted in the right panel of Figure 3. Since all wedges are relative to the rest of the world, the figure depicts only Europe and the U.S.. A key contribution to the accounting literature is that the international wedge is identified off of *relative* consumption *growth* rates from the Euler equation for international asset purchases (4). As a consequence, the wedge is quite volatile, and so, in addition to the recovered wedge (the dotted lines), we also plot the Hodrick-Prescott trend of the wedge (solid line) in order to highlight its medium-term movements.[1] The left panel of the figure depicts the consumption for the U.S. and Europe relative to the rest of the world.

To interpret Figure 3, note that a positive wedge reduces payments on net foreign assets and hence acts as a tax on foreign savings and a subsidy on foreign borrowing; a negative wedge is a subsidy on foreign savings and a tax on foreign borrowing. That is, a value of 0.02 is equivalent to a 2 percent subsidy on foreign borrowing. The intuition behind this result is simple. From the relative consumption plot, one can see that prior to 1973, both the U.S. and Europe are loosing consumption relative to the rest of the world. Because they are both consuming more today than tomorrow in relative terms, the model interprets this front-loading of relative consumption, as a desire to borrow today that is motivated by a subsidy to foreign borrowing.

What is really important to note here is that the international wedge is very different during the Bretton Woods era and after. In other words, one can see that prior to 1973 the United States and Europe were facing a subsidy to foreign borrowing and post 1973 it switches to a tax on foreign borrowing or very close to zero. Figure 4 shows the ratio of international wedges, such

[1]We set the smoothing parameter $\lambda = 6.25$ given our annual data.

Figure 3: The International Wedge

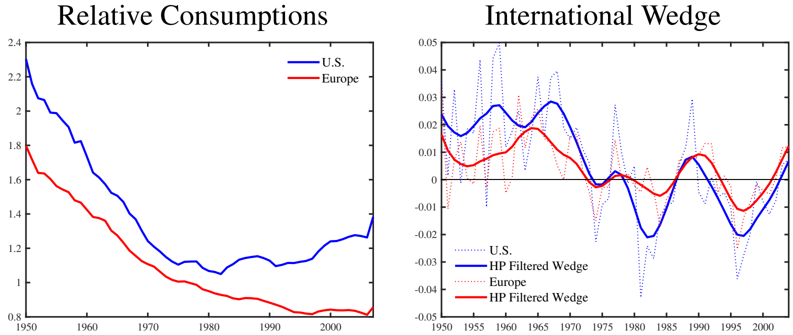
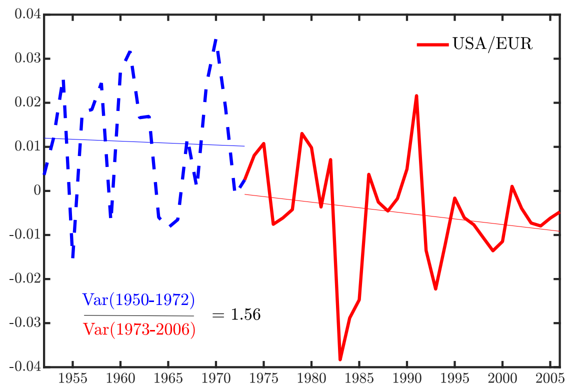


Figure 4: Ratio of International Wedges



that we recover the international wedge of the U.S. relative to Europe. In order to corroborate that there was a regime switch around 1973, we ran several regime switching tests on the ratio of the international wedges. The results can be found in Appendix D.

The results of the tests show, that there is a regime change that starts in 1970 for the mean, and in 1973 for the standard deviation of the series describing the ratio of international wedges. The mean is higher and positive in the post-Bretton Woods era, while the regime that starts in 1973 shows a lower standard deviation. Furthermore we can see that the wedge is around 56% more volatile during the Bretton Woods era, reflecting more changes in the intervention of international capital markets than later on.

Based on the fact that the international wedge reflects frictions on international capital markets, and that there is a clear break in the frictions after 1973, we can carry a counterfactual exercise by shutting down the international wedge. What would have happened to consumption, hours worked and capital flows if Bretton Woods hadn't been in place. We show the results to this experiment in Subsection 4.2.

4.1.3 The Labor Wedge

Figure 5 reports our estimate of the labor wedge τ^h (right panel) and per capita hours worked (left panel). Recall that this wedge is identified off of the relationship among consumption, wages, and hours worked in equation (2). Bearing in mind the caveat that the level of the recovered labor wedge cannot separately be identified from preference parameters that could vary across countries, under our normalization a wedge that is greater than zero is interpreted as a tax on labor income and reflects employment levels lower than predicted by the model with a labor wedge that is equal to zero; a number less than zero identifies relatively high employment, which is interpreted as a subsidy to labor. A value of 0.4 denotes a 40 percent tax on wage income.

To interpret the labor wedge, note that it reflects various factors that affect the relationship between the household's marginal rate of substitution between consumption and leisure and the marginal product of labor. These may include forces that can be affected by policy, such as labor and consumption taxes (Chari, Kehoe, and McGrattan (2007) and Ohanian, Raffo, and Rogerson (2008)), employment protection laws and other restrictions on hiring or firing workers (Cole and Ohanian (2015)), unemployment benefits (Cole and Ohanian (2002)), and limitations on product market competition that increase firm monopoly power (Chari, Kehoe, and McGrattan (2007)), as well as search and matching frictions (Cheremukhin and Restrepo-Echavarria (2014)) that form part of the "technology" of the economy. As with the international wedge, we show that the labor wedges estimated here often move with changes in taxes and changes in labor market rigidities, leading us to conclude that our estimated labor wedge is capturing structural policy changes that affect the labor market.

Studies of taxes on labor income and consumption in European countries coincide closely with the European labor wedge. Prescott (2002) and Ohanian, Raffo, and Rogerson (2008) report that in most European countries consumption and labor taxes rose substantially between 1950 and the mid-1980s and then were roughly stable on average after that. This closely mimics the pattern of our labor wedge for Europe that shows an increase until the mid-1970s and little movement thereafter.

In summary, our method recovered quantitatively large movements in labor wedges that coincide with important policy changes affecting labor taxes and labor market regulations.

4.1.4 The Capital Wedge

Figure 6 presents our estimates of the capital wedge τ^K. This wedge is identified off of the Euler equation (3) and thus reflects the difference between returns to investment estimated from the marginal product of capital and the return to savings estimated from the growth rate of consumption. Bearing in mind our caveat about the recovered levels of this wedge, under our normalization

Figure 5: The Labor Wedge

Per-capita Hours Worked / Labor Wedges

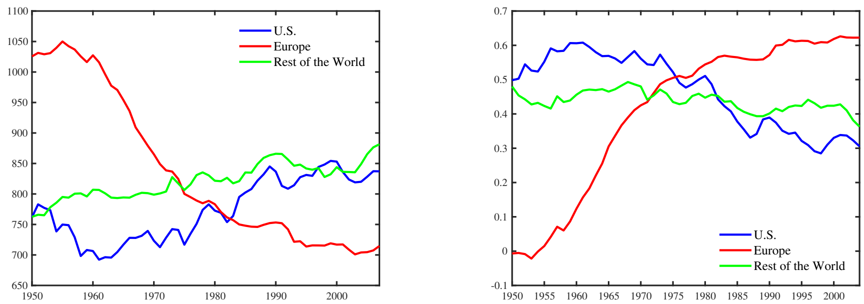
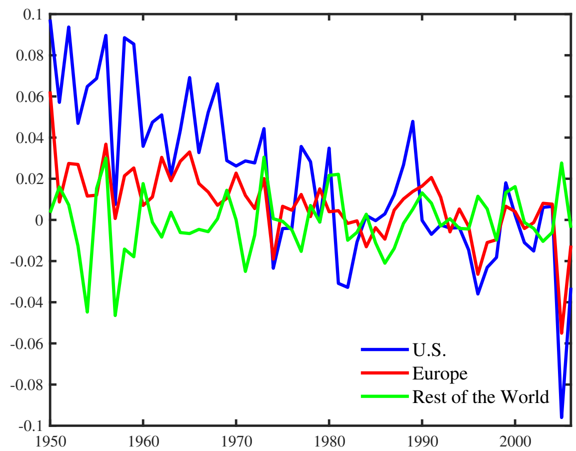


Figure 6: The Capital Wedge



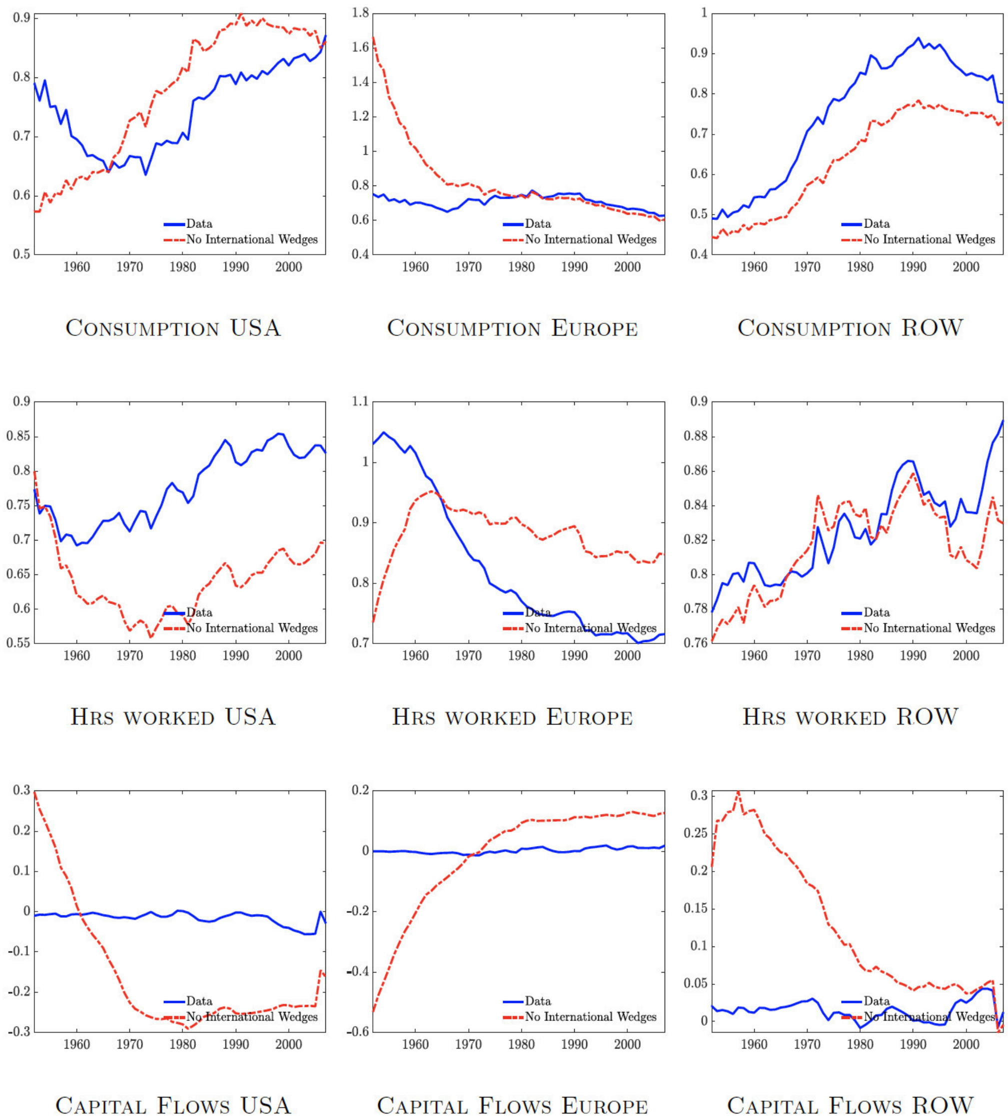
a value of 0.05 is equivalent to a 5 percent tax on capital income. As can be seen from the figure, the capital wedge is decreasing for the United States and Europe (although more so for the United States) and it is pretty constant around zero for the rest of the world.

It is also clear from the picture that for the United States and Europe the wedge was much larger during the Bretton Woods era.

4.2 Counterfactuals

In order to assess the effect of Bretton Woods as a capital control system, we run a counterfactual exercise where we shut down both international wedges at the same time by treating them parametrically and fixing them to their steady state value of zero to ensure non-degenerate long-run relative consumption levels.

Figure 7: Consumption, Hours Worked and Capital Flows (%GDP): No International Wedges



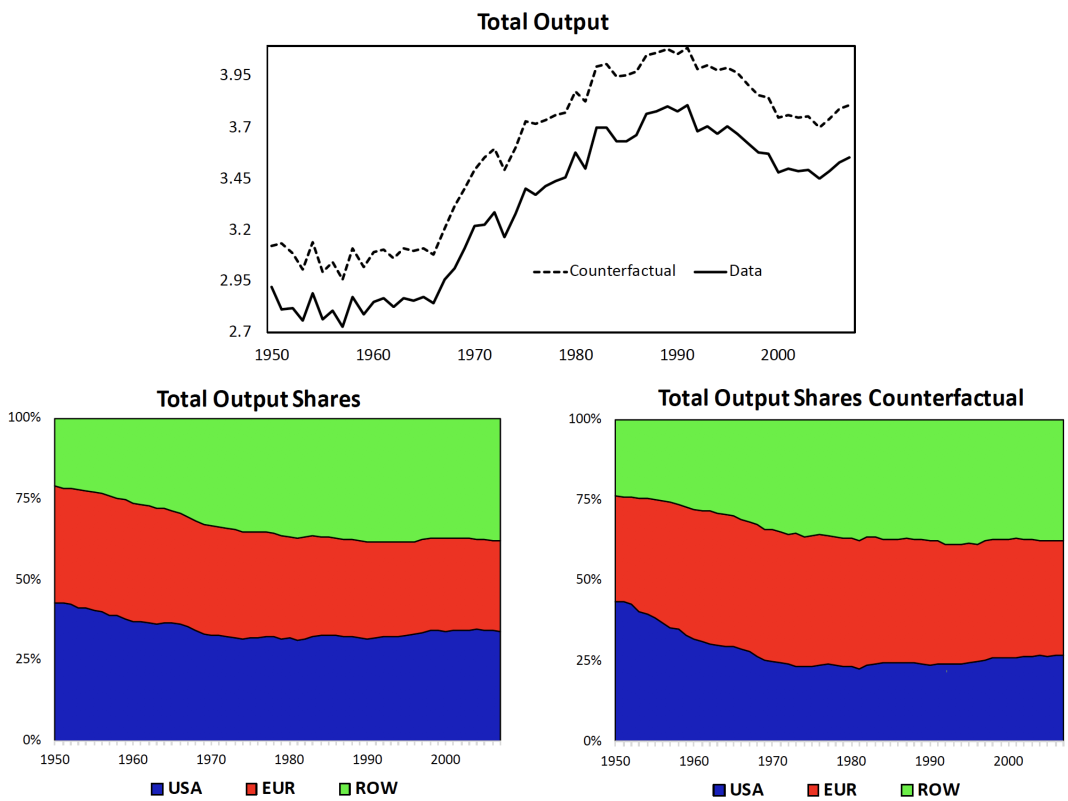
Every time we shut down movements in a wedge by fixing it parametrically, we re-solve the model so that agent expectations reflect the assumptions of the counterfactual experiment. This also implies that the effect of shutting down movements in a wedge will vary according to whether or not movements in other wedges have been shut down or are still operative.

When we shut down the international wedges, we can see that capital would have flown out of the United States and the rest of the world and into Europe for the first twenty years of the sample. On impact the capital flow would have been of 20% of GDP but it would have reverted into a capital outflow, only ten years after (see Figure 7). Hours worked in Europe would have been much higher, specially on impact, in order to accompany those capital inflows, but they remain higher throughout the period because then they have to keep working harder to repay what they borrowed initially.

Removing international capital frictions helps capital flow into Europe only during the first ten years, because at the beginning of the period, labor market frictions are still small (the labor wedge is close to zero), but they start increasing fast. This prevents any capital from flowing in a more permanent manner. Even though consumption is much higher throughout the period under the counterfactual, because they increase hours worked by so much utility is lower.

Figure 8 shows how total output would have been much higher under the counterfactual, and how the share of European output would have been higher, specially at the beginning of the period. This implies that if it hadn't been for Bretton Woods, the world would have grown even faster that it did.

Figure 8: Change in Total Output and Output Shares: No International Wedges



5 Conclusion

This paper studies the impact of the Bretton Woods system on the reconstruction of Europe, with a particular focus on the system's constraints on the operation of both domestic and international capital markets. We find these constraints acted to significantly slow the reconstruction of Europe, albeit with the benefit that Europe emerged from reconstruction significantly less indebted.

We apply an open economy, general equilibrium capital flows accounting framework and emphasize three main findings. First, we find a highly statistically significant break in the joint stochastic process generating the international capital market wedges in 1973 using a Markov Switching framework. We consider this a validation of the wedges methodology as it clearly isolates a policy change that is known to have occurred at approximately that date. Second, the methodology focuses attention on the changes in the wedges that are consistent with important changes in capital controls as well as other policies that affected the international accumulation and allocation of private capital. Similarly large changes in policies affecting domestic capital markets are also identified. Interestingly, the international wedge is much more volatile before the breakdown of Bretton Woods than afterwards, suggesting that much of the literature's focus on the increase in nominal and real exchange rate volatility is misplaced. Third, we conduct a counterfactual experiment in which distortions to international capital flows are removed starting in 1950. This experiment indicates that, absent Bretton Woods controls on capital flows, the reconstruction of Europe would have been significantly faster, although it would also have been associated with a significant rise in European indebtedness.

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APPENDIX

Appendix A: Model Solution and Computation

In this appendix we provide further details on the formulation, analysis, and solution of our benchmark competitive equilibrium model of the world economy. We begin by describing the pseudo social planners problem that we use to compute equilibria, and prove its equivalence with our competitive equilibrium problem. Given our stochastic trend, the model as formulated is not stationary. We next show how we transform both problems into intensive form problems that are stationary. We then discuss how we implement interventions in the pseudo social planners problem so that initial wealth in the competitive equilibrium problem stays constant. Finally, we discuss the balanced growth path of the deterministic version of our model or, equivalently, the steady state of the deterministic intensive form model.

The Pseudo Social Planners Problem

Consider a social planner whose problem is to choose state, date, and country contingent sequences of consumption, capital, and hours worked to maximize:

$$E_0\left[\sum_j \chi^C_{jt} \sum_{t=0}^{\infty} \beta^t \left\{ \ln\left(\frac{C_{jt}}{N_{jt}}\right) - \chi^I_{jt}\chi^H_{jt}\frac{\varphi}{1+\gamma}\left(\frac{h_{jt}N_{jt}}{N_{jt}}\right)^{1+\gamma}\right\} N_{jt}\right],$$

subject to a world resource constraint for each state and date

$$\begin{aligned} & \sum_j \left\{C_{jt} + \chi^I_{jt}X_{jt} + G_{jt}\right\} \\ = \; & \sum_j \chi^I_{jt} Y_{jt} + T^{PSPP}_t \\ = \; & \sum_j \chi^I_{jt} A_{jt} K^{\alpha}_{jt}\left(h_{jt}N_{jt}\right)^{1-\alpha} + T^{PSPP}_t, \end{aligned}$$

capital evolution equations for each country j of the form

$$K_{jt+1} = (1-\delta)K_{jt} + X_{jt} - \phi\left(\frac{X_{jt}}{K_{jt}}\right)K_{jt},$$

an exogenous path for the series of additive shocks to the resource constraint T^{PSPP} (which the social planner takes as given, but in equilibrium satisfy $T^{PSPP}_t = \sum_j \chi^I_{jt}\left(X_{jt} - Y_{jt}\right)$), and exogenous paths of population, productivity, and the social planner's "wedges" χ^I_{jt}, χ^H_{jt}, and χ^C_{jt} to be described next.

For χ^H_{jt} we assume the process is given by

$$\ln\chi^H_{jt+1} = \left(1-\rho^h_j\right)\ln\chi^H_{jSS} + \rho^H_j \ln\chi^H_{jt} + \sigma^H_j \varepsilon^H_{jt+1}, \tag{15}$$

and link the process for this wedge to the processes for the competitive equilibrium wedge through the parameter restrictions

$$\begin{aligned}
\chi^H_{jSS} &= 1/\left(1-\tau^h_{jSS}\right), \\
\rho^H_j &= \rho^h_j, \\
\sigma^H_j &= \sigma^h_j.
\end{aligned}$$

For the social planners consumption wedge, we normalize $\chi^C_{Rt} = \chi^C_{RSS} = 1$, while for $j = A, L$ we require

$$\ln\chi^C_{jt+1} = \left(1-\rho^C_j\right)\ln\chi^C_{jSS} + \rho^C_j \ln\chi^C_{jt} + \varepsilon^C_{jt+1},$$

with the process for ε^C_{jt} assumed to be autoregressive and of the form

$$\varepsilon^C_{jt+1} = \rho^{\varepsilon^C}_j \varepsilon^C_{jt} + \sigma^{\varepsilon^C}_j \varepsilon^{\varepsilon^C}_{jt+1},$$

with $\varepsilon^{\varepsilon^C}_{jt+1}$ assumed standard normal. To ensure consistency with our competitive equilibrium problem we impose the parameter restrictions

$$\begin{aligned}
1-\rho^C_j &= \frac{\psi_{j1}}{1+\psi_{j1}}, \\
\chi^C_{jSS} &= \psi_{j0}, \\
\rho^{\varepsilon^C}_j &= \frac{\rho^B_j}{1+\psi_{j1}}, \\
\sigma^{\varepsilon^C}_j &= \frac{\sigma^B_j}{1+\psi_{j1}}.
\end{aligned}$$

For the investment wedge, we assume that it's growth rate is related to past growth rates of itself, and to contemporaneous and lagged growth rates of the consumption wedge

$$\ln\left(\frac{\chi^I_{jt+1}}{\chi^I_{jt}}\right) = \left(1-\rho^I_j\right)\ln\left(1+g^{\chi^I}_{jSS}\right) - \ln\left(\frac{\chi^C_{jt+1}}{\chi^C_{jt}}\right) + \rho^I_j \ln\left(\frac{\chi^I_{jt}}{\chi^I_{jt-1}}\frac{\chi^C_{jt}}{\chi^C_{jt-1}}\right) + \sigma^{\chi^I}_j \varepsilon^I_{jt+1},$$

and impose parameter restrictions linking it to the evolution of the capital wedge in the competitive equilibrium problem.

$$
\begin{aligned}
\rho_j^I &= \rho_j^K, \\
1+g_{jSS}^{\chi^I} &= 1-\tau_{jSS}^K \\
\sigma_j^{\chi^I} &= \sigma_j^K.
\end{aligned} \tag{16}
$$

Note that, compared to the competitive equilibrium problem, the formulation of this problem, and the specification of the wedges, is non-standard. As just one example, the investment wedge χ^I now appears in the objective function *and* multiplies *both* the production function *and* investment in the resource constraint. This specification is necessary to recover the competitive equilibrium allocations. The is quite intuitive: the investment wedge χ^I must multiply both output and investment in the resource constraint in order to replicate the capital wedge, which is modeled as a tax on the gross return to capital inclusive of the value of capital, but this causes it to enter the planners optimality condition for labor. The addition of the investment wedge as a multiplier on leisure ensures that the investment wedge cancels when determining optimal labor supply. As another example, the error term in the social planners consumption wedge is autoregressive. As yet another example, we impose a very precise relationship between the investment wedge and the consumption wedge. As a result of the unusual nature of this formulation, we work with the competitive equilibrium benchmark in the paper, instead of directly introducing the social planning problem.

Under a restriction on the growth of the world economy (so that the expected summation in the objective function is finite), this problem is well defined. It is also convex. Hence, the necessary and sufficient conditions for an optimum include

$$
C_{jt} \quad : \quad \beta^t \chi_{jt}^C \frac{N_{jt}}{C_{jt}} = \lambda_t^{PSPP}, \tag{17}
$$

$$
h_{jt} \quad : \quad \beta^t \chi_{jt}^C \chi_{jt}^H \psi h_{jt}^\gamma = \lambda_t^{PSPP} (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}} \tag{18}
$$

$$
\begin{aligned}
K_{jt+1} \quad : \quad \mu_{jt}^{PSPP} = E \Bigg[& \lambda_{t+1}^{PSPP} \chi_{jt+1}^I \alpha \frac{Y_{jt+1}}{K_{jt+1}} \\
& + \mu_{jt+1}^{PSPP} \left(1-\delta-\phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right)+\phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)\frac{X_{jt+1}}{K_{jt+1}}\right)\Bigg]
\end{aligned} \tag{19}
$$

$$
X_{jt} \quad : \quad \lambda_t^{PSPP} \chi_{jt}^I = \mu_{jt}^{PSPP} \left(1-\phi'\left(\frac{X_{jt}}{K_{jt}}\right)\right) \tag{20}
$$

where λ_t^{PSPP} is the multiplier on the resource constraint at time t and μ_{jt}^{PSPP} the one of the capital evolution equation in country j at time t.

To establish the legitimacy of using the pseudo social planner to find a solution to the competitive equilibrium problem, it is sufficient to show that a solution to these necessary and sufficient conditions is also a solution to the necessary conditions for the competitive equilibrium problem. We do this next.

Equivalence Between the Solution of the Pseudo Social Planner's Problem and the Competitive Equilibrium

To establish the legitimacy of using the pseudo social planner's problem (PSPP) to find a solution to the competitive equilibrium problem (CEP), we need to show that the solution to the necessary and sufficient conditions for an optimum of the PSPP is also a solution to the necessary conditions for the competitive equilibrium problem. For this, it is sufficient to exhibit both the prices and the Lagrange multipliers that ensure that the optimality conditions from the CEP are satisfied.

Consider the first order condition (FOC) of the PSPP with respect to consumption (17). The corresponding FOC of the households problem from the CEP is

$$\beta^t \frac{N_{jt}}{C_{jt}} = \lambda_{jt}^{HH},$$

and so the two conditions are equivalent iff

$$\lambda_{jt}^{HH} = \frac{\lambda_t^{PSPP}}{\chi_{jt}^C}. \tag{21}$$

Likewise, the FOC of the PSPP with respect to hours (18) can be compared with the corresponding FOC of the households problem from the CEP

$$\beta^t \psi h_{jt}^{\gamma} = \lambda_{jt}^{HH} \left(1 - \tau_{jt}^h\right) W_{jt}.$$

Hence, the two conditions are equivalent iff

$$\lambda_{jt}^{HH} \left(1 - \tau_{jt}^h\right) W_{jt} = \frac{\lambda_t^{PSPP}}{\chi_{jt}^C} \frac{1}{\chi_{jt}^H} (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}}.$$

But imposing (21), we can see that the conditions will be equivalent if

$$W_{jt} = (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}}, \tag{22}$$

$$1 - \tau_{jt}^h = \frac{1}{\chi_{jt}^H}. \tag{23}$$

Note that (22) implies that the FOC in hours for the firm producing the consumption good in the CEP is now satisfied. Moreover, given assumption (15), the derived process for $1-\tau_{jt}^{h}$ satisfied the law of motion (8) from the CEP because

$$\ln \chi_{jt+1}^{H} = \left(1-\rho_{j}^{h}\right) \ln \chi_{jSS}^{H} + \rho_{j}^{H} \ln \chi_{jt}^{H} + \sigma_{j}^{H} \varepsilon_{jt+1}^{H},$$

becomes

$$\ln\left(1-\tau_{jt+1}^{h}\right) = \left(1-\rho_{j}^{h}\right) \ln\left(1-\tau_{jSS}^{h}\right) + \rho_{j}^{h} \ln\left(1-\tau_{jt}^{h}\right) + \sigma_{j}^{h} \varepsilon_{jt+1}^{h},$$

under our assumptions on parameters above with $\varepsilon_{jt+1}^{H} = -\varepsilon_{jt+1}^{h}$.

The FOCs of the PSPP in consumption for country j and the rest of the world can be combined to yield

$$\frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}} = \frac{\chi_{jt}^{C}}{\chi_{Rt}^{C}}.$$

Under our normalization and parameter restrictions, this implies

$$\ln \frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}} = \frac{\psi_{j1}}{1+\psi_{j1}} \ln \psi_{j0} + \frac{1}{1+\psi_{j1}} \ln \frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}} + \varepsilon_{jt+1}^{C},$$

which is precisely equation (12) from the CEP problem with $\varepsilon_{jt+1}^{C} = \ln\left(1-\tau_{jt+1}^{*B}\right)$.

The FOC with respect to capital from the PSPP (19) combined with the FOC with respect to investment (20) can be rearranged to yield

$$\frac{\lambda_{t}^{PSPP} \chi_{jt}^{I}}{1-\phi'\left(\frac{X_{jt}}{K_{jt}}\right)} = E_{t}\left[\lambda_{t+1}^{PSPP} \chi_{jt+1}^{I} \left(\alpha \frac{Y_{jt+1}}{K_{jt+1}} + \frac{1-\delta-\phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right) + \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right) \frac{X_{jt+1}}{K_{jt+1}}}{1-\phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)}\right)\right].$$

Comparing this with the FOC in capital from the households problem

$$\lambda_{jt}^{HH} P_{jt}^{K} = E_{t}\left[\lambda_{jt+1}^{HH}\left(1-\tau_{jt+1}^{K}\right)\left(r_{jt+1}^{K} + P_{jt+1}^{*K}\right)\right],$$

we can see that the two will be equivalent if

$$\begin{aligned} r_{jt+1}^{K} &= \alpha \frac{Y_{jt+1}}{K_{jt+1}}, \\ P_{jt}^{K} &= \frac{1}{1-\phi'\left(\frac{X_{jt}}{K_{jt}}\right)}, \\ P_{jt+1}^{*K} &= \frac{1-\delta-\phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right) + \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right) \frac{X_{jt+1}}{K_{jt+1}}}{1-\phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)}, \end{aligned}$$

$$1-\tau_{jt+1}^{K} \quad = \quad \frac{\chi_{jt+1}^{C}}{\chi_{jt}^{C}}\frac{\chi_{jt+1}^{I}}{\chi_{jt}^{I}}, \tag{24}$$

where in the last line we substituted from (21). The first of these conditions is simply the FOC in capital for the firm producing the consumption good in the CEP, while the second and third are the optimality conditions for the firm producing the capital good.

The fourth line gives us the relationship between the consumption and investment wedges in the PSPP and the capital wedge from the CEP. This is straightforward to impose in our analysis; for any process for the growth of the PSPP consumption wedge, we simply implicitly assume whatever process for the growth of the PSPP investment wedge necessary to generate a first order autoregressive process for the product of its growth rate with that of the consumption wedge. To see that the conditions presented above are sufficient to ensure that this is true, note that under this restriction we have

$$\ln\left(1-\tau_{jt+1}^{K}\right)=\ln\left(\chi_{jt+1}^{I}/\chi_{jt}^{I}\right)+\ln\left(\chi_{jt+1}^{C}/\chi_{jt}^{C}\right),$$

so that after substituting for (24) and imposing the restrictions in (16) we obtain the evolution equation for the capital wedge in the CEP

$$\ln\left(1-\tau_{jt+1}^{K}\right)=\left(1-\rho_{j}^{K}\right)\ln\left(1-\tau_{jSS}^{K}\right)+\rho_{j}^{K}\ln\left(1-\tau_{jt}^{K}\right)+\sigma_{j}^{K}\varepsilon_{jt+1}^{K}.$$

Lastly, note that the resource constraint of the PSPP is equal to the sum of the budget constraints of the CE problem after imposing market clearing in bonds. Or, conversely, substituting for the allocations, prices and transfers in the CEP budget constraints from the PSPP problem, we can deduce the implied sequences of foreign bond holdings.

The Intensive Form Problem

Recall that, as discussed in Section 2.3 of the text, the world economy is assumed to follow a stochastic trend identified with the rest of the world's level of effective labor $Z_t = A_{Rt}^{1/(1-\alpha)}N_{Rt}$. As the trend possesses a unit root, to make the model stationary we will work with first differences of this trend $z_{t+1} = Z_{t+1}/Z_t$ and scale all variables by the level of effective labor in the previous period Z_{t-1}. We also define

$$\begin{aligned}\pi_{t+1} &= \frac{A_{Rt+1}}{A_{Rt}},\\ \eta_{t+1} &= \frac{N_{Rt+1}}{N_{Rt}},\end{aligned}$$

so that

$$z_{t+1} = \frac{Z_{t+1}}{Z_t} = \frac{A_{Rt+1}^{1/(1-\alpha)} N_{Rt+1}}{A_{Rt}^{1/(1-\alpha)} N_{Rt}} = \pi_{t+1}^{1/(1-\alpha)} \eta_{t+1}.$$

For notational simplicity it also helps to define $a_{Rt} = n_{Rt} = 1$ for all t in all states.

This section outlines this process and derives the resulting intensive form competitive equilibrium. We also derive the intensive form social planning problem that is the basis for our numerical algorithm and estimation. In the next section, we use the intensive form versions of both problems to establish that solutions to the pseudo social planner's problem are also competitive equilibria.

Competitive Equilibrium Problem

Recall that the problem of country j is to maximize

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left\{ \ln\left(\frac{C_{jt}}{N_{jt}}\right) - \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma} \right\} N_{jt} \right],$$

subject to a flow budget constraint for each state and date

$$\begin{aligned} C_{jt} + P_{jt}^K K_{jt+1} + E_t\left[q_{t+1} B_{jt+1}\right] \quad \leq \quad & \left(1-\tau_{jt}^h\right) W_{jt} h_{jt} N_{jt} + \left(1-\tau_{jt}^B + \Psi_{jt}\right) B_{jt} + T_{jt} \\ & + \left(1-\tau_{jt}^K\right)\left(r_{jt}^K + P_{jt}^{*K}\right) K_{jt}, \end{aligned}$$

where, from the perspective of the country, Ψ_{jt} is a fixed sequence of interest penalties (analogous to a debt elastic interest rate that is not internalized) and where P_{jt}^K is the price of new capital goods, and P_{jt}^{*K} is the price of old capital goods.

Substituting for the evolution of the exogenous states and scaling by Z_{t-1}, and denoting all scaled variables by lower case, yields for the household's objective function

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\prod_{s=0}^{t} \eta_s \right) \left\{ \ln\left(\frac{C_{jt}}{N_{jt}}\right) - \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma} \right\} n_{jt} N_{R0} \right],$$

which is an affine transformation of

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\prod_{s=0}^{t} \eta_s \right) \left\{ \ln\left(c_{jt}\right) - \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma} \right\} n_{jt} \right].$$

For the household budget constraint we get

$$c_{jt} + P_{jt}^K z_t k_{jt+1} + z_t E_t\left[q_{t+1} b_{jt+1}\right] \quad \leq \quad \left(1-\tau_{jt}^h\right) \frac{W_{jt} h_{jt} N_{jt}}{A_{Rt-1}^{1/(1-\alpha)} N_{Rt-1}} + \left(1-\tau_{jt}^B + \Psi_{jt}\right) b_{jt} + t_{jt}$$

$$+\left(1-\tau_{jt}^{K}\right)\left(r_{jt}^{K}+P_{jt}^{*K}\right)k_{jt}.$$

Recall that there are two types of firm in this economy. The first produces the final consumption good. Optimization for these firms implies that

$$\begin{aligned}
W_{jt} &= (1-\alpha)A_{jt}\left(\frac{K_{jt}}{h_{jt}N_{jt}}\right)^{\alpha}, \\
r_{jt}^{K} &= \alpha A_{jt}\left(\frac{K_{jt}}{h_{jt}N_{jt}}\right)^{-(1-\alpha)}.
\end{aligned}$$

Noting that

$$\begin{aligned}
W_{jt} &= (1-\alpha)A_{jt}\left(\frac{K_{jt}}{h_{jt}N_{jt}}\right)^{\alpha} \\
&= (1-\alpha)a_{jt}A_{Rt}\left(\frac{K_{jt}}{h_{tj}n_{jt}N_{Rt}}\right)^{\alpha},
\end{aligned}$$

we let

$$\begin{aligned}
w_{jt} &= \frac{W_{jt}}{A_{Rt-1}^{1/(1-\alpha)}} = (1-\alpha)a_{jt}\left(\frac{K_{jt}}{h_{tj}n_{jt}A_{Rt-1}^{1/(1-\alpha)}N_{Rt}}\right)^{\alpha} \\
&= (1-\alpha)a_{jt}\pi_{t}\left(\frac{k_{jt}}{h_{jt}n_{jt}\eta_{t}}\right)^{\alpha}.
\end{aligned}$$

But note that for the return to capital

$$\begin{aligned}
r_{jt}^{K} &= \alpha A_{jt}\left(\frac{K_{jt}}{h_{jt}N_{jt}}\right)^{-(1-\alpha)} \\
&= \alpha a_{jt}A_{Rt}\left(\frac{K_{jt}}{h_{jt}n_{jt}N_{Rt}}\right)^{-(1-\alpha)} \\
&= \alpha a_{jt}A_{Rt}\left(\frac{K_{jt}}{h_{jt}n_{jt}A_{Rt-1}^{1/(1-\alpha)}N_{Rt-1}}\frac{A_{Rt-1}^{1/(1-\alpha)}N_{Rt-1}}{N_{Rt}}\right)^{-(1-\alpha)} \\
&= \alpha a_{jt}\pi_{t}\left(\frac{k_{jt}}{h_{jt}n_{jt}\eta_{t}}\right)^{-(1-\alpha)},
\end{aligned}$$

so that no scaling of capital returns is required.

The second type of firm produces new capital goods $z_t k_{jt+1}$ using x_{jt} units of deferred consumption and k_{jt} units of the old capital good. Their objective function is

$$P_{jt}^{K} z_t k_{jt+1} - x_{jt} - P_{jt}^{*K} k_{jt}.$$

Assuming a capital accumulation equation with adjustment costs of the form

$$z_t k_{jt+1} = (1-\delta) k_{jt} + x_{jt} - \phi\left(\frac{x_{jt}}{k_{jt}}\right) k_{jt},$$

we get that the firms problem is to choose x_{jt} and k_{jt} to maximize

$$P_{jt}^{K}\left[(1-\delta) k_{jt} + x_{jt} - \phi\left(\frac{x_{jt}}{k_{jt}}\right) k_{jt}\right] - x_{jt} - P_{jt}^{*K} k_{jt}.$$

The FOC in x implies

$$P_{jt}^{K} = \frac{1}{1-\phi'\left(\frac{x_{jt}}{k_{jt}}\right)},$$

while the one in k yields

$$P_{jt}^{*K} = P_{jt}^{K}\left(1-\delta-\phi\left(\frac{x_{jt}}{k_{jt}}\right)+\phi'\left(\frac{x_{jt}}{k_{jt}}\right)\frac{x_{jt}}{k_{jt}}\right).$$

The first order conditions of the household's intensive form problem are

$$\begin{aligned}
c_{jt} &: \quad \beta^t\left(\prod_{s=0}^{t}\eta_s\right) n_{jt}\frac{1}{c_{jt}} = \lambda_{jt}^{CE}, \\
h_{jt} &: \quad \beta^t\left(\prod_{s=0}^{t}\eta_s\right) n_{jt}\psi h_{jt}^{\gamma} = \lambda_{jt}^{CE}\left(1-\tau_{jt}^{h}\right) w_{jt} n_{jt}\eta_t, \\
k_{jt+1} &: \quad 1 = E\left[\frac{\lambda_{jt+1}^{CE}}{\lambda_{jt}^{CE}}\left(1-\tau_{jt+1}^{K}\right)\frac{r_{jt+1}^{K}+P_{jt+1}^{*K}}{P_{jt}^{K} z_t}\right], \\
b_{jt+1} &: \quad z_t q_{t+1}\lambda_{jt}^{CE} = \lambda_{jt+1}^{CE}\left[\left(1-\tau_{jt+1}^{B}+\Psi_{jt+1}\right)\right],
\end{aligned}$$

where λ_{jt}^{CE} is the multiplier on the budget constraint.

If transfers rebate all "tax revenues" beyond that required to finance government expenditure, then in equilibrium we have

$$c_{jt} + z_t k_{jt+1} + z_t E_t\left[q_{t+1} b_{jt+1}\right] + g_{jt} = w_{jt} h_{jt} n_{jt}\eta_t + \left(r_{jt}^{K} + 1 - \delta\right) k_{jt} - \phi\left(\frac{x_{jt}}{k_{jt}}\right) k_{jt} + b_{jt}.$$

From the labor-leisure condition we get

$$\psi h_{jt}^{\gamma} = \frac{1}{c_{jt}} \left(1 - \tau_{jt}^{h}\right) w_{jt} n_{jt} \eta_t.$$

From the Euler equation in physical capital we get

$$1 = E\left[\frac{\lambda_{jt+1}^{CE}}{\lambda_{jt}^{CE}} \left(1 - \tau_{jt+1}^{K}\right) \frac{r_{jt+1}^{K} + \left(1 - \delta - \phi\left(\frac{x_{jt+1}}{k_{jt+1}}\right) + \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right)\frac{x_{jt+1}}{k_{jt+1}}\right) / \left(1 - \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right)\right)}{z_t \left(1 - \phi'\left(\frac{x_{jt}}{k_{jt}}\right)\right)^{-1}}\right].$$

After substituting for λ^{CE} we obtain

$$1 = E\left[\beta \eta_{t+1} \frac{c_{jt}}{c_{jt+1}} \frac{n_{jt+1}}{n_{jt}} \left(1 - \tau_{jt+1}^{K}\right) \frac{r_{jt+1}^{K} + \left(1 - \delta - \phi\left(\frac{x_{jt+1}}{k_{jt+1}}\right) + \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right)\frac{x_{jt+1}}{k_{jt+1}}\right) / \left(1 - \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right)\right)}{z_t \left(1 - \phi'\left(\frac{x_{jt}}{k_{jt}}\right)\right)^{-1}}\right].$$

Lastly, from the Euler equation in foreign assets, we obtain

$$z_t q_{t+1} \frac{n_{jt}}{c_{jt}} = \beta \eta_t \frac{n_{jt+1}}{c_{jt+1}} \left(1 - \tau_{jt}^{B} + +\Psi_{jt}\right).$$

Pseudo Social Planners Problem

Following an analogous process for the pseudo social planner's problem introduced above, the intensive form pseudo social planners objective function becomes

$$\begin{aligned} & E_0\left[\sum_j \chi_{jt}^{C} \sum_{t=0}^{\infty} \beta^t \left\{\ln\left(\frac{C_{jt}}{N_{jt}}\right) - \chi_{jt}^{I} \chi_{jt}^{H} \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma}\right\} n_{jt} N_{Rt}\right] \\ = \quad & E_0\left[\sum_j \chi_{jt}^{C} \sum_{t=0}^{\infty} \beta^t \left(\prod_{s=0}^{t} \eta_s\right) \left\{\ln\left(\frac{C_{jt}}{N_{jt}}\right) - \chi_{jt}^{I} \chi_{jt}^{H} \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma}\right\} n_{jt} N_{R0}\right], \end{aligned}$$

which is equivalent to maximizing

$$E_0\left[\sum_{t=0}^{\infty} \beta^t \left(\prod_{s=0}^{t} \eta_s\right) \sum_j \chi_{jt}^{C} \left\{\ln\left(c_{jt}\right) - \chi_{jt}^{I} \chi_{jt}^{H} \frac{\psi}{1+\gamma} h_{jt}^{1+\gamma}\right\} n_{jt}\right].$$

The resource constraint becomes

$$\sum_j \left\{c_{jt} + \chi_{jt}^{I} x_{jt} + g_{jt}\right\}$$

$$
\begin{aligned}
&= \sum_j \chi_{jt}^I y_{jt} + t_t^{SP} \\
&= \sum_j \chi_{jt}^I a_{jt} \pi_t k_{jt}^{\alpha} \left(h_{jt} n_{jt} \eta_t\right)^{1-\alpha} + t_t^{SP},
\end{aligned}
$$

while the capital evolution equation is

$$
z_t k_{jt+1} = (1-\delta) k_{jt} + x_{jt} - \phi\left(\frac{x_{jt}}{k_{jt}}\right) k_{jt}.
$$

The first order conditions of this problem are

$$
\begin{aligned}
c_{jt} &: \beta^t \left(\prod_{s=0}^{t} \eta_s\right) \chi_{jt}^C \frac{1}{c_{jt}} n_{jt} = \lambda_t^{SP}, \\
h_{jt} &: \beta^t \left(\prod_{s=0}^{t} \eta_s\right) \chi_{jt}^C \chi_{jt}^I \chi_{jt}^H \psi h_{jt}^{\gamma} n_{jt} = \lambda_t^{SP} (1-\alpha) \chi_{jt}^I a_{jt} \pi_t n_{jt} \eta_t k_{jt}^{\alpha} \left(h_{jt} n_{jt} \eta_t\right)^{-\alpha} \\
k_{jt+1} &: \mu_{jt}^{SP} z_t = E\left[\lambda_{t+1}^{SP} \chi_{jt+1}^I \alpha a_{jt+1} \pi_{t+1} k_{jt+1}^{\alpha-1} \left(h_{jt+1} n_{jt+1} \eta_{t+1}\right)^{1-\alpha} + \right. \\
&\quad \left. \mu_{jt+1}^{SP} \left(1 - \delta - \phi\left(\frac{x_{jt+1}}{k_{jt+1}}\right) + \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right) \frac{x_{jt+1}}{k_{jt+1}}\right)\right], \\
x_{jt} &: \lambda_t^{SP} \chi_{jt}^I = \mu_{jt}^{SP} \left(1 - \phi'\left(\frac{x_{jt}}{k_{jt}}\right)\right),
\end{aligned}
$$

where λ_t^{SP} is the multiplier on the resource constraint at time t and μ_{jt}^{SP} the one of the capital evolution equation in country j at time t. We can rearrange these, after substituting for λ_t^{SP}, to get

$$
\begin{aligned}
1 &= E\left[\beta \eta_{t+1} \frac{c_{jt}}{c_{jt+1}} \frac{n_{jt}}{n_{jt+1}} \frac{\chi_{t+1}^C}{\chi_t^C} \frac{\chi_{jt+1}^I}{\chi_{jt}^I} \times \right. \\
&\left. \frac{\alpha a_{jt+1} \pi_{t+1} k_{jt+1}^{\alpha-1} \left(h_{jt+1} n_{jt+1} \eta_{t+1}\right)^{1-\alpha} + \left(1 - \delta - \phi\left(\frac{x_{jt+1}}{k_{jt+1}}\right) + \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right) \frac{x_{jt+1}}{k_{jt+1}}\right) / \left(1 - \phi'\left(\frac{x_{jt+1}}{k_{jt+1}}\right)\right)}{z_t \left(1 - \phi'\left(\frac{x_{jt}}{k_{jt}}\right)\right)}\right].
\end{aligned}
$$

Imposing the "equilibrium" restriction on the wedges and additive shock yields

$$
\sum_j \left\{c_{jt} + z_t k_{jt+1} - (1-\delta) k_t - \phi\left(\frac{x_{jt}}{k_{jt}}\right) k_{jt} + g_{jt}\right\} = \sum_j a_{jt} \pi_t k_{jt}^{\alpha} \left(h_{jt} n_{jt} \eta_t\right)^{1-\alpha}.
$$

The Equivalence of Interventions in the Competitive Equilibrium and Pseudo Social Planner's Problems

In the paper, we aim to quantify the contributions of the different wedges to capital flows by conducting a particular set of interventions. Specifically, we set the wedge in question equal to its average level, and then track how capital flows evolve under this intervention. In the competitive equilibrium problem, this change would occur for a given level of initial wealth or net foreign assets. However, as we use a pseudo social planners problem to solve and estimate the equilibrium, and simulate the effect of an intervention, we need to change the level of the Pareto weight (the social planning analog of initial wealth) or, equivalently, the initial level of the pseudo social planner's international wedge, so as to keep wealth in the competitive equilibrium problem constant. This is done by allowing the initial values of the pseudo social planner's international wedge (equivalently, the planner's Pareto weight) to jump to the level required to keep net foreign assets constant.

To see how we do this, note that in the competitive equilibrium problem at the beginning of period t after the resolution of uncertainty, the $j'th$ country's net foreign asset position is given by the number B_{jt}. From the resource constraint we know that

$$B_{jt} = -NX_{jt} + E_t\left[q_{t,t+1}B_{jt+1}\right].$$

We also know, from the Euler equation in bonds, that for $j = ROW$ (with no taxes)

$$\frac{1}{C_{jt}}N_{jt}q_{t,t+1} = \beta\frac{1}{C_{jt+1}}N_{jt+1}.$$

Substituting gives

$$\begin{aligned} B_{jt} &= -NX_{jt} + E_t\left[\beta\frac{C_{Rt}}{C_{Rt+1}}\frac{N_{Rt+1}}{N_{Rt}}B_{jt+1}\right] \\ &= -NX_{jt} + E_t\left[\beta\frac{C_{Rt}}{C_{Rt+1}}\eta_{t+1}B_{jt+1}\right]. \end{aligned}$$

The intensive form analog is then

$$\frac{B_{jt}}{Z_{t-1}} = -\frac{NX_{jt}}{Z_{t-1}} + E_t\left[\beta\frac{C_{Rt}/Z_{t-1}}{C_{Rt+1}/Z_t}\frac{Z_{t-1}}{Z_t}\eta_{t+1}\frac{B_{jt+1}}{Z_t}\frac{Z_t}{Z_{t-1}}\right],$$

so that

$$b_{jt} = -nx_{jt} + E_t\left[\beta\frac{c_{Rt}}{c_{Rt+1}}\eta_{t+1}b_{jt+1}\right],$$

which after recursively substituting becomes

$$
\begin{aligned}
b_{jt} &= -E_t\left\{nx_{jt}+\beta\eta_{t+1}\frac{c_{Rt}}{c_{Rt+1}}nx_{jt+1}+\beta^2\eta_{t+1}\eta_{t+2}\frac{c_{Rt}}{c_{Rt+2}}nx_{jt+2}+...\right\}\\
&= -E_t\left\{\sum_{s=0}^{\infty}\beta^s\left(\prod_{r=1}^{s}\eta_{t+r}\right)nx_{jt+s}\right\}, \qquad (25)
\end{aligned}
$$

where

$$\prod_{s=0}^{1}\eta_{t+r}=1.$$

In solving the pseudo social planners problem, we compute the solution for net foreign assets as a function of the state (which includes the pseudo social planner's international wedge) using equation (25), which allows us to numerically vary the level of the social planner's international wedge in order to keep net foreign assets constant.

The Balanced Growth Path of the Deterministic Model

In this section we derive the balanced growth path of our model or, equivalently, the steady state of the intensive form version of our model. We then use this derivation to go into further detail about why we needed to add the portfolio adjustment costs in order to establish the existence of a non-degenerate balanced growth path for our model. Lastly, we use the derivation to show why the labor wedge has little role on the balanced growth path of the model, even though it matters a great deal along the transition to this balanced growth path, and hence why analyses based on steady state relations will tend to understate the importance of the labor wedge in determining capital flows.

As noted in the text, which can be easily verified from the resource constraint of the economy, along the balanced growth path the growth rates of consumption, investment, capital, output, government spending and net exports for all countries are all equal to the long run growth rate of effective labor, or

$$z_{ss}=\eta_{ss}\pi_{ss}^{\frac{1}{1-\alpha}}.$$

From the household's optimality condition in the accumulation of international assets, we can see that on the balanced growth path the price of these assets satisfies

$$\frac{1}{1+r_{ss}^{W}}\equiv q_{ss}=\beta\frac{\eta_{ss}}{z_{ss}}=\beta\pi_{ss}^{\frac{-1}{1-\alpha}},$$

where we have defined r_{ss}^{W} to be the steady state world interest rate. That is, as usual, the world interest rate increases in the discount rate (decreases in the discount factor) and increases in the rate of growth of productivity.

As far as country specific levels of variables, the steady state level of government spending relative to output is given by assumption as g_{jss}. Steady state investment relative to capital is determined from the capital accumulation equation to be

$$\left(\frac{X_j}{K_j}\right)_{ss} = \delta + z_{ss} - 1,$$

where we have imposed the fact that adjustment costs are zero on the balanced growth path (or steady state), and where we have written the subscript "ss" outside of the parentheses to denote the fact that the ratio of investment to capital is constant on the balanced growth path, but the levels of investment and capital themselves are not. Hence, investment relative to output is given by

$$\left(\frac{X_j}{Y_j}\right)_{ss} = (\delta + z_{ss} - 1)\left(\frac{K_j}{Y_j}\right)_{ss},$$

and so will be pinned down once we know the steady state output to capital ratio.

From the Euler equation in capital, imposing steady state, we have

$$1 + r_{ss}^W = \left(1 - \tau_{jss}^K\right)\left(\alpha\left(\frac{Y_j}{K_j}\right)_{ss} + 1 - \delta\right)$$

which pins down the capital to output ratio as

$$\frac{K_{jss}}{Y_{jss}} = \alpha \frac{1}{\frac{1+r_{ss}^W}{1-\tau_{jss}^K} - (1-\delta)}.$$

All that remains is to pin down is consumption, hours, net exports and net foreign assets on the balanced growth path. It turns out that all of this can be done once we have the level of net foreign assets relative to output. Given $\left(B_j/Y_j\right)_{ss}$ we have that

$$\left(\frac{B_j}{Y_j}\right)_{ss}(1 - qz_{ss}) = -\left(\frac{NX_j}{Y_j}\right)_{ss}.$$

This simply states that the level of net exports in steady state is equal to the growth adjusted world interest rate on net foreign assets.

As an aside, it is worthwhile to note that, since net foreign assets are growing on the balanced growth path, the current account—in a deterministic model, this is equal to the change in the level of net foreign assets—is not zero on the balanced growth path. Given our timing convention, the ratio of the current account CA to output is given by

$$\left(\frac{CA_j}{Y_j}\right)_{ss} = \left(\frac{B_j' - B_j}{Y_j}\right)_{ss} = (z_{ss} - 1)\left(\frac{B_j}{Y_j}\right)_{ss} = \frac{1 - z_{ss}}{1 - qz_{ss}}\left(\frac{NX_j}{Y_j}\right)_{ss}.$$

Given the ratio of net exports to output, we can back out the ratio of consumption to output from the resource constraint of a country

$$\left(\frac{C_j}{Y_j}\right)_{ss} = 1 - \left(\frac{X_j}{Y_j}\right)_{ss} - g_{jss} - \left(\frac{NX_j}{Y_j}\right)_{ss}.$$

The level of hours per person (which is constant on the balanced growth path) is then pinned down by the first order condition in hours

$$h_{jss} = \left(\frac{1 - \tau_{jss}^h}{\psi}\left(\frac{Y_j}{C_j}\right)_{ss}\right)^{1/(1+\gamma)}.$$

What determines the level of net foreign assets relative to output on the balanced growth path? In a complete markets model without wedges, this would be pinned down by initial conditions. In an incomplete markets model, in general, this level would not be pinned down at all, but would instead vary forever with the sequence of shocks that hit the economy. This is why the model does not possess a unique steady state: if the shocks are all set to zero after some date T, and the economy jumped immediately to the balance growth path, the level of net foreign assets that had been accumulated up until that time period, scaled by output, would persist forever after. This is why we, and all of the literature up until this point, has adopted some mechanism for pinning down the long run level of net foreign assets relative to output. Our specification of a tax on deviations of net foreign assets from a benchmark allows us to estimate the balanced growth path of assets from the data.

It is also worth pointing out that, as constructed above, the labor wedge had no impact on the balanced growth path except for determining the level of hours worked relative to consumption. This is a little misleading; in general, realizations of the labor wedge will affect the economy on the transition to steady state and hence will affect the accumulation of net foreign assets. However, analysis of capital flows from the balanced growth perspective, that ignores the transition path, will find no role for the labor wedge to impact long run capital flows.

Appendix B: Data and Methods

As noted in the text, to recover our wedges we need data on the main national accounts expenditure aggregates—output Y_{jt}, consumption C_{jt}, investment X_{jt}, government spending G_{jt}, and net exports NX_{jt}—along with data on population N_{jt} and hours worked h_{jt}, for each of our three "countries" or regions. In this Appendix, we describe our data sources, data aggregation techniques, and sample definitions, and provide plots of the raw data used in our analysis. A data file will be made available after the paper has been accepted for publication. We then go on to discuss our estimation method in greater detail than provided in the text.

Sample Definition

The rest of the world is defined to be the aggregate of Japan, Korea, Taiwan, Hong Kong, Singapore, Canada, Australia, New Zealand, Iceland, Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela, Costa Rica.

Europe is the aggregate of Austria, Belgium, Denmark, Luxembourg, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Sweden, Switzerland, Turkey and the Unted Kingdom.

General Data Sources

Data were obtained from a number of sources (this is also described in Ohanian and Wright (2008)). Briefly, where available, data from the Organization for Economic Cooperation and Development's *Annual National Accounts* (OECD) was used for its member countries. For other countries, data from the World Bank's *World Development Indicators* (WDI) was our primary source. Data prior to 1960 is often scarce; our primary source was the World Bank's *World Tables of Economic and Social Indicators* (WTESI). The Groningen Growth and Development Center's (GGDC) was a valuable source of hours worked data. Taiwanese data came from the National Bureau of Statistics of China. More specifics are provided in the country specific notes below.

For the purpose of comparing our model generated estimates of the level of productivity and capital stocks to the data, we use the estimate of capital stocks in 1950 from Nehru and Dhareshwar (1993) combined with the perpetual inventory method to construct a reference series for the capital stock and the implied level of productivity.

Data Aggregation, Manipulation and Cleaning

All national accounts data were transformed to constant 2000 U.S. dollar prices. Data were aggregated by summation for each region. Net exports for the rest of the world were constructed to ensure that the world trade balance with itself was zero, and any statistical discrepancy for a region was added to government spending.

Our measure of output is gross domestic product. Hence, net exports do not include net exports of factor services, and correspond to the trade balance (and not the current account balance). Where available, our measure of investment was gross capital expenditure. When this was not available, we used data on gross fixed capital expenditure.

For some countries and variables, data was missing for a small number of years. More details on these cases are presented in the country specific notes below; in general, missing data was filled in by assuming that data for the missing country evolved in the same way as the rest of the regional aggregate.

Country Specific Notes on Data

Next, we add a series of country specific notes on data sources and construction. These notes focus on details about missing data that are specific to each country, and on any other issues with country specific data.

Asia

1. Hong Kong. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1965 and so gross fixed capital expenditure was used instead.

2. Japan. NIPA and population data from 1960 to 2007 is from the OECD. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead. Hours data was missing for 1950 and were imputed using trends in the data for other Asian countries.

3. South Korea. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data from 1963 to 2007 was from GGDC; no hours data are available prior to 1963. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead.

4. Singapore. Official NIPA data for Singapore first becomes available in 1960 and was taken from the WDI. Prior to 1960, NIPA estimates derived from colonial data were obtained from Sugimoto (2011). Hours worked data were taken from GGDC from 1960. Prior to 1960, we computed total hours worked from data on the employment and hours worked of laborers,

shop assistants, shop clerks and industrial clerks in both public and private sector establishments as tabulated in the *Annual Report of the Labour Department* for the Colony of Singapore (1950-1956) and State of Singapore (1957-1960).

5. Taiwan. NIPA data for Taiwan begins in 1951 and comes from the National Bureau of Statistics of China. Hours worked data comes from GGDC starting in 1960. Population, and hours worked data prior to 1960, come from the Penn World Tables v.9.0.

Latin America

1. Argentina. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960, and for some years after 1979, and so gross fixed capital expenditure was used instead.

2. Brazil. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead.

3. Chile. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC.

4. Colombia. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead.

5. Mexico. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead.

6. Peru. NIPA and population data from 1960 to 2007 is from the WDI. NIPA and population data from 1950 to 1960 is from WTESI. Hours data was from GGDC. Inventory investment was not available prior to 1960 and so gross fixed capital expenditure was used instead.

Rest of the World

We end up with an aggregate of 22 advanced economies from North America, Europe and Australasia. The specific list of countries is: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States of America.

1. Australia. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1953, and extended back to 1950 using the series in Butlin (1977).
2. Austria. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
3. Belgium. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
4. Canada. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
5. Denmark. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
6. Finland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
7. France. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
8. Germany. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
9. Greece. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
10. Iceland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
11. Ireland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
12. Italy. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
13. Luxembourg. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1958.
14. Netherlands. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
15. New Zealand. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

16. Norway. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

17. Portugal. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1956.

18. Spain. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1954.

19. Sweden. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1959.

20. Switzerland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

21. United Kingdom. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

22. The United States of America. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

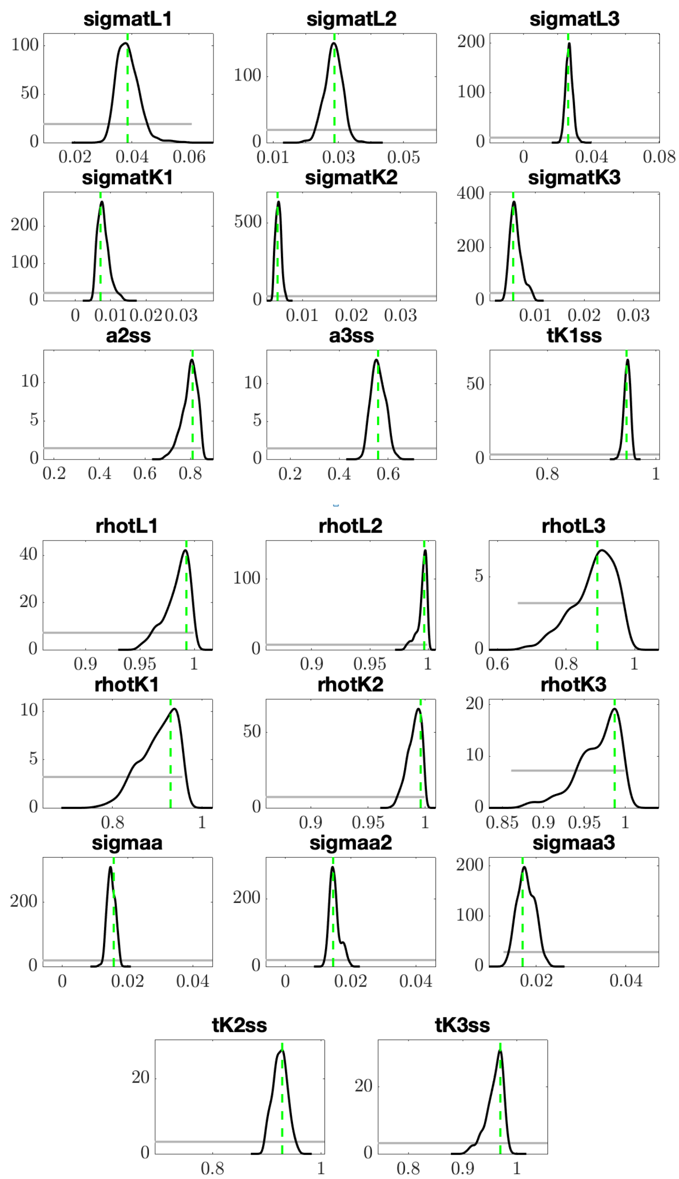
Estimation

The linearized equations of the model combined with the linearized measurement equations form a state-space representation of the model. We apply the Kalman filter to compute the likelihood of the data given the model and to obtain the paths of the wedges. We combine the likelihood function $L\left(Y^{Data}|p\right)$, where p is the parameter vector, with a set of priors $\pi_0\left(p\right)$ to obtain the posterior distribution of the parameters $\pi\left(p|Y^{Data}\right) = L\left(Y^{Data}|p\right)\pi_0\left(p\right)$. We use the Random-Walk Metropolis-Hastings implementation of the MCMC algorithm to compute the posterior distribution. Table 9 reports the prior and posterior distributions of the persistence and variance parameters of the wedges that we estimate using maximum likelihood.

Figure 9: Prior and posterior distributions of wedge parameters

Parameter	Prior	Posterior	
	Distribution	Mean	Dev
$\rho_R^{\tau^h}$	Uniform	0.95	0.09
$\rho_L^{\tau^h}$	Uniform	0.92	0.09
$\rho_A^{\tau^h}$	Uniform	0.75	0.09
$\rho_R^{\tau^K}$	Uniform	0.94	0.09
$\rho_L^{\tau^K}$	Uniform	0.95	0.09
$\rho_A^{\tau^K}$	Uniform	0.98	0.09
σ_π	Uniform	0.02	0.01
σ_E^a	Uniform	0.02	0.01
σ_R^a	Uniform	0.02	0.02
$\sigma_U^{\tau^h}$	Uniform	0.04	0.02
$\sigma_E^{\tau^h}$	Uniform	0.05	0.02
$\sigma_R^{\tau^h}$	Uniform	0.03	0.02
$\sigma_U^{\tau^K}$	Uniform	0.01	0.02
$\sigma_E^{\tau^K}$	Uniform	0.01	0.02
$\sigma_R^{\tau^K}$	Uniform	0.01	0.02

Figure 10: Priors and Posteriors



Appendix C: Conceptual Issues About Measuring Capital Flows

In the paper, we use net exports of goods and services as our measure of international capital flows. This is a common approach, although some researchers studying capital flows in more recent decades have focused on the current account as a measure of capital flows (which includes income from net exports of factor services, otherwise known as net factor income). In this appendix, we discuss the reasons for our approach in more detail.

In brief, there are several reasons for our approach: (1) net factor income is poorly measured; (2) balance of payments data is limited by its focus on transactions data and its inconsistent treatment of transfers such as debt restructuring, which matter a lot for Latin America in the middle of our sample; (3) balance of payments data is not available for many countries prior to 1970 and has sometimes severe measurement issues; and (4) there is no unique mapping from model outcomes to implications for the balance of payments, although there is a unique mapping of net exports. We elaborate on these reasons in detail below.

First, on data availability, it is important to note that data on net factor income (the difference between net exports and the current account balance) are often not available, particularly before 1970. For example, Alfaro, Kalemli-Ozcan, and Volosovych (2014), who conduct the most exhaustive study of data on international capital flows that we know of, focus most of their analysis on the period after 1980, for which the most data are available for 156 countries. Their "1970" sample covers only 46 countries and includes only a limited subset of the variables contained in their wider analysis. This means that these data do not speak to a key period of interest: the decades leading up to 1970.

Second, on the issue of data reliability, it is important to note that even when these data are available, they are subject to significant measurement error. As a number of people have pointed out, including the International Monetary Fund itself, according to their data the world often runs a large current account deficit with itself. Until recently, this deficit was almost entirely concentrated in the net factor income component of the current account. Moreover, the error has often been extremely large, peaking at around 5 percent of world imports in 1982 (see Marquez and Workman (2000)).

Third, at a deeper level, our focus on net exports data (and not data on the current account or on the capital account) is driven by issues related to the way the balance of payments is constructed. Conceptually, a country's net foreign asset position can change for roughly three reasons. First, it may change because of a transaction in which assets change hands or income is paid. Second, it may change due to capital gains and valuation effects. Third, it may change due to a gift or transfer, such as foreign aid, a nationalization or expropriation, or due to debt forgiveness and restructuring.

The way the balance of payments is constructed, it is designed to capture transactions. It is explicitly *not* designed to capture the effect of valuation changes on a country's net foreign asset position (this has, in and of itself, led to a significant debate about how to interpret data on the balance of payments and data on net foreign assets; see the issues raised by Lane and Milesi Ferretti (2001, 2005, and 2007); Tille (2003); Higgins, Klitgaard, and Tille (2005) and Gourinchas and Rey (2007)). In addition, its ability to capture transfers such as sovereign default depends on whether the country has adopted accrual accounting standards (in which case, a debt restructuring is paired with an artificial accounting transaction) and whether it is believed that accrual accounting standards are adequate for this purpose (Sandleris and Wright (2013) and others have argued that, when a country defaults on its debts, it is better to use cash accounting concepts in evaluating their balance of payments). As a result of all these concerns, amplified by the fact that the asset structure of international finance has changed over time to emphasize more derivative securities and valuation effects have become more important in an era of floating exchange rates, confidence in the reliability and backwards comparability of balance of payments data is low, even in the absence of the measurement error noted above. The issues are well summarized by Alfaro, Kalemli-Ozcan, and Volosovych (2014) who write:

> There are substantial country differences in terms of time coverage, missing, unreported, or misreported data, in particular for developing countries. Some countries do not report data for all forms of capital flows. Outflows data tend to be misreported in most countries and, as the result, captured in the "errors and omissions" item.
>
> Unfortunately, it is hard to verify whether the data are really missing as opposed to simply being zero. Due to the debt crisis of the 1980s there are several measurement problems related to different methodologies of recording non-payments, rescheduling, debt forgiveness and reductions.

Fourth, on the issue of mapping models to data, it has been known for a long time that a given model of international capital markets can be mapped into data on the balance of payments in different ways depending on which of many alternative equivalent asset structures is used. For example, in a complete markets framework, it may be possible to decentralize the equilibrium allocations using Arrow securities, Arrow-Debreu securities, a portfolio of equities and debt, or a combination of debt and derivative securities and so on. Each will typically have different implications for the balance of payments. A model with only Arrow or Arrow-Debreu securities has many assets experiencing a 100 percent capital loss each period, with one asset experiencing a large capital gain. In principle, these capital gains would not be recorded in the balance of payments at all. With only Arrow-Debreu securities, no transactions occur after the first initial period. With Arrow securities, a portfolio of new securities is bought every period. Again, these can have very different implications for the balance of payments. Likewise, the equilibrium will look different if it is decentralized with a mixture of debt and equity or with financial derivatives.

As a consequence, it is has become traditional in the literature to (1) work with models that either have a very limited asset structure (such as with bonds only or a bond and one equity), which misses much of the richness of the international asset trade but can give precise predictions for the balance of payments, or (2) to work with complete market models to focus on allocations—such as net exports—which are invariant across different decentralizations. A particularly strong statement of this position is provided by Backus, Kehoe, and Kydland (1994). This is the approach we have adopted in this paper.

Moreover, even when a particular stand is taken on the asset structure in the model, it is not always obvious how best to map the model to the data. This might be more easily understood in the model of this paper, under the assumption that the asset structure is one in which the world trades Arrow securities each period (the assumption made in the text).

To begin, we can start by looking at the change in a country's net foreign asset position from one period to the next. If the current account in the data was constructed to include valuation effects, this would be the natural measure of the current account in the model. However, even with this simple concept, we can measure the change at different points within the period by looking at either start or end-of-period levels.

The start-of-period definition is

$$CA_{jt}^{1} = B_{jt+1} - B_{jt},$$

so that, recalling also that

$$B_{jt} = -NX_{jt} + E_t\left[q_{t+1}B_{jt+1}\right],$$

we can write the current account as

$$CA_{jt}^{1} = NX_{jt} + B_{jt+1} - E_t\left[q_{t+1}B_{jt+1}\right],$$

where the two terms after net exports correspond to net factor income (which can be thought of as earned between t and $t+1$),

$$NFI_{jt} = B_{jt+1} - E_t\left[q_{t+1}B_{jt+1}\right].$$

The end-of-period definition is

$$\begin{aligned} CA_{jt}^{2} &= E_t\left[q_{t+1}B_{jt+1}\right] - E_{t-1}\left[q_tB_{jt}\right] \\ &= NX_{jt} + B_{jt} - E_{t-1}\left[q_tB_{jt}\right]. \end{aligned}$$

This differs from the previous version in that it adds net factor income between periods $t-1$ and t

to net exports in period t, as opposed to income earned between t and $t+1$.

As noted previously, current accounts are not measured this way in practice. Specifically, the current account does not include the capital gains or losses on foreign assets. One could try to compute a model analog of net factor income exclusive of capital gains and losses in the model. One way to do this, although far from the only way, would be to define the model in terms of the expected profits and losses from the country's net foreign asset position:

$$NII_{jt} = E_{t-1}\left[B_{jt}\left(1-q_t\right)\right].$$

Intuitively, if we define the interest rate between $t-1$ and t as satisfying

$$q_t = \frac{1}{1+r_t}$$

so that

$$1-q_t = \frac{r_t}{1+r_t},$$

we get

$$B_{jt}\left(1-q_t\right) = r_t \frac{B_{jt}}{1+r_t}.$$

This leads to an alternative measure of the current account, designed to more-closely mimic that available in the data, or

$$CA^3_{jt} = NX_{jt} + E_{t-1}\left[\frac{r_t}{1+r_t} B_{jt}\right].$$

A fourth alternative would be to try to measure net foreign investment income using an average (or expected) interest rate. For example, we might define an average interest rate $\bar{r}_t$ from

$$\bar{q}_t = E_{t-1}\left[q_t\right]$$

as

$$1+\bar{r}_t = 1/\bar{q}_t.$$

Then we have a fourth measure of the current account:

$$CA^4_{jt} = NX_{jt} + \frac{\bar{r}_t}{1+\bar{r}_t} B_{jt}.$$

In summary, in the context of a complete markets model where multiple decentralizations are possible, even when attention is restricted to a decentralization using Arrow securities alone, there are multiple plausible ways of mapping model outputs into the analog of the current account measured in the data.

Appendix D: Regime Change and the Ratio of International Wedges

Figure 11 shows how there was a significant regime change in 1973, examining the series of the ratio of international wedges. All figures are computed using a Markov regime switching model (Hamilton, 1994), assuming that the world has only two states.

- Panel A computes the regime changes *assuming each regime has a different mean and a different volatility*;
- Panel B only assumes each regime has *has a different mean*, while
- Panel C distinguishes between regimes *only based on volatility*.

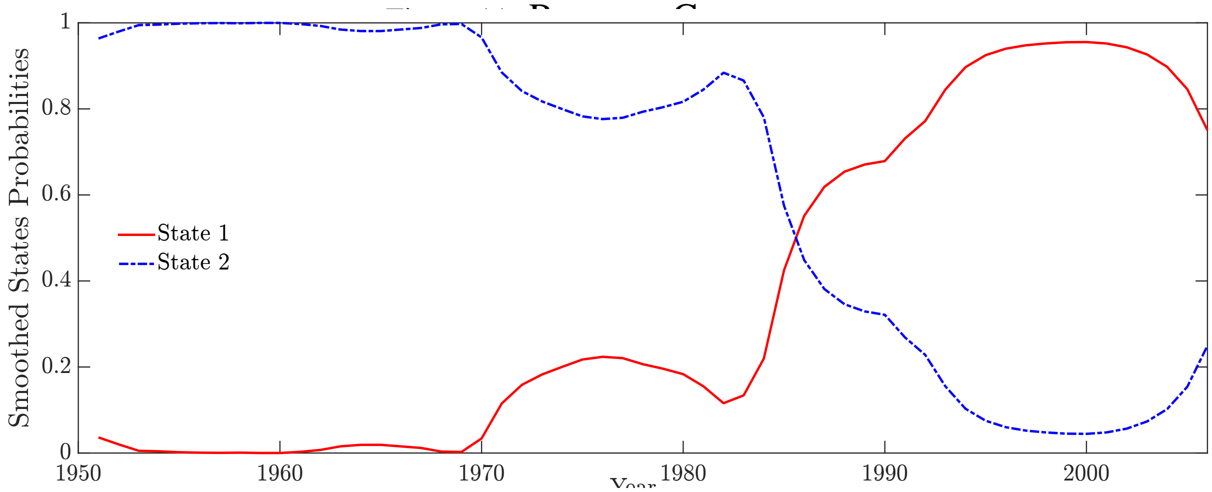
Table 2 summarizes the values of the switching parameters for each of these computations.

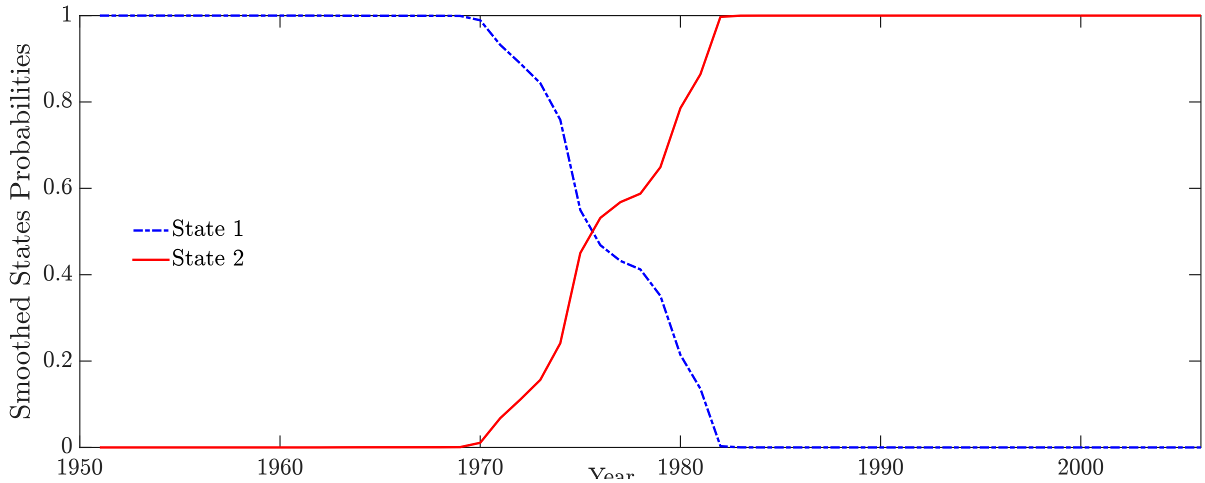
Table 2: RESULTS OF THE MARKOV REGIME SWITCHING MODEL

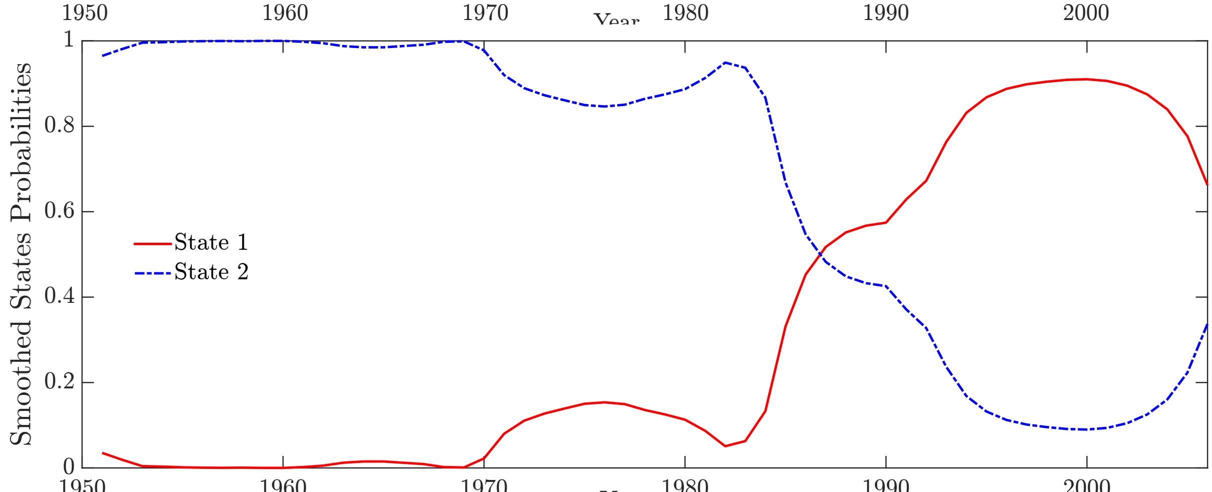
2 Country	Pre-Bretton Woods		Post-Bretton Woods	
Panel	Mean	Std. Dev.	Mean	Std. Dev.
A	-0.02^{***}	0.029^{***}	0.010^{***}	0.010^{***}
B	-0.01^{***}	-	0.006^{***}	-
C	-	0.033^{***}	-	0.010^{***}
2				

Notes: Significance levels: $^{*}p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

As Table 2 and Figure 11 show, the regime change that starts in 1970 for the mean, and in 1973 for the standard deviation of the series describing the ratio of international wedges. The mean is higher and positive in the post-Bretton Woods era, while the regime that starts in 1973 shows a lower standard deviation.







*figure(C) Δ VARIANCE