The Positive and Normative Consequences of Bretton Woods International Capital Controls and the Value of International Political Stability

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Abstract

This paper quantifies the positive and normative effects of international capital controls on global and regional economic activity under The Bretton Woods international financial system. A three region, open economy, DSGE capital flows accounting framework consisting of the U.S., Western Europe, and the Rest of the World is developed to quantify capital controls and evaluate their impact. We find these controls had large positive and normative effects. Counterfactual analyses show world output would have been around 0.5% higher had there been perfect capital mobility, with substantial capital flowing from the ROW to the U.S. Capital controls raised welfare substantially in the rest of the world at the expense of somewhat lower welfare in Europe and much lower welfare in the U.S. We interpret U.S. welfare loss as cost of attempting to preserve international economic and political stability based on US international political goals during the cold war.

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1 Introduction

This paper quantitatively evaluates the positive and normative impacts of capital controls on the world economy under The Bretton Woods international financial system. Bretton Woods was the most significant modern policy experiment 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 monetary aspects, particularly fixed exchange rates and the consequences of shifting to flexible rates following its' failure (see Baxter and Stockman (1989), Bordo (1993, 2018), Obstfeld and Rogoff (2000), Mussa (1986)), and many others.

In contrast, this paper analyzes an important real aspect of the Bretton Woods system, capital controls. The fact that international net capital flows were so small during Bretton Woods (nearly zero between the U.S. and Western Europe and between the U.S. and the rest of the world), particularly after 20 years of severe economic dislocations from the Great Depression through World War II, suggests that capital controls substantially impeded the flow of global capital, and that postwar global economic activity may have been very different in their absence.

This paper evaluates three related questions about Bretton Woods capital controls: (i) how much did Bretton Woods capital controls affect the international flow of capital; (ii) where would capital have flowed in the absence of those controls; and (iii) what were the impacts of these controls on the world economy and on welfare.

Addressing these questions is challenging along several dimensions. Obstfeld et al. (2004) describe how the complex nature of capital controls makes them difficult to quantify. Moreover, the simultaneous use of various types of controls further complicates measurement, and the de facto application of controls may have differed considerably from their de jure specification.

Given these measurement difficulties, this paper develops an open economy, general equilibrium capital flows accounting framework that provides a model-based alternative to measuring effective (de facto) capital controls. We use the model to quantify the effects of capital controls on the world economy between 1950 and 2010.

The world economy is divided 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 (ROW). The modeling approach is an accounting framework that captures the observed levels of consumption, labor, investment, output, and capital flows in each of these three regions with a relatively small number of identified distortions that are measured off of the model's first order conditions. These include an international capital markets distortion that is a tax on international financial transactions between regions. This distortion captures capital controls, as it affects region-specific capital flows and net exports, as developed in Ohanian, Restrepo-Echavarria, and Wright (2018).

We conduct a counterfactual experiment that eliminates the identified distortions affecting international borrowing and lending to evaluate what would have happened if international capital markets had been much more open, such as the global system in place during the "Golden Age" of capital flows in the late 19th and early 20th centuries, when world capital flows were very high and when capital controls were largely absent in international financial markets (see Ohanian and Wright (2010)).

We find that model-inferred capital controls substantially impeded the flow of capital across countries and that the allocation of economic activity across countries would have been very different in their absence. Moreover, we find that substantial amounts of capital would have flowed out of the ROW and into the U.S. during the Bretton Woods period in the absence of controls, and that world output would have been about 0.5 percent higher. The model-inferred capital controls line up consistently with actual capital controls implemented over time and across countries, which leads us to conclude that the model is reasonable capturing these controls.

These controls have large welfare effects, with a perpetual consumption-equivalent welfare benefit of about 5.55 percent for the ROW, while in contrast, we find that U.S. welfare was about 2.78 percent lower, and Europe's was 1.27 percent lower due to impediments to international capital flows.

This finding that capital controls substantially reduced U.S. welfare begs the question of why the U.S. had so strongly promoted these controls in the first place, when the U.S. was the principal architect of the design of Bretton Woods. To address this question, we distill the historical literature on how the U.S. viewed capital controls as central for keeping capital within ally countries, which the U.S. saw as a necessary component for preserving and promoting economic and political stability in these countries. We therefore interpret the high welfare cost of Bretton-Woods capital controls to the U.S. as an estimate of the implicit value of promoting stability in foreign countries whose governments were friendly to the U.S. at a time of U.S. concerns about fascism and communism spreading.

The paper is organized as follows. Section 2 describes how the paper relates to the literature. Section 3 presents the capital flow accounting framework. Section 4 discusses its implementation. Section 5 presents the identified distortions, including a comparison with actual changes in capital control policies. Section 6 shows the counterfactual analyses and the welfare calculations. Section 7 presents a political economy discussion regarding why the U.S. wanted capital controls as part of Bretton Woods. We describe the U.S. concerns that substantial capital would have flowed out of ally countries and into the U.S. in the absence of capital controls, and that the U.S. worried that such flows would be politically and economically destabilizing to U.S. ally countries. Section 8 concludes, interpreting the cost of capital controls within the model as a measure of the implicit value of promoting economic and political stability within ally countries.

2 Relationship to the Literature

Our paper is related to four different strands of the literature. It contributes to the literature on the Bretton Woods agreement, but from a very different perspective. Much of the existing literature focuses on monetary issues, particularly regarding fixed exchange rates and the relationship between real and nominal exchange rates during and after Bretton Woods. Bordo (1993) offers an overview of Bretton Woods from a historical perspective and compares its performance to other international monetary policy regimes. Eichengreen (1992) discusses three different perspectives on the system in terms of how the perspective on the agreement has changed over time. Bordo and Eichengreen (2008) study how the rules imposed by the Bretton Woods agreement regarding balance of payments management ended up affecting FOMC decisions, and Bordo (2018) studies the relationship between inflation and the collapse of the Bretton Woods system. Mussa (1986) documents what is known today as the Mussa Puzzle–a sharp and simultaneous increase in the volatility of the nominal and real exchange rates after the end of the Bretton Woods system. In a more recent paper Itskhoki and Mukhin (2021), revisit the Mussa Puzzle and argue that financial segmentation is the key to understanding the behavior of both the nominal and real exchange rate after the end of Bretton Woods and not price stickiness as has been previously argued. Ayres, Hevia, and Nicolini (2020) show how commodities can help explain the Mussa Puzzle as well as the low correlation between real exchange rates and consumption ratios (the Backus-Smith puzzle). Instead we focus on analyzing the positive and normative effects of Bretton Woods' impediments to international capital mobility on the world economy as opposed to the role of exchange rates which has been largely studied and move very little during the Bretton Woods era.

Our paper also contributes to the literature that tries to identify distortions to factor markets both at the domestic and the international level. Existing literature computes indices of distortions by examining legal restrictions on the operation of markets and then counting up the number of different types of restrictions, providing a qualitative measure of de jure controls or distortions. Examples of this approach in international capital markets include the large number of studies based on the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions, including Chinn and Ito (2008), Quinn (1997), Fernandez, Klein, Rebucci, Schindler, and Uribe (2016), and Ghosh and Qureshi (2016). Unlike these previously mentioned papers, we use data on equilibrium quantities to construct quantitative measures of the impact of de facto controls/distortions to domestic and international capital markets, and focus on the quantitative significance of such controls on macroeconomic variables. Because de jure measures are not always implemented, we argue that our methodology is important as it allows us to measure de facto or effective capital controls. However we show in Section 5 of the paper, that our de facto measures line up remarkably well with those de jure measures from the existing literature.

We build on the literature on business cycle accounting in closed economies following Cole and

Ohanian (2002) and Chari, Kehoe, and McGrattan (2007). Unlike these papers, we examine open economies and focus on medium- and longer-term movements in economic variables, which play a larger role in determining the level of consumption, and hence also savings and international capital flows, than do fluctuations at business cycle frequencies. Our paper is also related to the literature on business cycle accounting in small open economies (see Lama (2011) and Rahmati and Rothert (2014)). In contrast to their partial equilibrium (small open economy) approach with incomplete markets, we show how to apply a general equilibrium complete markets model to data on the world economy constituted from multiple countries. Finally Cheremukhin, Golosov, Guriev, and Tsyvinski (2017) study the structural transformation of Russia in 1885-1940 using an accounting approach to identify the frictions driving such transformation. They use a perfect foresight approach while we incorporate uncertainty.

Finally, our paper is also related to the literature on capital flows and its determinants. Feldstein and Horioka's (1980) examine the correlation between domestic savings and investment rates, and subsequent papers like Bayoumi and Rose (1993), Taylor (1996), Tesar (1991), and many others, interpret their analyses as "tests" of international capital market efficiency. In response to the failure of these tests, the literature has responded by developing models of international financial frictions ranging from limited commitment (Wright (2001), Kehoe and Perri (2002), and Restrepo- Echavarria (2018)) and default risk (Eaton and Gersovitz (1981), Arellano (2008), Aguiar and Gopinath (2006), Tomz and Wright (2013), and many others) to exogenous market incompleteness (Bai and Zhang (2010)) and asymmetric information (Atkeson (1991)). A problem with these "tests" of capital mobility is that they typically rely on strong assumptions about the existence and source of gains from trade, and hence these have low power against plausible alternatives as to the nature of the gains from trade. Our approach complements this literature on international financial market inefficiency by evaluating these frictions using a different framework that uses data on a wider set of macroeconomic variables to simultaneously identify the sources of gains from international trade in capital and to back out the potential role of distortions in limiting that trade. Our emphasis on measuring the gains from trade and in exploring the role of frictions outside of capital markets is shared by a number of other recent studies of international capital flows. Caselli and Feyrer (2007) directly estimate the marginal product of capital for many countries and find that these estimates have converged over time, once the marginal products are adjusted for the share of non-reproducible capital, such as land and natural resources. Obstfeld and Rogoff (2000), Reyes-Heroles (2016), Eaton, Kortum, and Neiman (2016), and others explore the role of trade costs in explaining a number of facts about international flows. In Ohanian, Restrepo-Echavarria, and Wright (2018) we argue that our approach is complementary in that it provides evidence that can be used to test for the role of trade costs. We follow in the footsteps of Alfaro, Kalemli-Ozcan, and Volosovych (2008), who study the role of institutions in driving the incentive to reallocate capital around the world. Unlike them, we focus on how capital controls divert this flows and the geopolitical stability motivation.

3 A Multi-Region Model Economy

This section develops a general equilibrium model as in Ohanian, Restrepo-Echavarria, and Wright (2018) to construct the international capital market distortion and the domestic labor and capital market distortions for the U.S., Western Europe, and the ROW.

3.1 Model Economy

Households The world economy has three "regions" 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 is discrete and is indexed by $t = 0, 1, ...$, so that N_{jt} denotes the population of country j at time t. There is a single traded good. There is a representative agent in each country with preferences over total 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 common across countries. The representative household of country j chooses a state-contingent stream of tradable consumption C_{jt}, hours worked h_{jt}, purchases of capital to be rented out the following 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:

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

where initial capital K_{j0} and bonds B_{j0} are given. The traded good is produced by a representative firm using labor and capital, such that 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 existing capital goods, which will differ from the price of new capital goods due to adjustment costs. 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 securities on the left-hand side of the flow budget constraint. Households also receive profits Π_{jt} from their ownership of domestic firms.

The τ's represent country-specific distortions that are isomorphic to taxes on factor payments and investment income. Specifically, τ^h is a distortion on domestic labor markets, τ^K is a distortion on domestic capital markets, while τ^B is a distortion on international capital markets. Note that a positive value of τ^B is a tax on capital inflows and a negative value of τ^B is a tax on capital outflows.

The revenue from these taxes net of the level of government spending G_{jt} are rebated as lump-sum transfers to/from households each period as T_{jt},

$$T_{jt} = \tau^h_{jt} W_{jt} h_{jt} N_{jt} + \tau^B_{jt} B_{jt} + \tau^K_{jt} \left(r^K_{jt} + P^{*K}_{jt} \right) K_{jt} - G_{jt}. \tag{1}$$

This implies that there is no government borrowing. Since Ricardian equivalence holds, this is without loss of generality.

Finally, Ψ_{jt} is a an international portfolio adjustment cost that ensures long-run consumption stationarity. Even though there are complete markets, the introduction of a time-varying distortion on international capital markets means that consumption can no longer be identified out of relative shares. We discuss this issue in detail in Subsection 3.3.

Firms Each country is populated by two types of competitive, representative firms. The first hires labor and capital to produce the tradable consumption good using a standard Cobb-Douglas technology of the form $A_{jt} K^{\alpha}_{jt} \left(h_{jt} N_{jt} \right)^{1-\alpha}$, 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:

$$W_{jt} = (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}}, \tag{2}$$

and

$$r^K_{jt} = \alpha \frac{Y_{jt}}{K_{jt}}. \tag{3}$$

The second firm produces new capital goods K_{jt+1} using I_{jt} units of investment (deferred consumption) and K_{jt} units of the existing capital good. They maximize profits $P^K_{jt} K_{jt+1} - I_{jt} - P^{*K}_{jt} K_{jt}$ subject to the capital accumulation equation with convex adjustment costs ϕ of the form

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

Although the capital good K_{jt+1} is used for production in period $t+1$, it is produced and sold in period t at price P^K_{jt}. This yields the following first-order conditions:

$$P^K_{jt} = \frac{1}{1 - \phi' \left(\frac{I_{jt}}{K_{jt}} \right)}, \tag{4}$$

$$P^{*K}_{jt} = P^K_{jt} \left(1 - \delta - \phi \left(\frac{I_{jt}}{K_{jt}} \right) + \phi' \left(\frac{I_{jt}}{K_{jt}} \right) \frac{I_{jt}}{K_{jt}} \right), \tag{5}$$

We specify quadratic adjustment costs, which is common in the literature:

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

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

3.2 Growth and Uncertainty

The world economy has grown substantially over the period under study. However, this growth has changed considerably across regions and over time. While the U.S. has had fairly stable growth since World War II, growth in Europe and the ROW has been more volatile. Both of these regions initially grew faster than the U.S. after World War II, but growth slowed considerably, particularly in the ROW, around the 1970s. To capture these region and country-specific growth dynamics, we adopt a specification for the growth of the population and productivity levels with country-specific parameters as in Ohanian, Restrepo-Echavarria, and Wright (2018).

There is a stochastic world trend for both population and productivity based off of U.S. data (for similar approaches, see Canova (1998), Fernandez-Villaverde and Rubio-Ramirez (2007), and Cheremukhin and Restrepo-Echavarria (2014)). United States productivity and population evolve according to

$$\begin{aligned}\ln A_{Ut+1} &= \ln A_{Ut} + \ln \pi_{ss} + \sigma_U^A \varepsilon_{Ut}^A, \\ \ln N_{Ut+1} &= \ln N_{Ut} + \ln \eta_{ss} + \sigma_U^N \varepsilon_{Ut}^N,\end{aligned}$$

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 the model, such that $\pi_t = \frac{A_{Ut+1}}{A_{Ut}} = \pi_{ss} \exp\left(\sigma_U^A \varepsilon_{Ut}^A\right)$ and $\eta_t = \frac{N_{Ut+1}}{N_{Ut}} = \eta_{ss} \exp\left(\sigma_U^N \varepsilon_{Ut}^N\right)$. To achieve stationarity, we scale variables by the level of effective labor in the United States $Z_t = A_{Ut}^{1/(1-\alpha)} N_{Ut}$. Note that this specification nests a constant growth rate as a special case.

Population and productivity levels in Europe and the Rest of the World 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. 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, and we estimate the parameters of the processes below.

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

$$\ln\left(1-\tau_{jt+1}^m\right) = \left(1-\rho_j^m\right) \ln\left(1-\tau_{jss}^m\right) + \rho_j^m \ln\left(1-\tau_{jt}^m\right) + \sigma_j^m \varepsilon_{jt+1}^m, \tag{6}$$

where τ^m_{jss} is the level the distortion would take in the deterministic steady-state of the model and ρ^m_j governs the rate of mean reversion. The evolution of the level of government spending in each country G_{jt} is specified so that the ratio of government spending to national income $g_{jt} = G_{jt}/Y_{jt}$ also follows a first-order autoregressive process:

$$\ln g_{jt+1} = \left(1 - \rho^g_j\right) \ln g_{jss} + \rho^g_j \ln g_{jt} + \sigma^g_j \varepsilon^g_{jt+1}.$$

3.3 Stationarity and International Bond Portfolios

To our knowledge, the capital controls specification developed in Ohanian, Restrepo-Echavarria, and Wright (2018) and applied here is unique within the open economy literature in terms of modeling taxes/subsidies on inflows and outflows with a large set of assets. Notable papers that analyze capital controls within general equilibrium models include Bianchi (2011), who studies a small open economy with a single asset that yields a constant (world) return, and Farhi and Werning (2014), who model capital controls using a tax/subsidy specification, but who study a deterministic environment and a single asset. We view the complete markets specification in this model as a natural and interesting benchmark for two reasons. One is that there are many ways in which markets can be incomplete, so analyzing complete markets provides a baseline which is informative in its own right and provides context for assessing a broad array of incomplete markets models. Another reason is that complete markets captures the spirit of the very complex asset trades observed in actual economies, and can handle many more assets than can be accommodated in a tractable incomplete markets model.

A significant challenge with complete markets, however, is that the continuous state space formulation we specify means each country has an infinite dimensional portfolio decision to solve each period. In the next subsection we show how the solution to a particular pseudo-social planner's problem corresponds to the competitive equilibrium of our complete markets economy, which makes computation of the equilibrium tractable.

Stationarity is achieved by scaling all growing variables with 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, which requires a unique non-degenerate deterministic steady-state. We therefore make some assumptions to ensure this holds. We begin with the Euler equations for state-contingent assets which imply:

$$\left(\frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}}\right)\left(\frac{C_{Rt}/N_{Rt}}{C_{jt}/N_{jt}}\right) = \frac{1 - \tau^B_{jt+1} + \Psi_{jt+1}}{1 - \tau^B_{Rt+1} + \Psi_{Rt+1}} = \zeta^B_{jt+1}. \tag{7}$$

Since the ratio of the international distortions of two regions appears on the right hand side of the equation, we normalize the international distortion for the ROW to one such that

$$\left(\frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}}\right)\left(\frac{C_{Rt}/N_{Rt}}{C_{jt}/N_{jt}}\right) = 1 - \tau^B_{jt+1} + \Psi_{jt+1} = \zeta^B_{jt+1}. \tag{8}$$

This means that the distortions for the U.S. and Europe are identified relative to that in the ROW.

The equation also shows that if the steady-state of τ^B_{jt+1}, is not equal to zero then there is a long-run trend in relative aggregate consumption levels so that the deterministic steady-state distribution of consumption is degenerate (one country's share of consumption must converge to zero). Moreover, assuming that $\tau^B_{jss} = 0$ for all j does not pin down a *unique* steady-state relative consumption level. Intuitively, the impediments to international capital mobility out of steady-state affect the accumulation of international assets, which in turn affect long-run consumption levels. In terms of equation (8), 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 distortion.

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 specify an international distortion that can be decomposed into a term that represents capital controls τ^B_{jt} and an adjustment cost term Ψ_{jt}, both of which the country takes as given:

$$\zeta^B_{jt} = 1 - \tau^B_{jt} + \Psi_{jt}.$$

The exogenous variable τ^B follows a first-order autoregressive process with the steady-state assumed to be zero:

$$\ln\left(1 - \tau^B_{jt+1}\right) = \rho^B_j \ln\left(1 - \tau^B_{jt}\right) + \sigma^B_j \varepsilon^B_{jt+1}. \tag{9}$$

The adjustment cost term can be positive or negative, and satisfies the following:

$$\Psi_{jt} = \left(1 - \tau^B_{jt}\right)\left[\left(\frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}}\frac{1}{\psi_{j0}}\right)^{-\psi_{j1}} - 1\right]. \tag{10}$$

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

$$\ln\frac{C_{jt+1}/N_{jt+1}}{C_{Rt+1}/N_{Rt+1}} = \frac{\psi_{j1}}{1+\psi_{j1}}\ln\psi_{j0} + \frac{1}{1+\psi_{j1}}\ln\frac{C_{jt}/N_{jt}}{C_{Rt}/N_{Rt}} + \frac{1}{1+\psi_{j1}}\ln\left(1 - \tau^B_{jt+1}\right). \tag{11}$$

The portfolio adjustment cost can be positive or negative because in steady-state, relative consumption levels map one-for-one into net foreign asset positions. These parameters are identified from the data by estimating the long-run net foreign asset position of each country from the data.

Given these assumptions, there is a unique non-degenerate deterministic steady-state. We take a first-order log-linear approximation of the pseudo-social planner's problem around this point.

3.4 Pseudo-Social Planning Problem

To compute the allocations of the competitive equilibrium model, we employ a *pseudo-social planning problem* that maps into the competitive equilibrium. We call it a pseudo-social planning problem because mapping it into the competitive equilibrium requires modifying some of the equations of the standard planner's problem, as shown below. Hereafter, we refer to this as the "planning problem."

The planning problem facilitates computation substantially because it allows us to construct the equilibrium allocations while sidestepping the solution of the continuous-choice, infinite dimensional portfolio of securities for the three regions. The planner's first-order conditions also provide intuition for understanding how the model works, so we present a simple version of the problem here. Appendix A shows the full mapping.

The planner chooses state, date, and country contingent sequences of consumption, capital, and hours worked to maximize:

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

subject to a global resource constraint for each state and date:

$$\sum_j \left\{ C_{jt} + \chi_{jt}^I X_{jt} + G_{jt} \right\} = \sum_j \chi_{jt}^I A_{jt} K_{jt}^{\alpha} \left(h_{jt} N_{jt} \right)^{1-\alpha}$$

and region-specific capital evolution equations of the form:

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

The planning problem features time-varying planner weights, χ_{jt}^C. They vary over time because relative consumptions across the regions will vary over time, and this time variation in the planner weights provides intuition about the international capital market distortions in the competitive equilibrium.

To capture the equilibrium model's time allocation distortion, the planner's objective function includes the term χ_{jt}^H. The planner's first order condition maps into the competitive equilibrium first order condition with $\chi_{jt}^H = 1/(1-\tau_{jt}^h)$.

The competitive equilibrium domestic capital allocation distortion is captured in the planner's problem with the term χ_{jt}^I. The intertemporal nature of this distortion in the equilibrium problem requires that this term appears in several places in the planner's problem. This allows us to create the equivalence between the planner and the equilibrium's first-order conditions for investment in each region, and ensures that the time allocation first-order condition mapping is preserved:

$$1-\tau^K_{jt+1}=\frac{\chi^C_{jt+1}}{\chi^C_{jt}}\frac{\chi^I_{jt+1}}{\chi^I_{jt}}.$$

We now turn to the mapping between the international capital market distortion in the equilibrium model and the analogous objects in the planner's problem. As is well known (see Backus, Kehoe, and Kydland (1992) for an example without any distortions), separable, time-invariant utility functions and frictionless markets implies that the equilibrium allocations coincide with planner allocations with constant planner weights across regions.

However, when international capital markets experience time-varying τ^B, then relative consumptions will change over time in the equilibrium problem, since these time-varying τ^B distort the incentives for regions to engage in international trade and asset accumulation over time. The planner's problem captures this time variation in relative consumptions with time-varying planner weights, such that:

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

The equivalence between the equilibrium problem with time-varying τ^B and the planner's problem (see Appendix A for details) implies:

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

which is the same equation (11) from the competitive equilibrium problem with $\varepsilon^C_{jt+1}=\ln\left(1-\tau^B_{jt+1}\right)$.

Thus, the mapping between the equilibrium and the planner's problem relates the international capital market distortion in the equilibrium problem to the time-variation in the planner's weights. This provides context for understanding the counterfactual experiments we conduct below. Specifically, an increase in relative consumption growth for region j, which occurs with a declining τ^B, implies an increase in the planner's weight. This in turn implies that changes in τ^B will redistribute wealth between regions in the equilibrium. These wealth transfers are central in understanding our counterfactual experiments.

4 Implementation

The model described in the previous section has been designed to replicate data from the national income and product account expenditure aggregates. This means the model can be used as an accounting framework for the observed data. This section describes how the model uses these data to identify the different distortions. It also summarizes the sources of the data, with a detailed data discussion in Appendix B.

A small number of structural parameters governing preferences and production are calibrated. Some distortions can be recovered, and the parameters governing their evolution estimated, without solving the model. The remaining parameters are estimated using maximum likelihood.

4.1 Using the Data and Model to Measure Distortions

Realizations of the domestic labor, and capital distortions, as well as international capital market distortions can all be measured by feeding data from the national income and accounting expenditure aggregates through the equilibrium of the model. Realizations of the domestic labor and international distortions are computed directly from first-order conditions without needing the general equilibrium solution of the model. The domestic capital market distortion, on the other hand, requires computing expectations of future capital returns and hence requires both estimating and solving the model.

To see this, note that under our assumption of complete markets, the overall international distortion, ζ^B_{jt+1}, can be recovered from the growth in relative consumption levels, as shown in equation (8). Estimation of equation (11) serves to both decompose ζ^B_{jt+1} into τ^B_{jt+1} and the portfolio adjustment cost Ψ_{jt+1} and estimate the parameters governing the evolution of both. Note that under the assumptions of our model, the residual in this equation—the international distortion—follows an autoregressive process and relative consumption follows an ARMA(1,1) process. Nonetheless, all that is needed to estimate the process governing the international distortion and the parameters of the portfolio adjustment cost is data on the growth in relative consumption levels. This can be done without solving the model.

The domestic labor market distortion can also be recovered and the parameters of its stochastic process can be estimated outside of the model. Specifically, using the first-order labor supply condition for the household and the optimal employment decision of the firm (2), we obtain

$$1 - \tau^h_{jt} = \frac{\varphi}{1-\alpha} h^{\gamma}_{jt} \frac{h_{jt} N_{jt}}{Y_{jt}} \frac{C_{jt}}{N_{jt}}. \tag{12}$$

Specifically, given data on consumption, population, hours worked, and output, and given values for the production and preference parameters, realizations of the labor distortion are recovered and used to estimate its stochastic process. Note it is not possible to separately identify the level of the labor distortion from the preference for leisure parameter φ, which in principle could also vary across countries. Hence, we normalize the leisure parameter to 1 for all countries, and we focus on changes in the levels of these distortions over time.

Lastly, the domestic capital distortion is determined from the Euler equation for the household, the optimal capital decision of the consumer good firm (3), and the optimality conditions of the capital goods firm (4) and (5). Denoting by $i_{jt+1} = I_{jt+1}/K_{jt+1}$ the ratio of investment to the capital stock, we obtain the domestic capital distortion from

$$1 = E_t \left[\beta \frac{C_{jt+1}/N_{jt+1}}{C_{jt}/N_{jt}} \left(1 - \tau^K_{jt+1}\right) \frac{\alpha \frac{Y_{jt+1}}{K_{jt+1}} + \frac{1-\delta-\phi(i_{jt+1})+\phi'(i_{jt+1})i_{jt+1}}{1-\phi'(i_{jt+1})}}{\frac{1}{1-\phi'(i_{jt})}} \right]. \tag{13}$$

Note that we can't separately identify the level of the domestic capital distortion from the level of the discount factor. We therefore focus on changes in the levels of these distortions. Unlike the labor and international distortions, 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. We also estimate the initial capital stock of each country.

4.2 Data, Model Solution, and Model Estimation

Recovering the wedges requires national accounts data, including output Y_{jt}, consumption C_{jt}, investment I_{jt}, and net exports NX_{jt}, and requires data on population N_{jt} and hours worked h_{jt}, for each of the three regions. We use the dataset constructed in Ohanian, Restrepo-Echavarria, and Wright (2018).

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 given the portfolio tax. There are 68 model parameters. This section describes how some parameters are calibrated to standard values in the literature and others are estimated by maximum likelihood using the Kalman Filter. For the welfare calculations of Section 6 we use a second-order approximation.

The empirical values of the portfolio adjustment cost are constructed using relative consumption growth rates across regions, and thus do not depend on any other model features.

The parameters governing preferences and production are constant across countries. Of these common parameters (collected in Table 1), six are calibrated to standard values, while a seventh is a normalization. Specifically, the output elasticity of capital in the Cobb-Douglas production function α is 0.36, the discount factor β is 0.96, and the depreciation rate δ is seven 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 value strikes a balance between estimates of labor supply elasticities using micro data on the intensive margin, using micro data on the extensive margin, and using aggregate data (see the surveys by Pencavel (1987), Keane (2011), and Reichling and Whalen (2012)). As is evident from equation (12), we cannot separately identify the household's preference for leisure φ from the long-run labor distortion τ^h_{jss}, so we normalize φ to 1. We therefore focus on analyzing changes in this wedge over time.

As is standard in the investment adjustment cost literature, 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

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

ν is chosen to generate a value for the elasticity of the price of capital with respect to the investment-capital ratio, $\nu\kappa$. 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 domestic labor, capital, and international distortions; the portfolio tax; and the initial levels of capital in each country.

The steady state growth rate of the the world economy is two percent per year: $z_{ss} = \pi_{ss}^{1/(1-\alpha)}\eta_{ss} = 1.02$.

Given our de-trending approach the model is estimated using the *growth rates* of the data. To ensure that the estimated model produces *levels* of hours worked, capital, and productivity that are consistent with the data, we set the steady-state labor distortion to match the sample average level of hours worked, set the steady-state of the domestic capital distortion 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 estimated using maximum likelihood.

The linearized equations form a state-space representation of the model. The Kalman filter computes the likelihood and generates the paths of the wedges. Table 2 presents the estimated parameters.

5 Model-Inferred Distortions

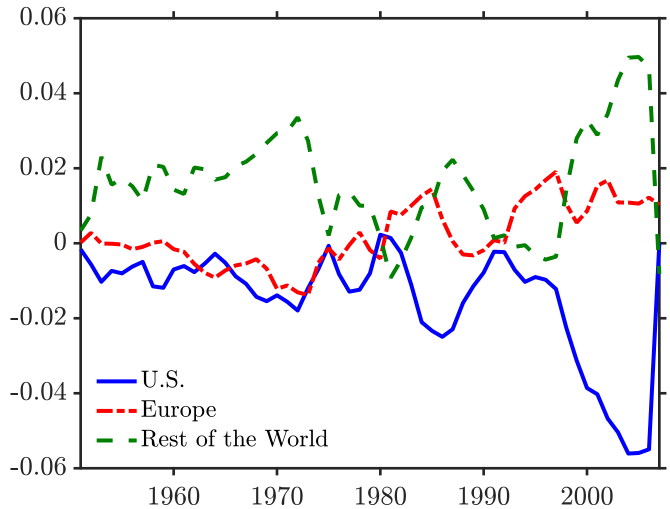
This section presents the model distortions, which pinpoint the precise margins-the allocation of time between market and non-market activities, and the allocation of resources between consumption and investment at home and abroad-that drive observed capital flows and other variables. We discuss how

Table 2: Country-Specific Parameter Values

Process	Region	Steady State	Persistence	Standard Deviation
Population	United States	η_{ss} =0.84	ρ_U^n =1	σ_U^n =0.003
	Europe	n_{Ess} =0.77	ρ_E^n =0.99	σ_E^n =0.002
	Rest of World	n_{Rss} =0.82	ρ_R^n =0.98	σ_R^N =0.003
Productivity	United States	π_{ss} =1.01	ρ_π =1	σ_π =0.08
	Europe	a_{Ess} =0.74	ρ_E^a =0.99	σ_E^a =0.02
	Rest of World	a_{Rss} =0.52	ρ_R^a =0.99	σ_R^a =0.03
Government Distortion	United States	g_{Uss} =0.18	ρ_U^g =0.94	σ_U^g =0.03
	Europe	g_{Ess} =0.20	ρ_E^g =0.20	σ_E^g =0.03
	Rest of World	g_{Rss} =0.13	ρ_R^g =0.13	σ_R^g =0.10
Domestic Labor Market Distortion	United States	τ_{Uss}^h =1.93	ρ_U^h =0.99	σ_U^h =0.04
	Europe	τ_{Ess}^h =1.91	ρ_E^h =0.99	σ_E^h =0.03
	Rest of World	τ_{Rss}^h =1.79	ρ_R^h =0.99	σ_R^h =0.02
Domestic Capital Market Distortion	United States	τ_{Uss}^k =0.94	ρ_U^K =0.99	σ_U^K =0.03
	Europe	τ_{Ess}^k =0.94	ρ_U^h =0.99	σ_U^K =0.27
	Rest of World	τ_{Rss}^k =0.98	ρ_R^h =0.99	σ_R^K =0.01
International Distortion	United States	τ_{Uss}^B =0	ρ_U^B =0.93	σ_U^B =0.02
	Europe	τ_{Ess}^B =0	ρ_E^B =0.93	σ_E^B =0.01
Portfolio Tax	United States	$\psi_{U0} = 1.95$	$1-\psi_{U1}$ =0.94	—
	Europe	$\psi_{E0} = 1.46$	$1-\psi_{E1}$ =0.97	—

Notes: Appendix C contains more details on the estimation.

Figure 1: Capital Flows (Net-Exports %GDP)



these model-constructed distortions align with actual policies, with a focus on capital controls and labor income and consumption taxes.

5.1 International Capital Market Distortions

We begin with Figure 1, which shows capital flows across the three regions. These data provide context for interpreting the international capital market distortions presented below.

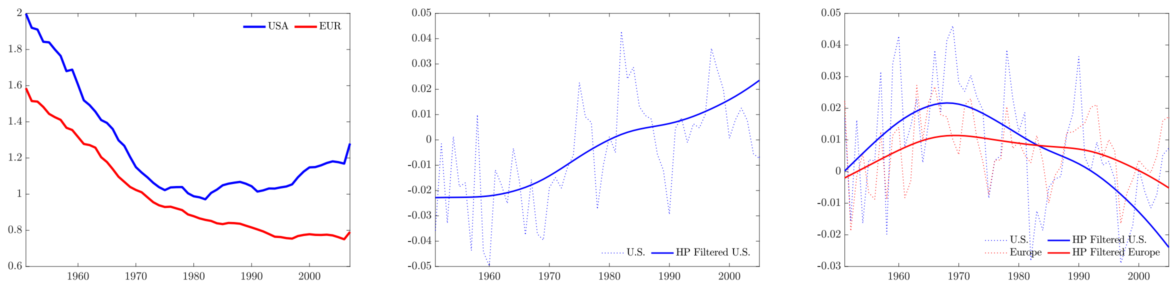
Capital flows were small during Bretton Woods, which is surprising given that much of the 1930s and 1940s was a period of limited capital mobility that coincided with the large shocks of the Great Depression and World War II. This suggests the possibility of strong accumulated incentives to move global capital after World War II. Moreover, TFP and GDP growth across these regions was very different during Bretton Woods, as Europe and the ROW grew much faster than the U.S. This suggests another factor incentivizing global capital flows during Bretton Woods.

To provide evidence on the size of capital flows that did occur during Bretton Woods, we note capital flows were much higher during the late 19th and early 20th centuries, the period known as the "Golden Age of International Finance." Capital controls were largely absent in this era and capital flows were much higher, ranging from inflows as high as nearly eight percent of GDP per year between 1880 and 1913, and outflows that averaged nearly five percent of GDP per year over the same period (See Ohanian and Wright (2010)).

The model economy reproduces the small observed capital flows during Bretton Woods with significant international capital market distortions, which are measured off of relative consumption growth.

Figure 2: Relative Consumption and International Capital Market Distortions

U.S. and Europe Consumptions Relative to RoW | U.S. Consumption Growth Per Capita Relative to RoW | Tax on International Capital Mobility (τ_{jt}^B)



The left panel of Figure 2 shows the consumption of the U.S. and Europe relative to that of the rest of the world. Note in particular the very steep and large decline in U.S. per-capita consumption relative to the ROW, which falls nearly 50 percent during Bretton Woods. This rapid and large change in relative consumption is puzzling, ceteris paribus, given standard consumption-smoothing motives. The middle panel of 2 shows raw and Hodrick-Prescott smoothed relative consumption growth for the U.S. which is negative (as is for Europe although not depicted in the graph) during Bretton Woods.

The right panel of Figure 2 shows raw and Hodrick-Prescott smoothed international capital market distortions for the U.S. and Europe, constructed using their relative consumption growth rates. The main feature of the right panel is the rising distortion to importing capital in the U.S., which increases to nearly 2.5 percent in the smoothed data and is significant compared to the steady state return to investment. Moreover, this distortion is a tax that applies to the entire stock of foreign assets.

The international distortion redistributes consumption across regions. Equation 8 shows that higher values of τ^B imply that both the U.S. and Europe are worse off relative to the ROW, because these consumptions are growing at a slower rate due to the tax on foreign borrowing.

The figure shows that during Bretton Woods, both the U.S. and Europe faced international capital market distortions that on average made capital inflows more expensive, while after 1973 τ_j^B declined, with capital flowing back into the U.S. (see Figure 1).

We will see that removing these distortions during Bretton Woods in a counterfactual experiment will lead to substantial capital inflows to the U.S., which is exactly what the U.S. wanted to prevent when they designed the Bretton Woods system with capital controls.

This analysis interprets the model-inferred international capital market distortions as capital control/regulatory policies that affect the incentives and/or opportunities to move capital internationally. To assess their empirical plausibility, we compare the model measure of international capital market distortions to actual capital control policies implemented at the country level.

We proceed as follows. We first recover the τ^B for the U.S. and the three biggest Western European countries (U.K., France, and Germany), and compare them to actual capital control policy changes (de jure capital controls) that were implemented to affect international capital flows. We chose these countries because of their size and because they have received considerable attention in the literature.

Next, we identified all the capital control policies in these four countries cited in the international capital controls literature as represented by the following set of papers: Bordo (2020), Chinn and Ito (2008), Ghosh and Qureshi (2016), Fernandez, Klein, Rebucci, Schindler, and Uribe (2016), and Ilzetzki, Rheinhart, and Rogoff (2019)). These studies describe 37 separate international capital control/regulatory policies across these four countries.

Then, for each country, we (i) graph its model τ^B over time, (ii) indicate each policy by name at the date of implementation marked by an arrow on the graph, and (iii) describe the intention of each policy, specifically whether it was to discourage capital inflows or to discourage capital outflows.

If the actual policy changes had quantitatively large enough effects on capital flows, then we expect to see a corresponding change in τ^B in the intended direction of the actual policy change.

We will show that the model's measure of capital controls (τ^B) changes, often substantially, when the policies are implemented, and they almost always change in the direction of the intention of the actual policy change. A policy intended to discourage inflows will align with an increase in τ_U^B, and one intended to discourage outflows will align with a decrease in τ_U^B.

United States Figure 3 shows τ_U^B between 1950 and 2007. This corresponds to the dotted line in the right hand panel of Figure 2. We found eight major U.S. international capital flow policies within the literature for comparison. In 1961 the U.S. Treasury's Exchange Stabilization Fund was created to deter capital outflows. The implementation of this policy coincides with a large drop in τ_U^B at that time, which represents a disincentive to capital outflows in the model. In 1963, an interest equalization policy was implemented reflecting concerns of capital outflows, which coincides with a decline in τ_U^B.

In 1969, a policy that broadened the 1963 policy with an interest equalization measure to incorporate mandatory foreign credit restraints was implemented to discourage capital inflows. This measure coincides with an increase in τ_U^B which is a disincentive to capital inflows. In 1971, the U.S. gold window was closed and an import tax was imposed. This coincides with a positive (albeit lower) τ_U^B which is a disincentive to capital inflows.

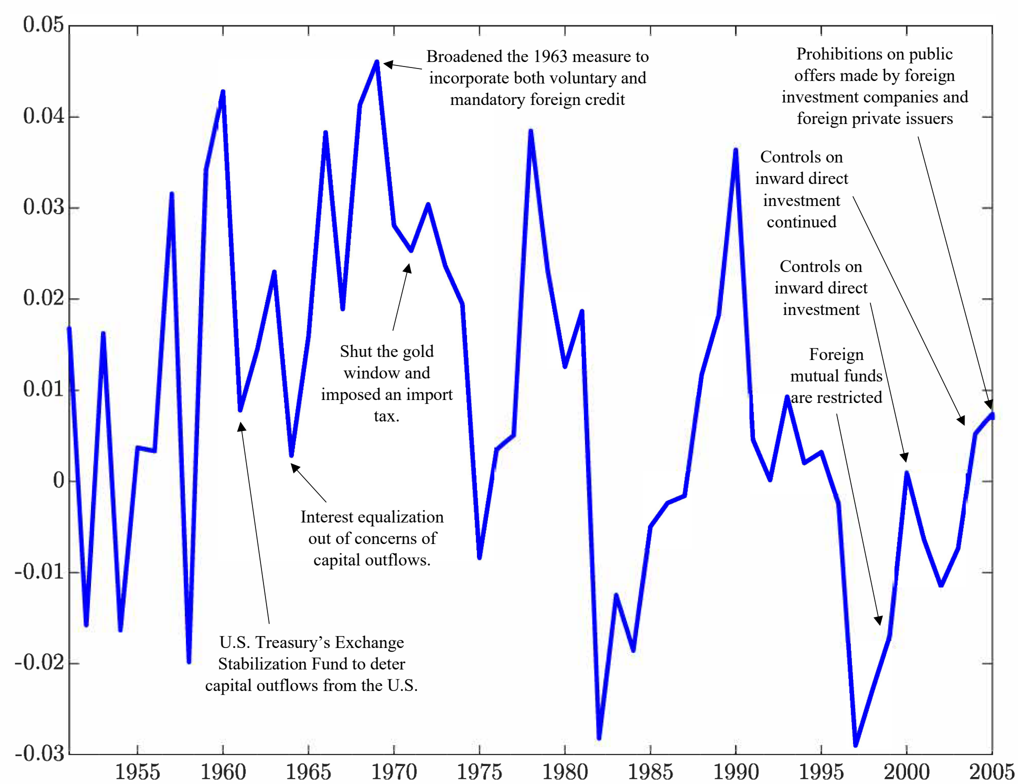
In 1999 Foreign mutual funds are restricted. This restriction applies to nonresident issuers that are defined as investment companies under the Investment Company Act. Also, The Johnson Act prohibits—with certain exceptions—persons within the United States from dealing in financial obligations or extending loans to foreign governments (with the exception of World Bank and IMF members) that have defaulted on payments of their obligations to the U.S. government. These policies institute controls on capital outflows and as such our measure of capital controls is negative during this period (although increasing).

In the year 2000, laws on inward direct investment apply to purchases in the United States by nonresidents. These are controls on capital inflows and as such our measure goes from negative to zero in that period. These measures were reinforced in 2004 reflecting a more positive τ_U^B.

In 2005, public offers made in the United States or to U.S. residents by foreign investment companies are prohibited under the Investment Company Act, unless an order from the Securities and Exchange Commission authorizing such offers is first obtained. This constitutes a control on capital inflows and as such our τ_U^B is positive.

This shows that the intention of all the U.S. policies identified within the capital controls literature matches up with the change or level in the U.S. τ_U^B.

Figure 3: Estimated versus Implemented Capital Controls in the United States



France Figure 4 shows the τ^B for France together with several policy changes. In 1957 France changed the method of monetary control to credit ceilings to prevent capital inflows by placing a cap on borrowing. This policy corresponds to a high value in τ_U^B for France, which disincentivizes capital inflows. In 1959 there was a return to cuurrent account convertibility, meaning that people could receive and convert into local currency resources sent from abroad. This reflects an easing of controls on capital inflows and is captured by a lower international distortion in our model. In 1962 France abolished their "devises-titres" policy, which facilitated cross-border financial transactions in order to deter capital outflows. This corresponds to a decline in τ_U^B which disincentivizes capital outflows. In 1963 french banks stopped paying interest on all foreign deposits. This policy discouraged capital inflows and coincides with an increase in τ_U^B, which disincentivizes inflows. In 1965, France prohibited interest payments on non-resident deposits and on loans by non-residents to residents to deter capital inflows, and this policy coincides with an increase in τ_U^B.

In 1968-69, France reimposed outflow controls, which coincides with a decline in τ_U^B, which is consistent with the policy of disincentivizing outflows. In 1969, the "devises-titres" market was re-established, making cross-border financial transactions more complicated. This in principal might encourage capital outflows and discourage inflows and our model accurately captures this with an increase of τ^B.

In 1973 there was a tightening of capital controls to prevent speculative capital outflows, and this accurately lines up with a decrease in τ^B. In 1974 controls on inflows, including 100% reserve requirements on new non-resident Franc deposits were implemented, and there is a slight increase in τ^B, consistent with discouraging inflows in the model. In 1982 exchange rate controls were adopted to prevent devaluation of the Franc, and as such corresponds to a low τ_U^B, which deters capital outflows. Finally most outflow controls were lifted in 1986 and this coincides with an increase in τ^B.

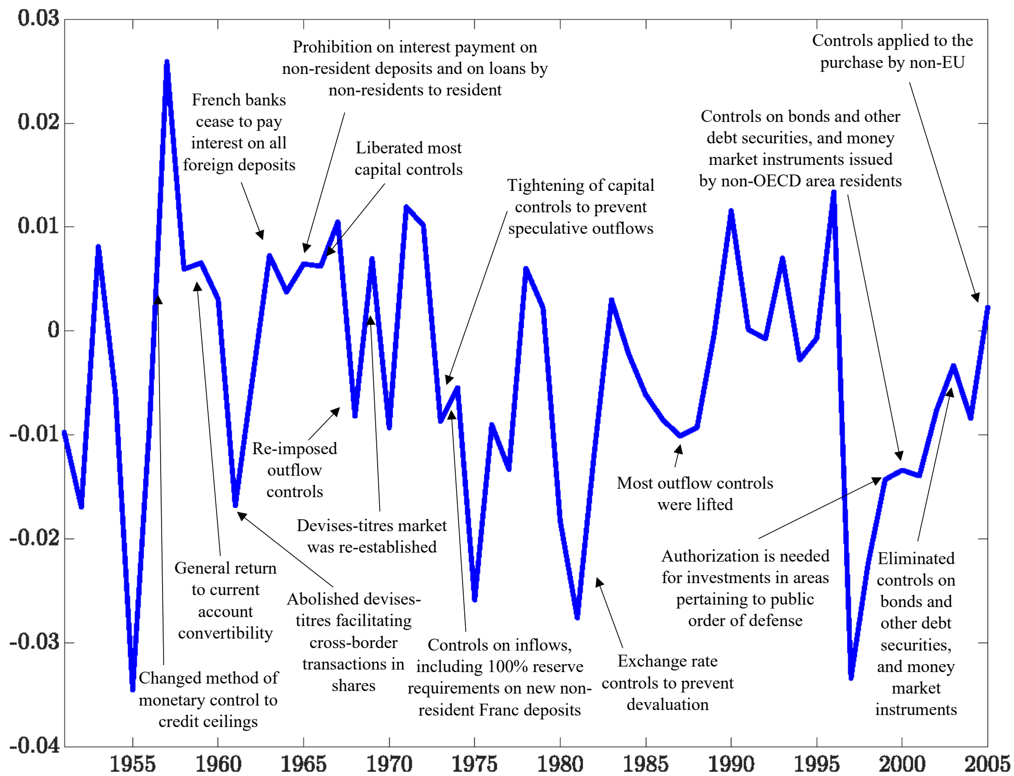
In 1999 an authorization was required for investments in areas pertaining to public order and defense and that the liquidation proceeds of foreign direct investment in France may be freely transferred abroad. These two policies are a tightening on capital inflows and this is reflected by an increase in τ^B.

In 2000 France imposed controls on bonds and other debt securities as well as money market instruments issued by non-OECD area residents. These in principal reflect a control on capital outflows, and our measure of capital controls is negative, though it is slightly increasing.

In 2003, controls on shares, bonds, money market instruments, or other securities of a participating nature issued by non-OECD residents no longer applied. This is a loosening of capital controls on outflows and us such these policies are captured by an increase in our τ^B.

In 2005 France applied controls on the purchase by non-EU residents of securities not quoted on a recognized securities market that may be affected by laws on inward direct investment and establishment as well as to the issue of certificates of deposit by nonresident banks and to foreign collective investment securities. This constitutes a control on capital inflows and it is captured by an increasing and positive τ^B.

Figure 4: Estimated versus Implemented Capital Controls in France



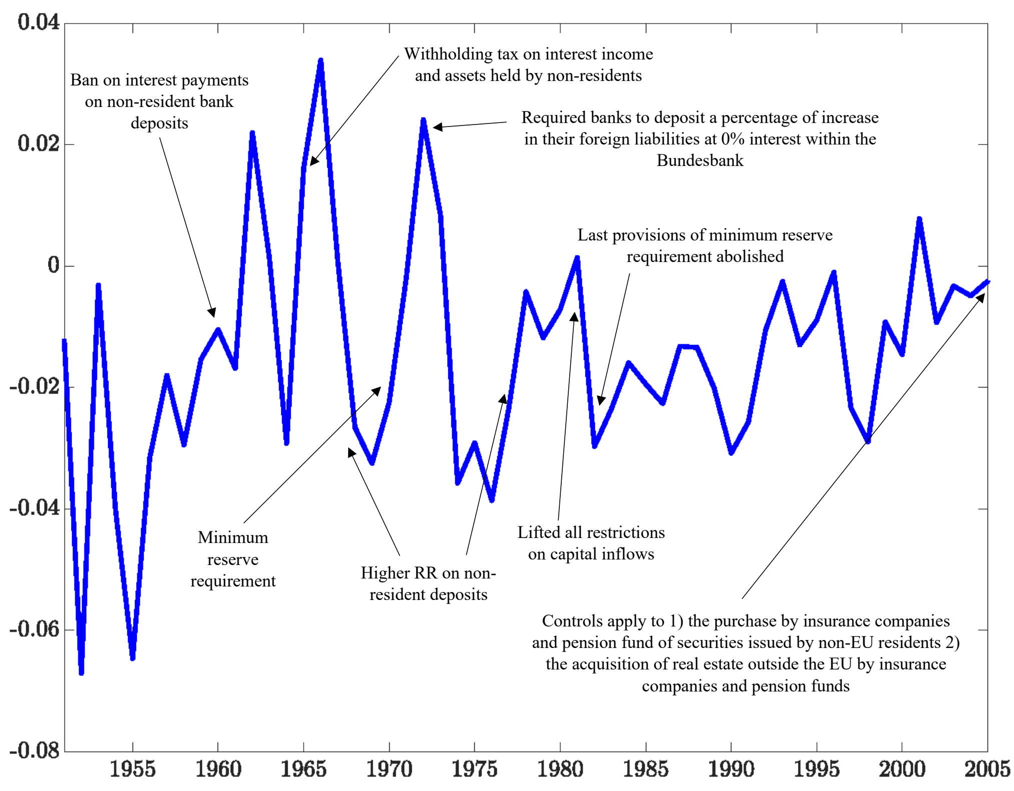
Germany Figure 5 compares τ^B for Germany with observed German capital control policies. In 1960 Germany imposed a ban on interest payments on non-resident bank deposits, discouraging capital inflows, and this coincides with an increase in τ^B. In 1965 Germany implemented a withholding tax on interest income and assets held by non-residents, again deterring capital inflows, which corresponds to a high τ^B in the model. In 1981 Germany lifted all restrictions on capital inflows, which coincides with a peak in our τ^B.

In 1969 and 1977 Germany imposed a higher reserve requirement on non-resident deposits and in 1972 they required banks to deposit a percentage of increase in their foreign liabilities at 0% interest within the Bundesbank. These are all policies that deter capital inflows, and our model identified the ones of 1972 and 1977 as such though note the 1969 policy.

At the begining of the 1980s Germany lifted restrictions on capital inflows and this is correctly reflected in a drop of τ^B.

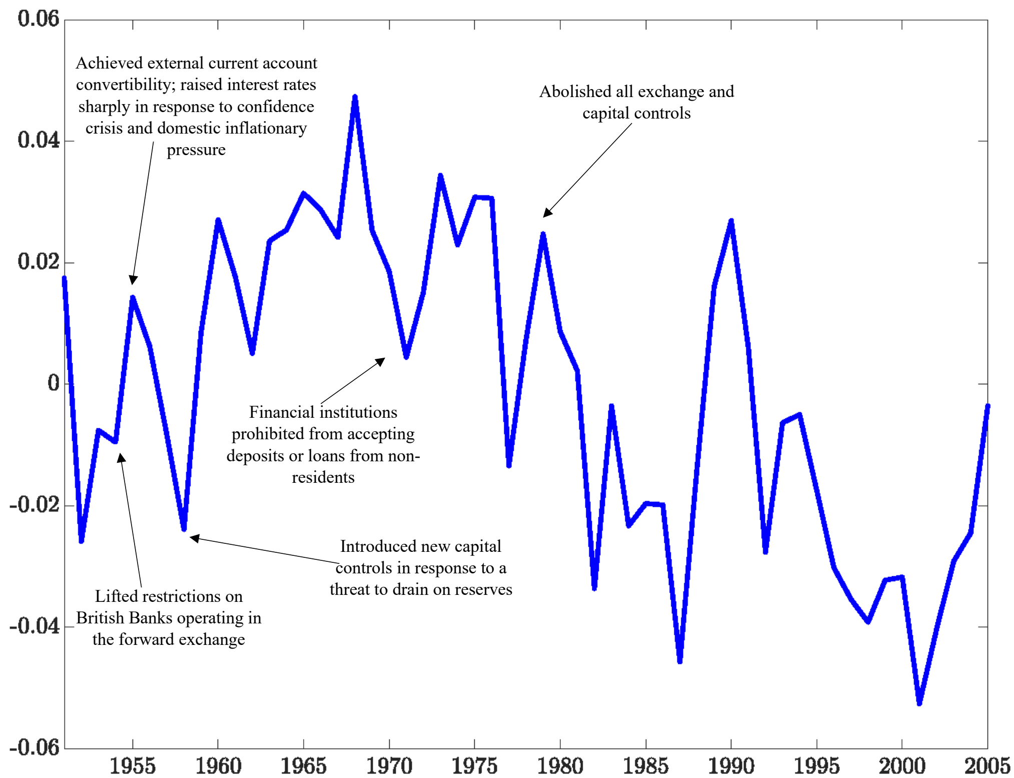
In 2005 controls were applied to the purchase by insurance companies and pension funds of (1) securities issued by non-EU residents if these assets are to form more than 5% of their guarantee assets or more than 20% of their other restricted assets, and (2) shares not quoted on an EU stock exchange if these assets are to form more than 6% of their guarantee assets or more than 20% of their other restricted assets. Also, Germany applied controls to the acquisition of real estate outside the EU by insurance companies and pension funds if the assets in question are to form more than 5% of their guarantee assets or more than 20% of their other restricted assets. These are controls on capital outflows and in our model they correspond to a negative albeit slightly increasing τ^B.

Figure 5: Estimated versus Implemented Capital Controls in Germany



United Kingdom Figure 6 compares our empirical estimate of τ^B with the policies implemented in the United Kingdom to impede international capital mobility. In 1954 the U.K. lifted restrictions on British Banks operating in the forward exchange market. In 1955 they achieved external current account convertibility; raised interest rates sharply in response to confidence crisis and domestic inflationary pressure. In 1957 they introduced new capital controls in response to a threat to drain on reserves, which would be aimed at preventing capital outflows, and it coincides with a low peak in our τ^B. In 1971 financial institutions are prohibited from accepting deposits or loans from non-residents. This is a direct ban on both inflows (deposits) and outflows (loans), so it is impossible to tell in which direction our empirical measure should move. Same as in 1979 when they abolished all exchange and capital controls, it may or may not be a wash and there is no way of knowing.

Figure 6: Estimated versus Implemented Capital Controls in the United Kingdom



In summary, the model inferred measures of the impediments to international capital mobility line up well with the actual policies that were implemented by the U.S., France, and Germany. In the few cases where it doesn't, it is important to keep in mind that our de facto measure of capital controls is a net measure, and it can be the case that controls on outflows are implemented to counteract controls on inflows, and vice-versa.

These findings suggest that the model inferred τ^B's are a reasonable measure of capital controls that we will use to conduct counterfactual experiments.

5.2 Productivity, and Domestic Labor and Capital Market Distortions

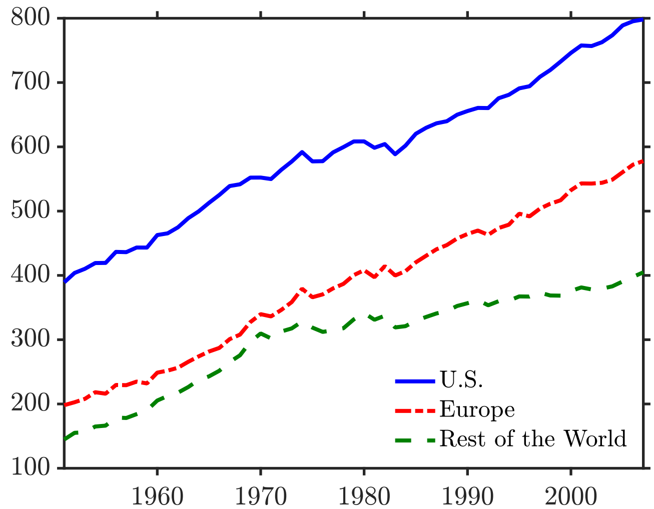
Productivity and capital flows Figure 7 shows total factor productivity for the three regions (A_{jt}). The figure shows that productivity grew rapidly, particularly during the Bretton Woods era. During Bretton Woods, United States TFP grew 1.84%, in Europe TFP grew 2.7% and in the rest of the world TFP grew 3.6%. Bretton Woods was also a period of extremely rapid real output growth, with an average annual growth rate of 3.7% for the United States, 4.6% for Europe and 7.4% for the rest of the world.

These productivity and output growth patterns highlight a rapidly evolving world economy with large differences in growth rates across regions. These large differences suggest an incentive to move capital to the rest of the world, where growth was highest. In sharp contrast, Figure 1 shows that during this period capital flows were very small, and that capital moved in larger quantities to the United States, the region with the slowest growth rate.

Domestic labor market distortions Figure 8 reports the estimated labor market distortions τ^h (right panel) and per capita hours worked (left panel). Recalling that a value of the labor wedge that is greater than zero is equivalent to a tax on labor income, and coincides with employment levels lower than predicted by the model with a distortion that is equal to zero; a value less than zero coincides with relatively high employment, and is interpreted as a subsidy to labor. A value of 0.4, for example, denotes a 40 percent tax rate on labor income.

To interpret this distortion, 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 factors 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

Figure 7: Total Factor Productivity



frictions (Cheremukhin and Restrepo-Echavarria (2014)) that form part of the "technology" of the economy.

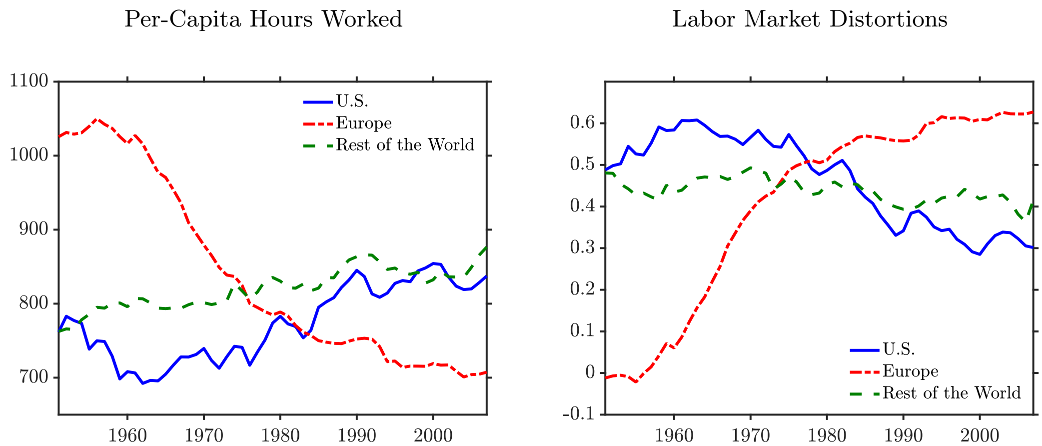
Studies of taxes on labor income and consumption in European countries coincide closely with the European labor wedge. Prescott (2002) and Ohanian, Raffo, and Rogerson (2008) report that in most European countries consumption and labor taxes rose substantially between 1950 and the early 1980s and then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

In summary, our method recovers quantitatively large movements in distortions to labor markets that plausibly coincide with important policy changes affecting labor taxes and labor market regulations in Europe.

Domestic capital market distortions Figure 9 presents the estimates of domestic capital market distortions τ^K. This distortion is identified from the Euler equation (13) and thus reflects the difference between returns to investment estimated from the marginal product of capital and the return estimated from the growth rate of consumption. Bearing in mind the caveat about the recovered levels of this distortion, under our normalization a value of 0.05 is equivalent to a 5 percent tax on capital income.

The volatility of the capital wedge is decreasing across time for Europe and the rest of the world, increasing for the U.S., and its value fluctuates around zero. The volatility of this wedge before 1973 is 49 percent and 65 percent higher for Europe and the rest of the world respectively, and 14 percent

Figure 8: Hours Worked and Labor Market Distortions



lower for the U.S. as compared with its relative volatility between 1973 and 2006.

In the following section, we conduct counterfactual analyses to evaluate the impact of the distortions affecting the international capital markets, domestic capital markets, and labor markets.

6 Counterfactual Analyses

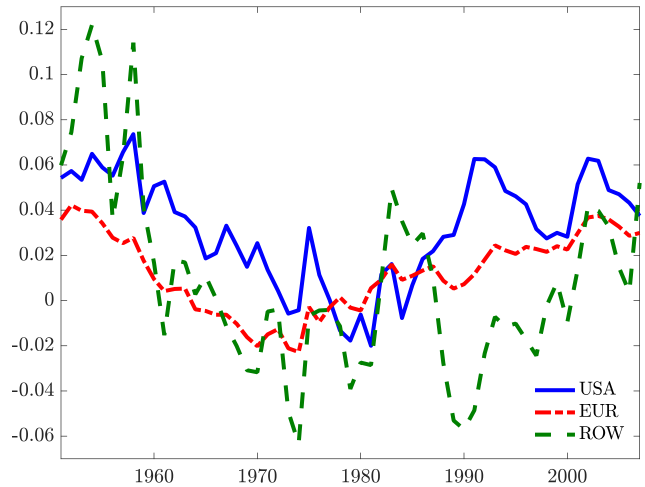
This section conducts counterfactual analyses. The first studies the impact of Bretton World capital controls by setting the international distortions for the U.S. and Europe, $\tau^B = 0$, to zero between 1950 and 1973, and then the process evolves stochasticaly after that. The model is re-solved so that agent expectations are consistent with this change. This analysis thus evaluates the positive and normative effects of perfect capital mobility between 1950-1973.[1]

Recall that the paths of the international capital control distortions are identified from the consumption paths of the U.S. and Europe relative to the ROW. Therefore, implementing this counterfactual pins down these relative consumptions. The levels of the individual consumptions and all the other endogenous variables, will reflect the policy change operating through all the equilibrium channels in the model.

The left panel of Figure 10 shows the relative consumption paths for the U.S. and Europe relative

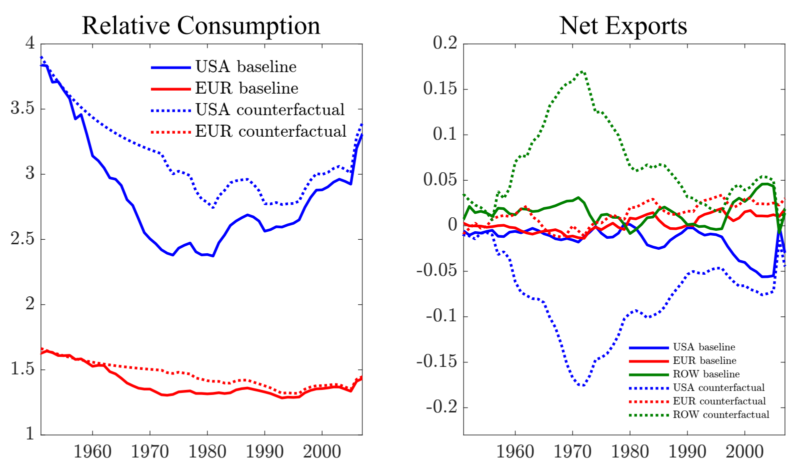
[1]This analysis indentifies capital controls and other policy-related impediments to international capital flows as the factor driving the model's international distortion. While attributing all of the international distortion to Bretton Woods omits other potential factors, the evidence presented above from country-specific policies suggests that Bretton Woods was quantitatively important in the realizations of the distortion. Moreover, interpreting this counterfactual as solely due to international capital control/regulatory policies is simple, and can provide a benchmark for other counterfactuals that include identifiable factors other than policies.

Figure 9: Domestic Capital Market Distortions



to the ROW for the benchmark/data and the counterfactual. The left panel shows net exports. We first discuss the larger changes in the U.S.

Figure 10: Counterfactual Relative Consumption and Capital Flows



The counterfactual path for U.S. relative consumption in the figure is much higher than in the data/benchmark analysis during the Bretton Woods period. To understand this pattern, we begin with the planner's problem. Recall from the equivalence between the planner and the competitive equilibrium that eliminating the U.S. international wedge means increasing the planner's Pareto weight for the U.S. relative to the ROW. This means the planner allocates more consumption to the U.S. and less to the ROW. Interpreting higher relative U.S. consumption within the competitive equilibrium reflects higher U.S. wealth and lower ROW wealth. This wealth transfer from eliminating the U.S. international capital market distortion occurs through a capital gain on the U.S. asset portfolio and a capital loss on the ROW's asset portfolio. Consequently, the wealthier U.S. consumes more, and the poorer ROW consumes less. Note that since we analyze the computationally tractable planner's problem, we do not solve for these portfolios.

In the model, a region or country can achieve higher consumption by either increasing production, or by importing resources (capital inflows). The way they achieve that increase will be determined by the behavior of the other distortions that remain in domestic markets as we show later on in this section.

The right panel of Figure 10 depicts the behavior of net-exports (capital flows). The solid lines show the benchmark (observed net-exports for the U.S. and the aggregate of Europe) and the dashed lines show the counterfactual. When we remove capital controls by setting $\tau^B = 0$ during the Bretton Woods period we can see that capital would have moved out of the rest of the world, and in much smaller amounts out of Europe, and into the United States.

This means that to attain a higher relative consumption, the U.S. imports it, rather than producing it. This is shown in Figure 11, where all plots depict the results in relative terms to the benchmark trajectory of the variable, a value of 1.1 means that the variable of interest is ten percent higher in the counterfactual relative to the benchmark. The blue line represents the U.S., the red line stands for Europe, and the green line for the rest of the world.

The figure shows that the U.S. enjoys a consumption that in 1971 is fifteen percent higher than in the benchmark, they decrease hours worked by up to eight percent, resulting in an output that is between five and six percent lower. In other words, in the absence of capital controls the U.S. would have imported capital to finance consumption while reducing hours and output. In the context of the planner's problem, this correspond to an increase in the relative planner's weights that reflect relative wealth levels.

Figure 8 and Figure 9 in the previous section, show how the U.S. had domestic distortions that represented a tax on labor income and the return to capital. Because this frictions were high during the Bretton Woods era, it is not worthwhile increasing production because these distortions make it costly. As such, in order to achieve the higher relative consumption path that is dictated by the counterfactual, it is better for them to borrow against future consumption.

Figure 11: The World Without Bretton Woods

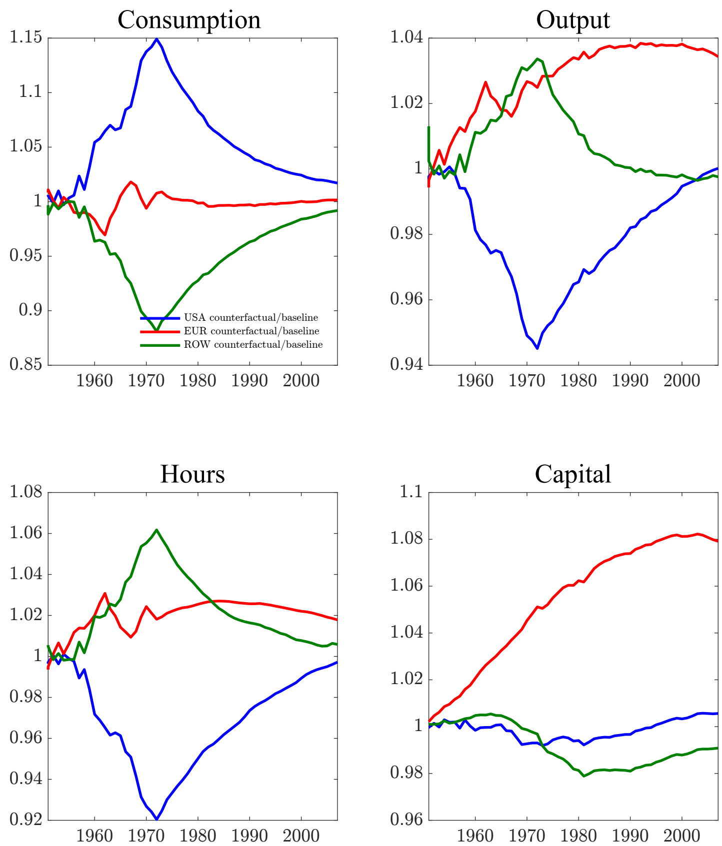


Figure 12: Counterfactual Relative Consumption and Capital Flows when U.S. faces no Distortions

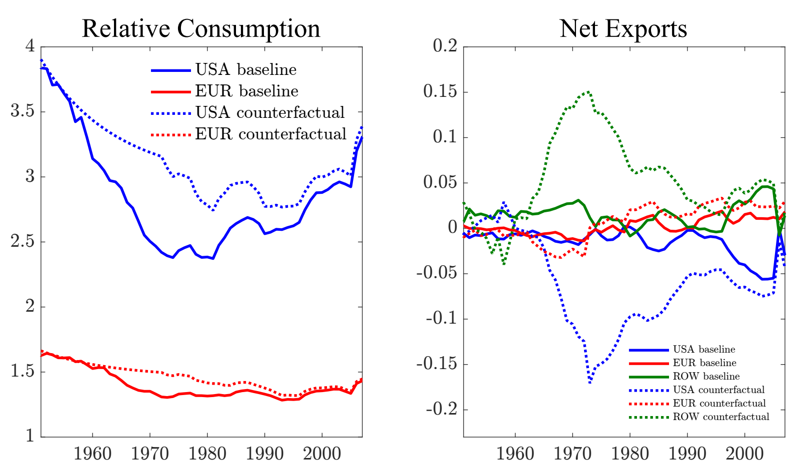
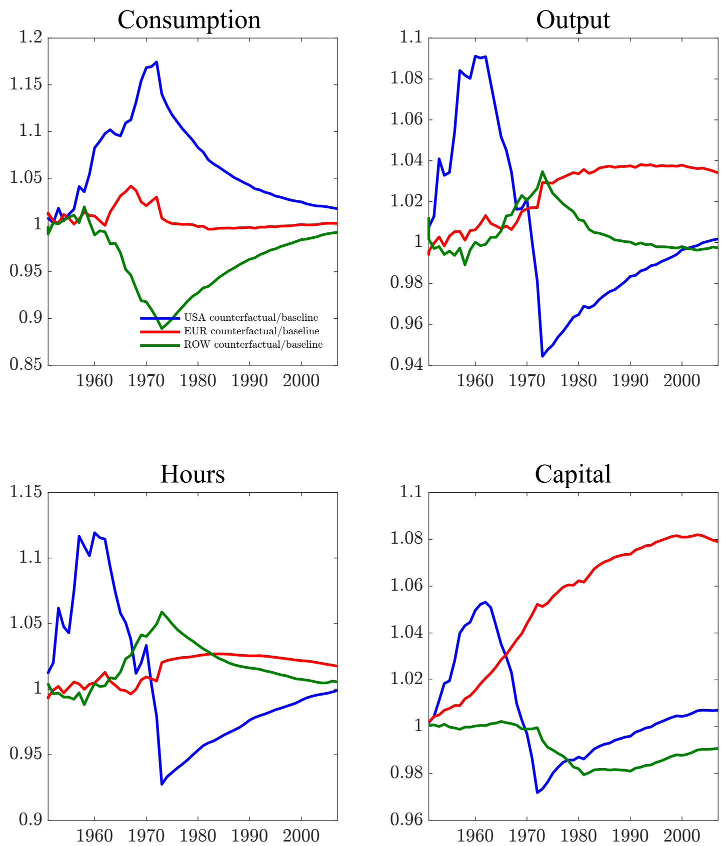


Figure 13: The World Without U.S. International and Domestic Distortions



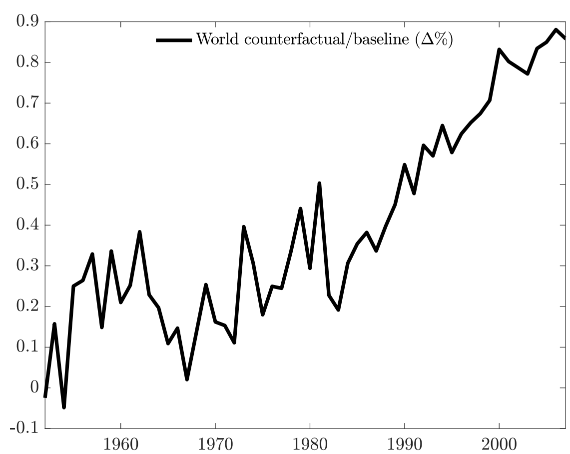
To make this point, Figures 12 and 13 show the results for a counterfactual where we not only shut down capital controls, but we also make both the domestic labor and capital market distortions for the U.S. equal to zero from 1950 to 1973. Note that in that case it is worthwhile increasing production within the U.S. because hours worked and the return to capital are not taxed, so they increase labor and capital to produce more output, and the capital inflows are delayed into later on in the period. So in the absence of domestic frictions the U.S. produces more to increase consumption rather than immediately importing that consumption.

Even though Europe has an international distortion with a fairly similar behavior to that of the U.S., and the counterfactual implies higher consumption from 1960 on wards (like for the U.S.), when we set their $\tau^B = 0$, there are no capital inflows to Europe (while there are to the U.S.). This difference also relies on the domestic market distortions. As shown in the right panel of Figure 8, Europe has a labor market distortion that is strongly increasing during the Bretton Woods era, reflecting an important increase in labor income taxes. As such, and due to the complementarity between labor and capital, the labor market distortion prevents capital from flowing into Europe as labor is scarce, which in turn depresses the productivity of capital. This result is consistent with what we have found in our previous work (see Ohanian, Restrepo-Echavarria, and Wright (2018)). Instead, to attain the higher levels of relative consumption implied by the counterfactual, Europe increases hours worked and investment to accumulate more capital and produce more output that they can consume.

Our counterfactual exercise implies capital inflows that reach a magnitude of about 18% of GDP right around 1970. At first, this might sound like an implausibly large amount. However, when looking back in history, we can see that capital flows averaged around 4% in the late 19th century rising to 7% before the first world war. Also Argentina had flows of 18.7% of GDP in the late 1870's, Finland of 14.2% between 1914 and 1918, Australia of 12.8% between 1927 and 1931, France of 11.7% between 1919 and 1926, and Italy of 11.7% between 1914 and 1918. So our counterfactual numbers are not unreasonable.

We find that these controls have very large effects on output and welfare. Figure 14 shows that the effects on world output oscillate between zero and zero point nine percent of GDP. Meaning that had there been no capital controls between 1950 and 1973, output could have been as much as zero point nine percent larger. Table 3 shows the welfare effects from a consumption equivalent perspective. The ROW had about 5.55 percent higher welfare in consumption-equivalent units for the 1950-1973 period, while Europe had a perpetual consumption-equivalent welfare loss of about 1.27 percent, and the loss for the U.S. was about 2.78 percent in consumption equivalent units under the capital controls imposed by Bretton Woods. When we consider the whole period (1950-2007), loses were smaller for the U.S. and Europe because they saw a slower consumption rundown after the Bretton Woods era.

Figure 14: Effects of Capital Controls on World Output



To understand why setting the international distortions to zero raises U.S., and Europe's welfare, but reduces ROW welfare, it is useful to think that in the pseudo-social planner's problem the negative of the international distortions ($-\tau_j^B$) are approximately equal to the innovation in the planner's Pareto

Table 3: Welfare Effects of Bretton Woods

	Consumption Equivalent	
Region	1950-1972	1950-2007
	(1)	(2)
U.S.	-2.78%	-2.40%
Europe	-1.27%	-1.09%
Rest of the World	5.55%	4.80%

Notes: Column (1) presents the change in consumption equivalent after shutting down the international wedge for the period 1950 to 1972, while making it coincide with the baseline's wedge thereafter. Column (2) shows the change in consumption equivalent after shutting down the international wedge for the entire period (1950 to 2007).

weight. Thus, reducing τ_U^B corresponds to an increase in the planner's Pareto weight for the U.S., which shifts resources from the ROW to the U.S., resulting in higher U.S. consumption and lower US labor supply, and lower ROW consumption and higher ROW labor supply.

The positive innovation to the US Pareto weight in the pseudo planner's problem is equivalent to a wealth transfer from the ROW to the US in the decentralized economy. The U.S. is significantly worse off under Bretton Woods' capital controls. This begs the question of why the U.S. had promoted these controls in the first place, which we discuss in the following section.

7 Why did the U.S. want capital controls?

Bretton Woods' goal was to support international economic and political stability through regulations that governed international trade, payments, and currency values. Bretton Woods immediately followed one of the most politically and economically unstable thirty-year periods in modern history, a three-decade span that included two world wars, a pandemic, the Great Depression, and trade wars.

This section focuses on the U.S.'s goals to support economic reconstruction and international economic growth and promote stability of ally governments to protect against future hostilities with other nations. We will describe how the two major architects of Bretton Woods, Harry Dexter White of the U.S. and John Maynard Keynes were very concerned that free-flowing international capital could endanger these goals, and that capital controls were implemented with these concerns in mind.

The evidence and discussion presented in this section provides context for interpreting the welfare results that show the U.S. would have been significantly better off had Bretton Woods capital controls not been adopted. We will describe how the U.S. was willing to adopt capital control policies that significantly depressed U.S. welfare within a standard, open economy growth model, to promote broader international economic and political stability goals. The evidence shows that the U.S. (i) was very concerned about international capital flight from other countries, (ii) that capital flight would damage economic and political stability in these countries, (iii) that developing countries were particularly vulnerable to capital flight, and (iv) that foreign capital would likely come to the United States. The U.S. concerns from that time that significant international capital would flow from developing countries to the U.S. dovetails with our model findings.

We therefore interpret Bretton Woods capital controls as a tool to preserve economic and political stability in ally countries. We find that the implicit value of capital controls is large, and perhaps plausibly so, given the literature's views about U.S. ambitious foreign policy goals, and given the size of U.S. military spending during Bretton Woods. The welfare costs of Bretton Woods capital controls calculated here thus provide the first quantification (to our knowledge) of U.S. international policy choices relating to the economic and political stability of other countries.

Economic Views of Capital Controls in the 1940s The key concern for both White and Keynes was that capital flows could destabilize a country by draining it of investment funds, which in turn could weaken the country's economy and political stability. They viewed capital controls being useful for several reasons, including economic reconstruction of ally countries after the war, the desire to support developing countries and keep capital in those economies, and the desire to keep unaligned countries from politically aligning with hostile countries, notably Nazi and communist countries.

White described the essence of capital controls as follows:

> [A capital control cooperation provision's] acceptance would go a long way toward solving one of the very troublesome problems in international economic relations, and would remove one of the most potent disturbing factors of monetary stability. Flights of capital, motivated either by prospect of speculative exchange gain, or desire to avoid inflation, or evade taxes or influence legislation, frequently take place especially during disturbed periods. Almost every country, at one time or another, exercises control over the inflow and outflow of investments, but without the cooperation of other countries such control is difficult, expensive, and subject to considerable evasion.

Bretton Woods' capital control design was based on White's and Keynes's views on capital flows during the 1920s and 1930s. Both White and Keynes agreed that capital flows during this period were "speculative,"and that capital flight had exacerbated economic crises during these periods. They believed that capital flows needed to be controlled during periods of instability and recovery, such as the reconstruction period after World War II, though Keynes viewed controls as being a permanent requisite for stability.

A primary goal of capital controls was promoting the reconstruction of devastated countries and the economic development of poor nations. White viewed capital controls as protecting these countries from capital flight [2]:

> Even more harmful than exchange disturbances is the steady drain of capital from a country that needs the capital but is unable for one reason or another to offer sufficient monetary return to keep its capital at home. The assumption that capital serves a country best by flowing to countries which offer most attractive terms is valid only under circumstances that are not always present.

For both White and Keynes, the interwar period contained several episodes of what both considered to be destabilizing capital flows, including the French capital flight in 1925 and 1926, the 1931 Austrian banking crisis, and related crises in Germany and in the U.S. This led White to write as follows[3]:

> There has been too easy an acceptance of the view that an enlightened trade and monetary policy requires complete abandonment of controls over international economic transactions. There is a tendency to regard foreign exchange controls, or any interference with the free movement of funds and of goods as, ipso facto, bad. This view is both unrealistic and unsound. It ignores the fact that there are situations in which many countries frequently find themselves, and which all countries occasionally meet, that make inevitable the adoption of controls of one character or another. There are times when it is in the best economic interests of a country to impose restrictions on movements of capital, and on movements of goods. There are periods in a country's history when failure to impose exchange controls, or import or export controls, have led to serious economic and political disruption.

American concerns with capital flight from developing countries prior to World War II influenced the Bretton Woods agreement. In 1939 American Treasury officials and Latin American officials actively worked on the creation of an Inter-American Bank (IAB) to halt capital flight from Latin America. Assistant Secretary of State Adolf Berle believed capital outflows from Latin America to the U.S. were largely responsible for the lack of capital in Latin America, and White was concerned about the rapid increase in Latin American capital coming into the U.S. in the 1930s (see Helleiner (2014), "International Development and the North-South Dialogue of Bretton Woods", Forgotten foundations of Bretton Woods: International development and the making of the postwar order. Cornell University Press).

By the early 1940s, the U.S. was actively promoting capital controls in Latin American countries, reflecting the extreme volatility these countries experienced from agricultural production. The view was that open markets and limited regulation were dangerous for developing economies, which often

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[2] International Monetary Fund. (1996). "The White Plan". In IMF History Volume 3 (1945-1965): Twenty Years of International Monetary Cooperation Volume III: Documents USA: INTERNATIONAL MONETARY FUND.

[3] International Monetary Fund. (1996). "The White Plan". In IMF History Volume 3 (1945-1965): Twenty Years of International Monetary Cooperation Volume III: Documents. USA: INTERNATIONAL MONETARY FUND.

were highly open economies that exhibited large output fluctuations outside of their control. Robert Triffin wrote[4]:

> We often lose sight of the fact that the general attitude taken in this country with respect to exchange controls may be related to the peculiar circumstances of our own economy and does not take into consideration the fundamentally different characteristics of other economies, more dependent on international transactions and subject to violent disruptions associated with quasi monoculture. In other words, we tend to generalize and give universal validity to rigid principles derived from familiarity with conditions specific to the United States or at least to highly developed and well balanced economies.

International Policy Restrictions to Counteract Nazi and Soviet Influences The U.S. also worried about Nazi influence in Latin America. Helleiner describes that White wrote that the U.S. would need to support Latin America, given that Latin America was being targeted by the Nazis. Helleiner writes[5]:

> "White argued 'Latin America will gradually succumb to the organized economic and ideological campaign now being waged by aggressor nations. A bold program of financial assistance to Latin America that could be an important part of our international political program of peace, security and encouragement of democracy.' In addition, White argued 'Latin America presents a remarkable opportunity for economic development. Only capital and technical skill are needed to develop the area so that it could provide for a much larger population, for a higher standard of living and a greatly expanded foreign trade."

More broadly, Helleiner (2014) argues[6]:

> What explains the US interest in promoting international development? Particularly important was the strategic goal of offsetting the Nazi threat. By offering to back the development aspirations of Southern (Latin American) governments, US officials helped secure alliances and provide a wider moral purpose to the Allied cause in the war, particularly at a time when fascist (and communist) ideals provided alternative routes to development from the preferred US model.

[4] Helleiner, E. (2014). "International Development and the North-South Dialogue of Bretton Woods", Forgotten foundations of Bretton Woods: International development and the making of the postwar order. Cornell University Press, p. 143-144.

[5] Helleiner, E. (2014). Forgotten foundations of Bretton Woods: International development and the making of the postwar order. Cornell University Press, p. 43.

[6] Helleiner, E. (2014). Forgotten foundations of Bretton Woods: International development and the making of the postwar order. Cornell University Press, p. 12.

By 1950, the Nazi influence was over, but the Cold War had begun with the Soviet Union. Eichengreen (2019) notes that even stricter capital controls were implemented in Europe at that time, with the view that these controls would support European reconstruction. This was an even more pressing matter, given geographic proximity between the USSR and free Europe.

Where would capital flow? Based on previous experiences of massive capital inflows to the U.S. during the Great Depression, and the relative health of the U.S. economy as World War II ended, it was expected that the U.S. would be the source for these flows after the war. Broughton (2009), who researched the history of the IMF, describes how in 1935 White advised Treasury Secretary Morgenthau that taxing foreign purchases of U.S. assets would be a way to limit capital inflows, as White viewed these inflows as a potential problem should investors withdraw those funds quickly. In 1938, White advised taxation again as capital inflows to the U.S. continued from France.

Taken together, the political and historical literature indicates that the U.S. viewed capital controls as a an important tool to prevent capital from moving from friendly countries to the U.S., which in turn would promote economic and political stability in those countries. The U.S. had important political/national defense motives for supporting allies and preventing neutral countries from becoming aligned with governments hostile to the U.S. at this time, which support our estimate of the large cost of capital controls to the U.S.

The large U.S. military budget at that time is also consistent with this view. Military spending averaged about 11.8 percent of GDP per year during Bretton Woods, whereas it averaged just 1.6 percent of GDP between 1929 and 1940. If one considers investments in military spending, and investments in political and economic stability in other countries, as complements in producing national defense, then one would expect the U.S. to be willing to pay a high cost of capital controls, given the size of military spending.

8 Summary and Conclusion

Little is known about the quantitative effects of capital controls on the world economy during Bretton Woods because of the number of controls implemented, because of their complexity, and because their *de facto* implementation may have differed from their *de jure* specifications.

This paper analyzed the positive and normative impact of Bretton Woods *de facto* capital controls within an open economy general equilibrium framework, and identifies the effect of capital controls using NIPA and other data, while bypassing the significant difficulties in trying to directly measure these controls and incorporate them into a general equilibrium model.

We find that capital controls had very large effects on world capital flows during Bretton Woods, preventing a considerable amount of capital flowing from the ROW to the U.S. These controls raised welfare for the ROW, but substantially reduced welfare for the U.S. In particular, U.S. per-capita consumption relative to the ROW dropped by 50 percent over the Bretton Woods period. Our analysis identifies capital controls as the factor responsible for this relative decline.

This finding raises an important question: why was the U.S. keen on international capital controls when this appears to be sharply at variance with U.S. interests? We find that the purpose of these controls - to promote political and economic stabiity in ally and unaligned countries - was highly valued because the US had a strong interest in preserving friendly relationships with these countries, many of which were fragile after the war.

The historical literature from that time documents that Harry Dexter White, the U.S. architect of Bretton Woods, viewed capital controls as an important tool that would prevent capital flight out of allied and developing countries to the U.S.

The cost of capital controls to the U.S. is considered here as an implicit U.S. investment that promoted US foreign interests and geopolitical stability. This view aligns with the expensive military involvements after World War II, including the Korean War, the Vietnam War, the Cold War, and smaller interventions in Latin America and the Middle East, in which military spending average nearly 12 percent of GDP between 1950-1973.

More broadly, these findings opens a new avenue for research that integrates open economy macroeconomics with political economy considerations and global conflict. Among other possible lines of inquiry, this type of research can provide a new perspective on U.S. international economic policies since World War II, with a focus on the provision of national defense, whose production includes both traditional investments in military machinery and personnel, and investments in promoting global political and economic stability among ally and unaligned countries.

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APPENDIX

Appendix A: Model Solution and Computation

In this appendix 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:

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

subject to a world resource constraint for each state and date

$$\begin{aligned} & \sum_j \left\{ C_{jt} + \chi_{jt}^I X_{jt} + G_{jt} \right\} \\ = & \sum_j \chi_{jt}^I Y_{jt} + T_t^{PSPP} \\ = & \sum_j \chi_{jt}^I A_{jt} K_{jt}^{\alpha} \left(h_{jt} N_{jt} \right)^{1-\alpha} + T_t^{PSPP}, \end{aligned}$$

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 $T_t^{PSPP} = \sum_j \chi_{jt}^I (X_{jt} - Y_{jt})$), and exogenous paths of population, productivity, and the social planner's "wedges" χ_{jt}^I, χ_{jt}^H, and χ_{jt}^C to be described next.

For χ_{jt}^H we assume the process is given by

$$\ln \chi_{jt+1}^H = \left(1 - \rho_j^h\right) \ln \chi_{jSS}^H + \rho_j^H \ln \chi_{jt}^H + \sigma_j^H \varepsilon_{jt+1}^H, \tag{14}$$

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

$$\chi_{jSS}^H = 1/\left(1 - \tau_{jSS}^h\right),$$

$$
\begin{aligned}
\rho_j^H &= \rho_j^h, \\
\sigma_j^H &= \sigma_j^h.
\end{aligned}
$$

For the social planners consumption wedge, we normalize $\chi_{Rt}^C = \chi_{RSS}^C = 1$, while for $j = U, E$ we require

$$
\ln \chi_{jt+1}^C = \left(1 - \rho_j^C\right) \ln \chi_{jSS}^C + \rho_j^C \ln \chi_{jt}^C + \varepsilon_{jt+1}^C,
$$

with the process for ε_{jt}^C assumed to be autoregressive and of the form

$$
\varepsilon_{jt+1}^C = \rho_j^{\varepsilon^C} \varepsilon_{jt}^C + \sigma_j^{\varepsilon^C} \epsilon_{jt+1}^{\varepsilon^C},
$$

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

$$
\begin{aligned}
1 - \rho_j^C &= \frac{\psi_{j1}}{1 + \psi_{j1}}, \\
\chi_{jSS}^C &= \psi_{j0}, \\
\rho_j^{\varepsilon^C} &= \frac{\rho_j^B}{1 + \psi_{j1}}, \\
\sigma_j^{\varepsilon^C} &= \frac{\sigma_j^B}{1 + \psi_{j1}}.
\end{aligned}
$$

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

$$
\ln\left(\frac{\chi_{jt+1}^I}{\chi_{jt}^I}\right) = \left(1 - \rho_j^I\right) \ln\left(1 + g_{jSS}^{\chi^I}\right) - \ln\left(\frac{\chi_{jt+1}^C}{\chi_{jt}^C}\right) + \rho_j^I \ln\left(\frac{\chi_{jt}^I}{\chi_{jt-1}^I} \frac{\chi_{jt}^C}{\chi_{jt-1}^C}\right) + \sigma_j^{\chi^I} \varepsilon_{jt+1}^I,
$$

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

$$
\begin{aligned}
\rho_j^I &= \rho_j^K, \\
1 + g_{jSS}^{\chi^I} &= 1 - \tau_{jSS}^K \\
\sigma_j^{\chi^I} &= \sigma_j^K.
\end{aligned} \tag{15}
$$

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

$$C_{jt} \quad : \quad \beta^t \chi_{jt}^C \frac{N_{jt}}{C_{jt}} = \lambda_t^{PSPP}, \tag{16}$$

$$h_{jt} \quad : \quad \beta^t \chi_{jt}^C \chi_{jt}^H \psi h_{jt}^\gamma = \lambda_t^{PSPP} (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}} \tag{17}$$

$$K_{jt+1} \quad : \quad \mu_{jt}^{PSPP} = E\left[\lambda_{t+1}^{PSPP} \chi_{jt+1}^I \alpha \frac{Y_{jt+1}}{K_{jt+1}} \right. \tag{18}$$

$$\left. + \mu_{jt+1}^{PSPP} \left(1 - \delta - \phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right) + \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right) \frac{X_{jt+1}}{K_{jt+1}}\right)\right]$$

$$X_{jt} \quad : \quad \lambda_t^{PSPP} \chi_{jt}^I = \mu_{jt}^{PSPP} \left(1 - \phi'\left(\frac{X_{jt}}{K_{jt}}\right)\right) \tag{19}$$

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 (16). 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

$$\lambda_{jt}^{HH} = \frac{\lambda_t^{PSPP}}{\chi_{jt}^C}. \tag{20}$$

Likewise, the FOC of the PSPP with respect to hours (17) 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 (20), we can see that the conditions will be equivalent if

$$W_{jt} = (1-\alpha) \frac{Y_{jt}}{h_{jt} N_{jt}}, \tag{21}$$

$$1 - \tau_{jt}^h = \frac{1}{\chi_{jt}^H}. \tag{22}$$

Note that (21) implies that the FOC in hours for the firm producing the consumption good in the CEP is now satisfied. Moreover, given assumption (14), the derived process for $1 - \tau_{jt}^h$ satisfied the law of motion (6) 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 (11) 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 (18) combined with the FOC with respect to investment (19) 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

$$\begin{aligned}
r_{jt+1}^{K} &= \alpha \frac{Y_{jt+1}}{K_{jt+1}}, \\
P_{jt}^{K} &= \frac{1}{1 - \phi'\left(\frac{X_{jt}}{K_{jt}}\right)}, \\
P_{jt+1}^{*K} &= \frac{1 - \delta - \phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right) + \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)\frac{X_{jt+1}}{K_{jt+1}}}{1 - \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)}, \\
1 - \tau_{jt+1}^{K} &= \frac{\chi_{jt+1}^{C}}{\chi_{jt}^{C}} \frac{\chi_{jt+1}^{I}}{\chi_{jt}^{I}}, \qquad (23)
\end{aligned}$$

where in the last line we substituted from (20). 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 (23) and imposing the restrictions in (15) 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 2.1 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

$$\begin{aligned} c_{jt}+P_{jt}^{K}z_{t}k_{jt+1}+z_{t}E_{t}\left[q_{t+1}b_{jt+1}\right] &\leq \left(1-\tau_{jt}^{h}\right)\frac{W_{jt}h_{jt}N_{jt}}{A_{Rt-1}^{1/(1-\alpha)}N_{Rt-1}}+\left(1-\tau_{jt}^{B}+\Psi_{jt}\right)b_{jt}+t_{jt} \\ &\quad +\left(1-\tau_{jt}^{K}\right)\left(r_{jt}^{K}+P_{jt}^{*K}\right)k_{jt}. \end{aligned}$$

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

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

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

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

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

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

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

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

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 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

$$1 + r^W_{ss} = \left(1 - \tau^K_{jss}\right)\left(\alpha\left(\frac{Y_j}{K_j}\right)_{ss} + 1 - \delta\right)$$

which pins down the capital to output ratio as

$$\frac{K_{jss}}{Y_{jss}} = \alpha\frac{1}{\frac{1+r^W_{ss}}{1-\tau^K_{jss}} - (1-\delta)}.$$

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 $(B_j/Y_j)_{ss}$ 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

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

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. Data on exchange rates per dollar spans the years 1950 to 2008. The country-level data was not available from a single source, thus, it was obtained from different sources. Namely, the OECD, the World Development Indicators, and the Penn World Tables.

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.

We proceed in several steps to create the regional exchange rates. First, we use data on each country's consumption across time, along with total yearly consumption by region. We then calculate the following weight for each country j: $w_{jt} = c_{jt}/\sum_{j\in R} c_{jt}$, where the denominator represents regional consumption, such that $R \in \{EUR, RoW\}$. Finally, we calculate the exchange rate for each region, as follows: $\sum_{j\in R} w_{jt}e_j$, where e_j is the real exchange rate between country j and the U.S.

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.

Rest of the World

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 popu-

lation 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. 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.

11. 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.

12. 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).

13. Canada. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
14. New Zealand. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
15. Iceland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

Europe

1. Austria. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
2. Belgium. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
3. Denmark. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
4. France. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
5. Germany. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
6. Greece. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
7. Italy. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
8. Luxembourg. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1958.
9. Netherlands. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
10. Norway. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
11. Portugal. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1956.
12. Spain. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1954.
13. Sweden. NIPA and population data are from the OECD. Hours worked were taken from GGDC back until 1959.
14. Switzerland. NIPA and population data are from the OECD. Hours worked were taken from GGDC.
15. United Kingdom. NIPA and population data are from the OECD. Hours worked were taken from GGDC.

United States of America

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

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; (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 1973.

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 (2001)).

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

$$CA^1_{jt} = B_{jt+1} - B_{jt},$$

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

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

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

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

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

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

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:

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

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.