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Working Paper Number	2020-042G
Revision Date	April 2025
Citable Link	https://doi.org/10.20955/wp.2020.042
Suggested Citation	Ohanian, L.E., Restrepo-Echavarria, P., Van Patten, D., Wright, M.L.J., 2025; The Impact of Bretton Woods International Capital Controls on the Global Economy and the Value of Geopolitical Stability: A General Equilibrium Analysis, Federal Reserve Bank of St. Louis Working Paper 2020-042. URL https://doi.org/10.20955/wp.2020.042

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The Impact of Bretton Woods International Capital Controls on the Global Economy and the Value of Geopolitical Stability: A General Equilibrium Analysis

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April 11, 2025

Abstract

This paper quantifies the positive and normative effects of Bretton Woods capital controls on global economic activity. It applies a three-region DSGE model of the U.S., Western Europe, and the Rest of the World (ROW) that measures capital controls using observed regional consumption growth differences. We find sizable controls during Bretton Woods that prevented ROW capital from flowing to the U.S., and which reduced U.S. welfare and raised ROW welfare. By preventing capital flight in developing economies, we find that Bretton Woods controls promoted the U.S. foreign policy objective of promoting geopolitical stability in ally countries during the Cold War.

Keywords: Bretton Woods, Capital Flows, Capital Controls, Business Cycle Accounting.

JEL Codes: E21, E65, F21, F33, F38, F41, J20.

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[1]We thank seminar participants, and Mark Aguiar, George Alessandria, Manuel Amador, Andy Atkeson, Michael Bordo, Andrés Fernandez, Erik Hurst, Oleg Itskhoki, Ellen McGrattan, Enrique Mendoza, Maurice Obstfeld, Fabrizio Perri, and Catherine Schenk for helpful discussions, and Patrick Kehoe and Juan Pablo Nicolini for detailed comments that improved the paper significantly. We thank Praew Grittayaphong and Manu Garcia for excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

1 Introduction

This paper quantitatively evaluates the positive and normative effects of capital controls on the global economy during the Bretton Woods international financial system. Bretton Woods was by far the most significant modern policy experiment to implement international capital flows, together with managing international payments and currency values. Because of the size and uniqueness of Bretton Woods, there are thousands of studies of the system. However, much of this literature focuses on its *monetary* aspects (see Baxter and Stockman 1989, Bordo 1993, Bordo 2020, Obstfeld and Rogoff 2000, Mussa 1986, and many others).[2]

This paper studies an important *real* aspect of Bretton Woods: *capital controls* on the global economy. International net capital flows were very small during Bretton Woods. They were nearly zero between the U.S. and Western Europe, between the U.S. and the Rest of the World (ROW), and between Western Europe and the ROW. Given that Bretton Woods immediately followed the severe economic dislocations of the Great Depression and World War II, it is easy to imagine that the incentives to move capital internationally were large after such a disruptive, and economically closed 20-year period. This suggests Bretton Woods controls may have substantially impeded flows and that postwar global economic activity might have been very different in their absence.

We evaluate three related questions about Bretton Woods capital controls: (i) How much did controls affect global capital flows? (ii) Where would capital have flowed in the absence of controls? (iii) What were the impacts of these controls on economic activity and welfare?

Addressing these questions is challenging. Despite 150 years of the use of capital controls, their effects remain largely unknown. Economists surveying the evidence include Dornbusch (2002), who stated, “The costs and benefits of capital controls remain ambiguous”; Prasad et al. (2003), who stated, “Neither theory nor empirical evidence has provided clear-cut general answers to the desirability and efficacy of selective capital controls”; Magud et al. (2018), who stated, "Theoretical models seem to suggest that controls on capital flows do work. Despite all the discussion, however, the debate on the effectiveness of capital controls in policy-making is still not settled."

Perhaps the most important reason why the impact of controls remains elusive is because they are so difficult to measure. Obstfeld et al. (2004) describe how the complex nature of

[2] Helleiner (2014) and Eichengreen (2019) provide excellent, detailed descriptions of Bretton Woods capital controls, including their prevalence compared to earlier periods, their goals of preventing capital flight and limiting financial arbitrage, and how financial innovation increasingly allowed circumvention of the controls. By developing model-based assessments and measurement of effective controls, our paper is a complement to these other studies.

capital controls makes them difficult to quantify. They also note the simultaneous use of various types of controls further complicates measurement, and the *de facto* application of controls can differ from their *de jure* specification. Edwards (1998), Rogoff (2004), Farhi et al. (2011), and Magud et al. (2018) all make similar points regarding the difficulty of measuring capital controls.

To overcome these measurement difficulties, this paper uses an open economy, general equilibrium capital flows accounting framework that provides a model-based approach to measuring effective (*de facto*) capital controls using regional differences in consumption growth. We use the model to quantify the effects of Bretton Woods capital controls on the world economy, which is divided into three regions: (1) the U.S., (2) Western and Northern Europe, and (3) the Rest of the World (ROW).

The modeling approach is an accounting framework that reproduces observed levels of consumption, labor, investment, output, and capital flows in each region with a relatively small number of identified distortions that are measured using the model's first-order conditions. These include a distortion on international financial transactions between regions to capture the effects of capital controls, which is observationally equivalent to a tax on net foreign assets.

We conduct a counterfactual experiment that eliminates the identified international capital markets distortion. This evaluates what would have happened if international capital markets during Bretton Woods had been much more open as they were during the "Golden Age" of capital flows in the late 19th and early 20th centuries, a period when world capital flows were very high and capital controls were largely absent from global financial markets.

We find that Bretton Woods 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 Bretton Woods in the absence of controls. The model-inferred capital controls line up broadly with *de jure* capital controls implemented over time and across countries, which suggests the model's distortion on international capital transactions reasonably captures actual policies. The key empirical identifier of large capital controls during Bretton Woods is observed large and persistent differences in consumption growth rates between the U.S. and the ROW. Specifically, the level of U.S. consumption falls about 50 percent relative to the ROW over the Bretton Woods period, reflecting large and persistently lower consumption growth in the U.S. which in this model implies large impediments to capital flows.

We find capital controls had large welfare effects. The ROW's welfare is 5.55 percent higher (measured as a perpetual consumption-equivalent flow) under Bretton Woods. In contrast, U.S. welfare is 2.78 percent lower, and Europe's is 1.27 percent lower under Bretton Woods. The observed 50 percent drop in U.S. consumption relative to ROW consumption is also the key empirical feature driving the large welfare results. Such a large difference in consumption growth rates between regions is strongly at variance with standard open economy consumption-smoothing motives, and suggests significant impediments to international capital mobility in place during the Bretton Woods period.

Our finding that capital controls substantially reduced U.S. welfare raises the obvious question of why the U.S. - the principal architect of Bretton Woods - wanted capital controls, and wanted them so badly. We address this question by distilling the political economy literature from that era. The U.S.'s key foreign policy objective was preventing the spread of communism and fascism to other countries. U.S. policy makers viewed capital controls as critically important tools for keeping capital within friendly countries to preserve their economic and political stability. This leads us to interpret the welfare cost of capital controls to the U.S. as an estimate of the value of promoting U.S. foreign policy goals during a period that included the Korean War, the Vietnam War, and the Cold War.

The remainder of the paper is organized as follows. Section 2 describes the relation of the paper to the literature. Section 3 presents the capital flows accounting framework. Section 4 discusses implementation. Section 5 presents the identified distortions and compares them to actual changes in capital control policies. Section 6 shows counterfactual analyses and the welfare calculations. Section 7 describes how the U.S. wanted capital controls as part of Bretton Woods to prevent capital from flowing out of friendly, developing countries into the United States. Section 8 concludes.

2 Relationship to the Literature

This paper connects with four strands of the open economy literature. It contributes to the literature on Bretton Woods, but from a different perspective than the many papers that have focused on monetary issues, particularly fixed exchange rates and the relationship between real and nominal exchange rates during and after Bretton Woods. This includes Bordo (1993), who offers a historical overview of Bretton Woods and compares its performance to other policy regimes, Bordo (2020), who studies the relationship between inflation and the collapse of Bretton Woods, and Mussa (1986), who studied the increase in the volatility of nominal and real exchange rates after the end of Bretton Woods. Mussa's paper has been extended by Itskhoki and Mukhin (2021), who argue financial segmentation is central for understanding both nominal and real exchange rates after Bretton Woods, and Ayres et al.

(2020), who show how commodities can resolve the Mussa puzzle and the Backus-Smith puzzle (Backus et al. 1992). In contrast, this paper measures capital controls using observed differences in consumption growth rates and evaluates their positive and normative global effects.

This paper also contributes to the literature on identifying distortions in capital markets. The existing literature computes distortion indices by examining legal restrictions on market operations and counting various types of restrictions, thereby measuring *de jure* controls. Many studies based on the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions include Chinn and Ito (2008), Fernández et al. (2016), and Ghosh and Qureshi (2016). We utilize equilibrium quantity data to construct quantitative measures of the impact of *de facto* controls/distortions on domestic and international capital markets and analyze their macroeconomic effects. Since *de jure* measures are not always implemented or may take time to take effect, our methodology enables the measurement of *de facto* or effective capital controls. However, we demonstrate in Section 5 that our *de facto* measures capture the effects of the *de jure* measures discussed in existing literature.

We build on the literature on business cycle accounting in closed economies following Cole and Ohanian (2002) and Chari et al. (2007). Unlike these papers, we examine open economies and focus on medium- and longer-term movements in variables. Our paper is also related to the literature on business cycle accounting in small open economies (see Lama 2011). 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. Cheremukhin et al. (2017) study the structural transformation of Russia over 1885-1940 using an accounting approach to identify the frictions driving such transformation. They use a perfect foresight approach while we incorporate uncertainty.

Our paper is also related to the large literature on capital flows. Feldstein and Horioka (1980) examine the correlation between domestic savings and investment rates, and subsequent papers (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 developed models of international financial frictions ranging from limited commitment (Kehoe and Perri 2002 and Restrepo-Echavarria 2019) and default risk (Eaton and Gersovitz 1981, Arellano 2008, Aguiar and Gopinath 2006, and many others) to exogenous market incompleteness (Arellano et al. 2012) and asymmetric information. Our approach complements this literature by evaluating these frictions using a different framework, which employs data on a wider set of macroeconomic variables to simultaneously identify the sources of gains from international trade in capital and to infer distortions limiting that trade. Our emphasis on measuring the gains from trade and on exploring the role of frictions outside of capital markets is shared by a number of other recent studies of international capital flows. Obstfeld and Rogoff (2000), Eaton et al. (2016), and others explore the role of trade costs in explaining a number of facts about international flows. In Ohanian et al. (2018) we show that our approach is complementary by providing evidence that can be used to test for the role of trade costs. Our paper is also related to Alfaro et al. (2008), who study the role of institutions in driving capital flows.

3 A Multi-Region Model Economy

This section applies the open-economy model of Ohanian et al. (2018), to construct the international capital market distortions and other distortions for the U.S., Western Europe, and the Rest of the World (ROW). In contrast to Ohanian et al. (2018), this paper focuses on the effect of capital controls during Bretton Woods between the U.S., Europe, and the ROW, which includes Asia and Latin America, whereas the former paper focused on the impact of labor market policies in influencing capital flows between East Asia, Latin America, and the rest of the world, which included the U.S. and Europe.

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 (ROW)." 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 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 preference parameters β, φ, and γ are common across countries. The representative household of country j chooses a state-contingent stream of 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 bonds 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. Final output is produced by a representative firm using labor and capital, such that W_{jt} is the wage, r^K_{jt} is the rental rate of capital, P^K_{jt} is the price of new capital goods, and P^{*K}_{jt} is the price of existing capital, which will differ from the price of new capital 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 terms are 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, and τ^B is a distortion on international capital markets. A positive τ^B is a tax on net foreign assets and a negative value is a subsidy.

The revenue from these taxes net of the level of government spending G_{jt} is rebated as lump-sum transfers 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 there is no government borrowing. Since Ricardian equivalence holds, this is without loss of generality. Finally, Ψ_{jt} is an international portfolio adjustment cost that ensures long-run consumption stationarity. 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 $A_{jt} K^{\alpha}_{jt} \left(h_{jt} N_{jt} \right)^{1-\alpha}$, where A_{jt} is the level of aggregate productivity. This yields expressions for the equilibrium wage and rental rate:

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

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 and K_{jt} units of existing capital. They maximize profits $P^K_{jt} K_{jt+1} - I_{jt} - P^{*K}_{jt} K_{jt}$ subject to capital's law of motion with convex adjustment costs ϕ

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

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

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

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

We specify quadratic adjustment costs:

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

All production parameters other than productivity are constant and identical across countries.

3.2 Growth and Uncertainty

The world economy grew substantially over Bretton Woods. However, this growth changed considerably across regions and over time. While U.S. growth has been fairly stable, 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 mid-1970s. To capture these growth dynamics, we specify stochastic processes for population and productivity as follows.

There is a stochastic world trend for both population and productivity based on U.S. data (for similar approaches, see Fernandez-Villaverde and Rubio-Ramirez 2007 and Cheremukhin and Restrepo-Echavarria 2014). U.S. 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 U.S. level of effective labor $Z_t = A_{Ut}^{1/(1-\alpha)} N_{Ut}$.

Population and productivity levels in Europe and the ROW evolve relative to the U.S. trend so that a non-degenerate long-run distribution of economic activity across countries is preserved. For Europe and the ROW 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:

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

This specification allows for long-lasting deviations from the world trend, and is broadly related to Aguiar and Gopinath's (2007) analysis of growth and TFP in emerging economies.

The labor, capital, and international distortions (indexed by $m = h, K$, and B) for each country/region 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_{jss}^m is the level in the model's deterministic steady state and ρ_j^m governs mean reversion. Government spending in each country/region G_{jt} is specified so that the ratio of spending to national income $g_{jt} = G_{jt}/Y_{jt}$ also follows a first-order autoregressive process:

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

3.3 Stationarity and International Bond Portfolios

To our knowledge, the capital controls specification developed in Ohanian et al. (2018) and applied here is unique within the literature, as it models taxes/subsidies on international flows with a very large set of assets and a large number of shocks. To see this, we note important papers analyzing 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 in a deterministic environment with a single asset.

We view our complete markets specification as a natural benchmark for three reasons. One is that there are so many ways in which markets can be incomplete that analyzing complete markets provides a baseline that is informative in its own right, and provides context for assessing any incomplete markets model. Another reason is that complete markets captures the spirit of the very complex set of assets traded in actual economies. A third reason is that this framework maps into the class of endogenously incomplete markets analyzed in Kehoe and Perri (2002), which means that one could interpret the findings presented here within the incomplete markets setting of limited commitment (see Ohanian et al. 2018).

Stationarity is achieved by scaling all growing variables with the stochastic world trend Z_{t-1}. We use perturbation methods given the large number of state variables (23). This requires a unique non-degenerate deterministic steady-state. The following assumptions 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, we normalize the international distortion for the ROW to one such that

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

Given this normalization, the U.S. and Europe distortions 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 affects 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 history of the distortion realizations.

Similar issues arise in multi-agent models with heterogeneous rates of time preference (see Uzawa 1968) and in small open economy incomplete markets models. In the latter context, alternative resolutions have been proposed, as in Schmitt-Grohe and Uribe (2003). We use the portfolio adjustment cost approach, adapted to our complete markets setting. 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:

$$\zeta_{jt}^{B} = 1 - \tau_{jt}^{B} + \Psi_{jt}.$$

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

$$\ln\left(1 - \tau_{jt+1}^{B}\right) = \rho_j^B \ln\left(1 - \tau_{jt}^{B}\right) + \sigma_j^B \varepsilon_{jt+1}^{B}. \tag{9}$$

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

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

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

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

The portfolio adjustment cost can be positive (subsidy on net foreign assets) or negative (tax on net foreign assets) because in the steady-state, relative consumption levels map one-for-one into net foreign asset positions. These parameters are identified by estimating the long-run net foreign asset position of each country from the data. Given the assumptions above, there is a unique non-degenerate steady state.

3.4 Social Planning Equivalence Formulation

The continuous state-space of this model means each country has an infinite dimensional portfolio decision to solve every period. To deal with this complexity, this section constructs a pseudo-social planner's problem that maps into the competitive equilibrium, which in turn makes computation very tractable. We call it a *pseudo-social planning problem* because mapping it into the competitive equilibrium requires modifying some of the equations of a typical planner's problem, as shown below. Hereafter, we refer to this as the *planning problem* to conserve space.

The planning problem facilitates computation because it allows us to construct equilibrium allocations without solving for the continuous-choice, infinite dimensional securities portfolio for each region. The planner's first-order conditions also provide intuition for the allocations when we analyze counterfactuals, so we present the key aspects of the planner and its mapping here, with details in the Online Appendix.

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 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 discussed below.

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 requires that this term appear in several places to construct the equivalence between the investment first-order condition for the planner and equilibrium:

$$1 - \tau_{jt+1}^K = \frac{\chi_{jt+1}^C}{\chi_{jt}^C} \frac{\chi_{jt+1}^I}{\chi_{jt}^I}.$$

We now map the equilibrium model's international capital market distortion into the planner's problem. As is well known (see Backus et al. 1992 for a general equilibrium, open economy with no distortions), separable, time-invariant utility functions and frictionless markets imply the model's equilibrium allocations coincide with the planner's allocations with constant planner weights across regions. However, when there are time-varying τ^B, then equilibrium relative consumption shares vary over time.

The planner captures this time variation in consumption shares with time-varying planner weights:

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

The equivalence between the competitive equilibrium with time-varying τ^B and the planner's problem with time-varying planner weights (see the Online Appendix for details) yields the following relationship between the planner's solution and the equilibrium:

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

Note this is the same equation (11) from the competitive equilibrium problem with $\varepsilon_{jt+1}^C = \ln\left(1-\tau_{jt+1}^B\right)$.

This equivalence result provides context for understanding the counterfactual experiments. For example, a decline in τ^B for region j will increase relative consumption growth for region j, and this rising consumption growth requires an increase in the planner's weight for region j within the planner's problem.

4 Implementation

The model replicates data from the national income and product accounts' (NIPA) 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 data sources, with a detailed discussion in the Online Appendix.

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 Data and Model to Measure Distortions

Realizations of the domestic labor and capital distortions, as well as international capital market distortions, are measured by feeding data from the NIPA 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. The domestic capital market distortion requires computing expectations of future capital returns and hence requires both estimating and solving the model.

To see this, note that under 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, the residual in this equation 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 also is recovered, and the parameters of its stochastic process can be estimated, outside of the model. Specifically, using the first-order labor supply condition 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, consumption, population, hours worked, and output data, and given values for the production and preference parameters, realizations of the labor distortion are recovered and used to estimate its stochastic process. Note that it is not possible to separately identify the level of the labor distortion from the leisure preference 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 log changes in 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, the capital distortion is given by

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

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 log changes of this distortion. 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 NIPA 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.

The dataset constructed in Ohanian et al. (2018) is used here. In terms of countries, Europe includes Austria, Belgium, Denmark, Luxembourg, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Sweden, Switzerland, Turkey, and the United Kingdom. The ROW includes Japan, Korea, Taiwan, Hong Kong, Singapore, Canada, Australia, New Zealand, Iceland, Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela, and Costa Rica.

We do not include the USSR or China, as they were command economies during Bretton Woods, and there are also significant data reliability issues during this period of time. However, the countries included in the dataset account for 75 percent of world GDP in 1950.

We solve the model numerically by taking a first-order log-linear approximation of the model around its deterministic steady-state. 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. 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. The production elasticity of capital, α, is 0.36, the discount factor β is 0.96, and the depreciation rate δ is 7 percent per year. These are all standard values. The curvature for the disutility of labor γ is set to 1.5, which implies a Frisch elasticity of 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 and Keane 2011). 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 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 steady state adjustment costs are zero, or $\kappa = (\delta + z_{ss} - 1)$. The adjustment cost scale parameter ν is chosen to generate an elasticity of the price of capital with respect to the

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

investment-capital ratio, $\nu\kappa$. Bernanke et al. (1999) use a value of 0.25 for this elasticity for the United States and suggest a range of plausible values from 0 to 0.5. We use 0.5 as our benchmark.

The remaining parameters govern the evolution of population, productivity, and 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 2 percent per year: $z_{ss} = \pi_{ss}^{1/(1-\alpha)}\eta_{ss} = 1.02$.

Given the detrending method, 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 distortions to match the sample average level of hours worked, and the steady states of the domestic capital distortions to match sample capital-to-output ratios from our benchmark capital series, and estimate the steady-states and persistence of the productivity processes from the productivity data. All other parameters are estimated using maximum likelihood. The Kalman filter computes the likelihood and generates the paths of the distortions. 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, and the allocation of resources between consumption and investment at home and abroad-that drive observed capital flows and the other variables. We also discuss how these model-constructed distortions align with actual policies, with a focus on international capital controls and labor income and consumption taxes.

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	ψ_{U0} = 1.95	$1-\psi_{U1}$ =0.94	—
	Europe	ψ_{E0} = 1.46	$1-\psi_{E1}$ =0.97	—

Notes: Appendix C contains more details on the estimation.

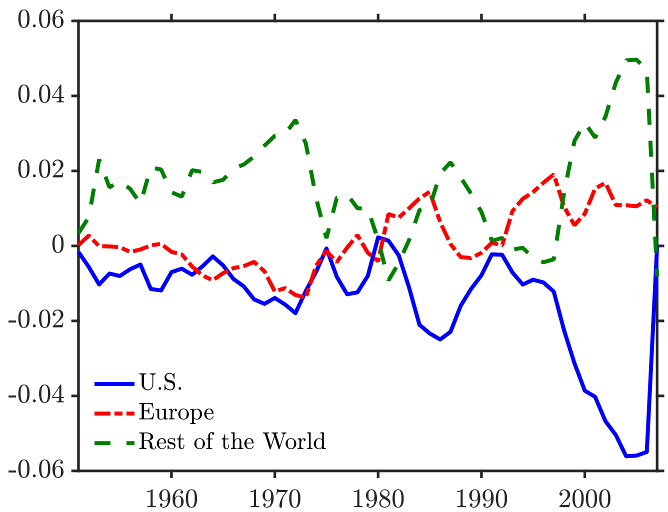
5.1 International Capital Market Distortions

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 the 1930s and 1940s was a period of very limited capital mobility that coincided with the disruptions of the Great Depression and World War II. This suggests the possibility of strong, accumulated incentives to move global capital after a very disruptive 15-year period. Moreover, TFP and GDP growth across regions were very different during Bretton Woods, as Europe and the ROW grew much faster than the U.S. This is another reason to expect sizeable capital flows during Bretton Woods.

To provide a comparative benchmark regarding 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 at that time and capital flows were much higher, ranging from inflows as high as eight percent of GDP per year between 1880 and 1913, and outflows that averaged nearly five percent of GDP per year over this long period (see Ohanian and Wright 2010). This period of time shows that very large global capital flows do occur if capital markets are open.

The model economy reproduces the small observed capital flows during Bretton Woods with significant international capital market distortions, which as described above, are measured from relative regional consumption growth. The left panel of Figure 2 shows the consumption of the U.S. and Europe relative to the Rest of the World. We focus on the very steep and large decline in U.S. per capita consumption relative to the ROW, which falls about 50 percent during Bretton Woods. This large and persistent difference in consumption growth between the U.S. and the ROW is striking, because this is strongly at variance with standard consumption-smoothing motives. Framed slightly differently, these very different consumption growth patterns across regions indicate a strong motive for much larger global capital flows than what occurred, and that shutting down flows suggest large distortions to the incentives and/or opportunities to move global capital.

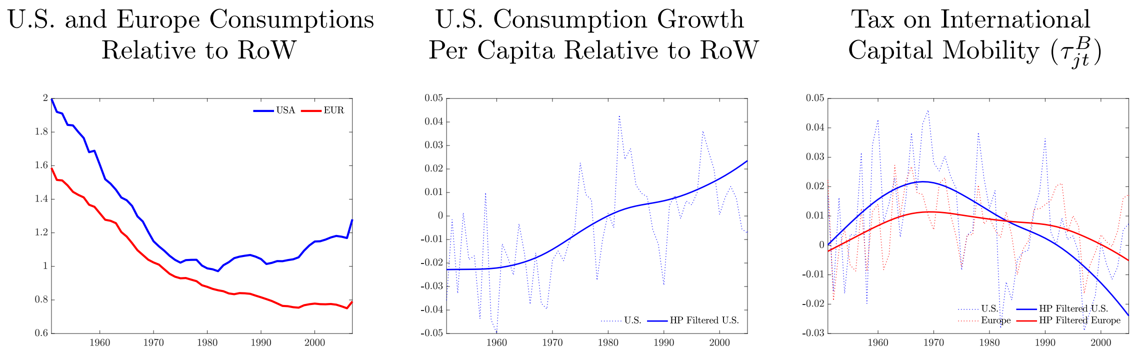
Figure 1: Capital Flows (Net-Exports %GDP)



The right panel of Figure 2 shows the raw and Hodrick-Prescott-smoothed model international capital market distortions for the U.S. and Europe. Recall that these distortions are approximately equal to the negative of their respective growth rates of consumption relative to the rest of the world. The main feature of the right panel is the rising distortion in the U.S., which increases to nearly 2.5 percent in the smoothed data and which is sizeable relative to the steady-state return to investment. The size of the distortion is significant in that it applies to the entire stock of net foreign assets. The international distortion redistributes consumption across regions, as Equation 8 shows that higher values of τ^B means consumption in the U.S. and Europe is growing slower than the ROW.

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 historical empirical plausibility, we compare the model's mea-

Figure 2: Relative Consumptions and International Capital Market Distortions



sures of international capital market distortions to actual historical capital control policies implemented at the country level.

To accomplish this, we commpare the τ^B for the U.S. and the three biggest Western European countries (U.K., France, and Germany) to actual changes in capital control policies (*de jure* capital controls) that were implemented. We choose these countries because of their size and because they have received considerable attention in the literature. We identified all the capital control policies in these four countries cited in the international capital controls literature as represented by the following papers: Bordo (2020), Chinn and Ito (2008), Ghosh and Qureshi (2016), and Fernández et al. (2016). These studies describe 37 separate international capital control/regulatory policies across these four countries.

For each region, we plot the model τ^B over time, indicate each policy by name at the date of adoption marked by an arrow on the graph, and describe the intention of each policy, specifically whether it was to discourage capital inflows (red arrow), whether it was to discourage capital outflows (blue arrow), or whether it was intended to broadly limit capital flows without a specific emphasis on thier direction of flows (black arrow).

If the actual controls had quantitatively large effects, and if other factors were not masking or offsetting the impact of these controls, then we expect to see a corresponding change in τ^B in the intended direction of the control after it was implemented. Given potential differences in *de jure* versus *de facto* capital controls, and that it may have taken some time to see the effects of the policies, we make this comparison over time rather than just at the immediate date at which the policy was adopted.

United States

Figure 3 shows τ^B for the United States between 1950 and 2007. This corresponds to the dotted blue line in the right-hand panel of Figure 2. We found six significant U.S. international capital flow regulations within the literature to be compared to the model's distortion. We 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 generate a *decrease* in τ^B, and one intended to discourage outflows will be followed by an *increase* in τ^B.[3]

The U.S. Treasury's Exchange Stabilization Fund (ESF) was established in 1934 to stabilize the dollar through foreign exchange interventions. By the early 1960s, rising U.S. balance of payments deficits led to concerns over capital outflows. In 1961, President Kennedy introduced voluntary capital restraints to address these concerns, followed by President Johnson's implementation of the Interest Equalization Tax on foreign securities in 1964. After the implementation of these measures aimed at reducing capital outflows, our model shows an increase in τ^B, which is consistent with these policies.

In 1969, there was a broadening of the 1964 interest equalization measure by imposing mandatory foreign credit restraints to discourage capital inflows. This policy was followed by a decrease in τ^B, which is consistent with the policy.

In 1971, the U.S. closed the gold window and imposed a tax on imports to protect a weakening U.S. dollar. As stated in Bordo and Eichengreen (2013), "With monetary policy sidelined, the pressure on the dollar could not be contained. On August 15th, facing the prospect of massive Western European conversion of outstanding dollar balances into gold, President Nixon closed the gold window...". This policy was aimed at preventing a massive entry of U.S. dollars into the U.S with the purpose of exchanging them for gold and generally preventing inflows through the tax on imports. This is captured in our model by a sharp decrease in τ^B that comes a year later after the policies are announced.

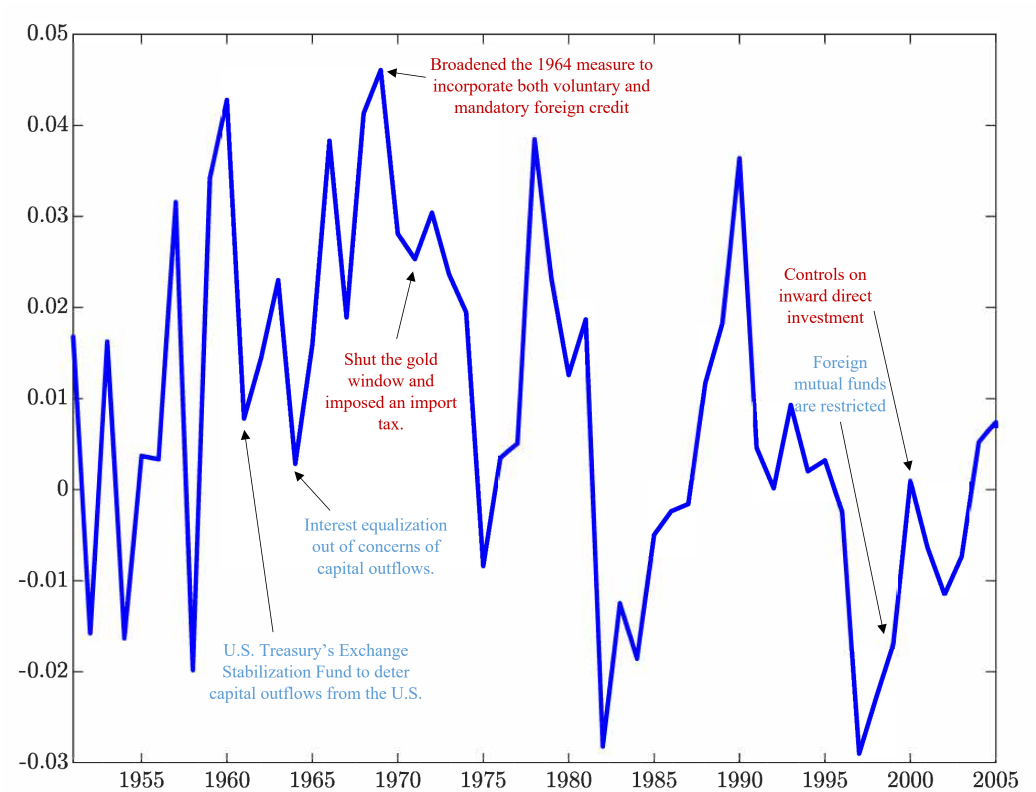
While our focus is on the Bretton Woods period, we do find two policies after Bretton Woods that are noteworthy. In 1999, restrictions were imposed on foreign mutual funds issued by nonresident investment companies under the Investment Company Act. At the same time, the Johnson Act barred U.S. persons from extending loans to foreign governments in default on U.S. obligations, with exceptions for World Bank and IMF members. These measure were intended to limit capital outflows by restricting U.S. investments abroad, and they are correctly identified by our model as an increase in τ^B.

In 2000, regulations on inward direct investment targeted nonresident purchases in the

[3]Because the international distortion works like a tax on foreign assets, one might argue that this same effect could alternatively reflect changes in trade costs over time. Appendix D evaluates this possibility by comparing the model's international distortions (τ^B) to trade costs constructed by Meissner and Novy (2011). We only find a weak relationship between the two, which suggests that the model's τ^B are not standing in for trade costs.

United States, aiming to protect sensitive sectors and safeguard national security. By restricting foreign capital in critical industries, these measures act as controls on capital inflows, and consequently our model generates a decrease in τ^B. This analysis shows that the intention of all of the U.S. policies identified within the capital controls literature matches up with the direction of the change in the U.S. τ^B.

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



Notes: The blue line represents τ^B over time. Labels mark each policy's name and adoption date with arrows. The font color indicates each policy's intent: red for discouraging capital inflows, blue for discouraging outflows, and black for affecting capital flows overall.

France

Figure 4 shows the τ^B for France together with several policy changes. In 1957, France shifted its method of monetary control to credit ceilings, aiming to prevent capital outflows by capping domestic borrowing and limiting the availability of funds for foreign investments. This measure aligns with an increase in τ^B, consistent with the policy. In 1958, the return to current account convertibility likely led to an increase in capital outflows, and accordingly, the model generates a decline in τ^B as a reflection of what the French called "normalization" of capital controls at that time. In 1962, France abolished its 'devises-titres' policy, removing restrictions on cross-border financial transactions. This policy can have several effects on capital flows, so there is no specific direction in which our international distortion should move. In 1963, French banks ceased paying interest on foreign deposits, discouraging capital inflows. The model correctly responds with a decrease in τ^B. In 1965, France prohibited interest payments on non-resident deposits and loans from non-residents to residents, aiming to deter capital inflows. The model exhibits a small decline.

In 1968-69, France reinstated outflow controls, generating a rise in our observed τ^B. In 1969, the 'devises-titres' market was re-established, making cross-border financial transactions more complicated in both directions (inflows and outflows), but the model identifies the net effect of the policy to be dominated by stronger restrictions on inflows given the observed decrease in τ^B after the policy was implemented, consistent with the policy.

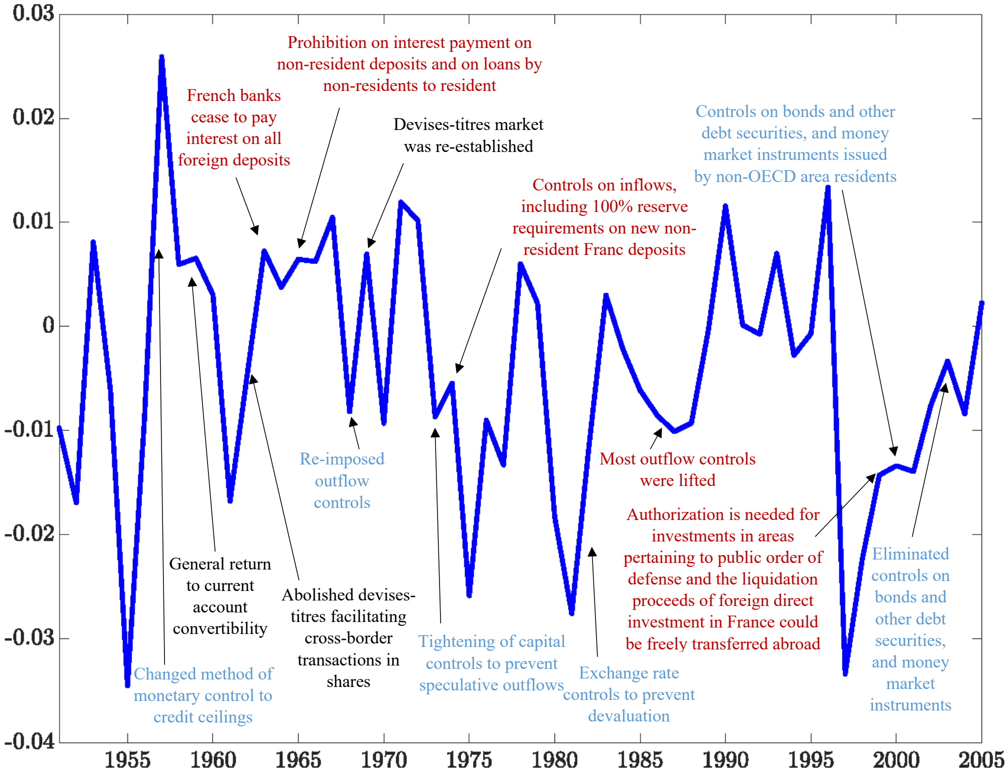
In 1973 there was a tightening of capital controls to prevent speculative capital outflows, and this accurately lines up with a small increase in τ^B. In 1974, controls on inflows were introduced, including a 100 percent reserve requirement on new non-resident franc deposits, consistent with a sharp decline in τ^B. In 1982, exchange rate controls were implemented to prevent the devaluation of the franc. This policy, aimed at deterring capital outflows, leads to an increase in τ^B, consistent with the policy.

In 1999 authorization was required for investments in areas pertaining to public order and defense and the liquidation proceeds of foreign direct investment in France could be freely transferred abroad. These two policies were aimed at loosening controls on capital inflows and this is reflected in a slight increase in τ^B, consistent with the policy.

In 2000, France imposed controls on bonds, other debt securities, and money market instruments issued by non-OECD residents. This policy, aimed at deterring capital outflows, coincides with a sizable increase in τ^B, which is consistent with the policy with a delay of one year.

In 2003, controls on shares, bonds, money market instruments, and other equity-like securities issued by non-OECD residents were lifted. This loosening of controls on capital outflows coincides with a decrease in τ^B, consistent with the policy.

Figure 4: Estimated versus Implemented Capital Controls in France

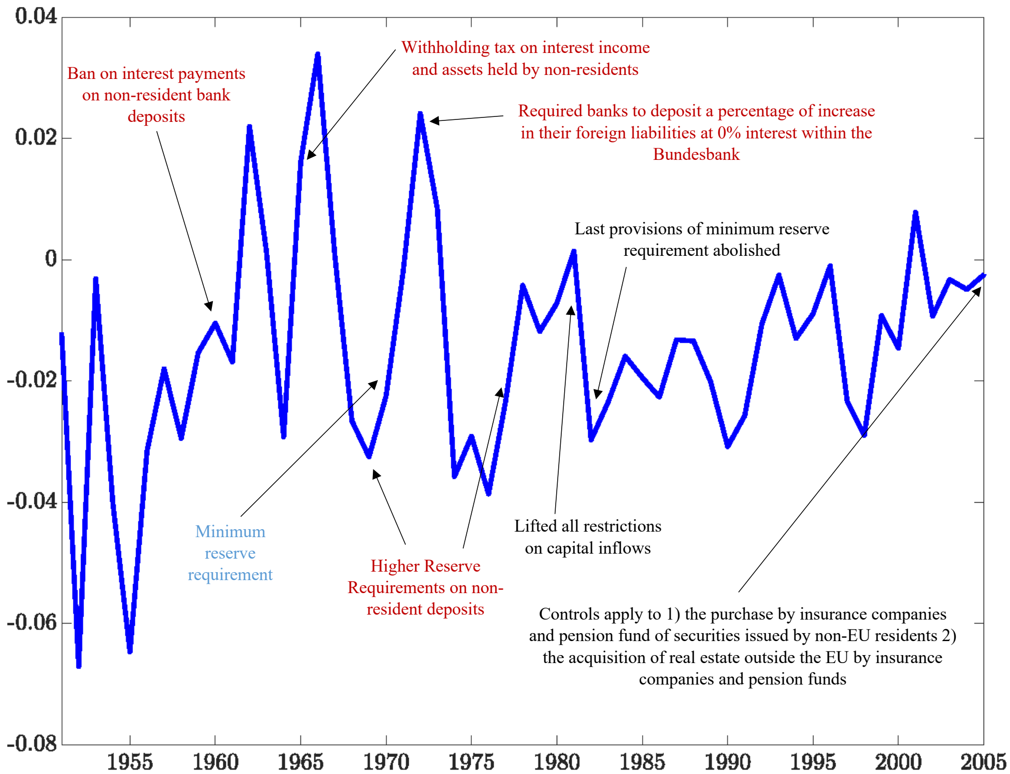


Notes: The blue line represents τ^B over time. Labels mark each policy's name and adoption date with arrows. The font color indicates each policy's intent: red for discouraging capital inflows, blue for discouraging outflows, and black for affecting capital flows overall.

Germany

Figure 5 compares τ^B for Germany with observed German capital control policies. In 1960, Germany banned interest payments on non-resident deposits, discouraging capital inflows, this is followed by a small decrease in τ^B, as expected. In 1965, Germany introduced a withholding tax on interest income on assets held by nonresidents, discouraging capital inflows. Soon after that policy was implemented τ^B reaches a peak and starts decreasing sharply. Presumably the time period for which it still goes up it's the time it takes for the policy to come into effect. In 1969 and 1977, Germany raised reserve requirements on non-resident deposits, discouraging capital inflows. This is not picked up by the model, implying that either the policy didn't have large enough quantitative effects, or that the minimum reserve requirements imposed on banks in 1970 are offsetting the effect of the higher reserve requirements on non-resident deposits imposed in 1969 and 1977. The 1970 minimum reserve requirements imposed on banks, are a control on capital outflows as they have less resources to lend. The model correctly identifies this with a sharp increase in τ^B. In 1972, banks were required to deposit a percentage of the increase in their foreign liabilities at 0 percent interest within the Bundesbank. This measure, is aimed at discouraging capital inflows, and is followed by a significant decline in τ^B as expected. At the start of the 1980s, Germany fully liberalized its capital account and this is reflected in lower values of τ^B throughout the rest of the period.

Figure 5: Estimated versus Implemented Capital Controls in Germany

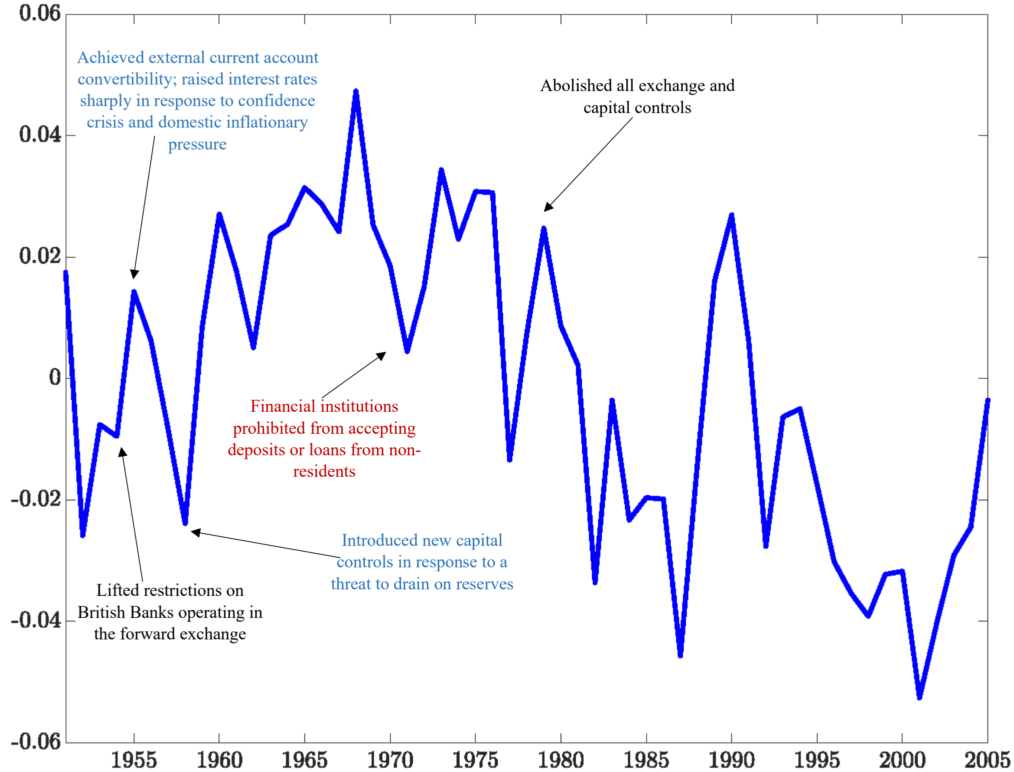


Notes: The blue line represents τ^B over time. Labels mark each policy's name and adoption date with arrows. The font color indicates each policy's intent: red for discouraging capital inflows, blue for discouraging outflows, and black for affecting capital flows overall.

United Kingdom

Figure 6 compares our model τ^B with U.K. capital control policies. In 1954 the U.K. lifted restrictions on British banks operating in the forward exchange market, which increased opportunities for the British to borrow and lend internationally, while the ability to hedge currency risk reduced uncertainty for both borrowers and foreign investors. In the model this is followed by an increase in τ^B. In 1955, the U.K. achieved external current account convertibility, reflecting an easing of controls on capital flows, and increased interest rates, meant to discourage capital outflows. However, there were inflationary pressures at the time which seem to have been encouraging capital outflows (see Cohen 1972). Thus, a reason

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



Notes: The blue line represents τ^B over time. Labels mark each policy's name and adoption date with arrows. The font color indicates each policy's intent: red for discouraging capital inflows, blue for discouraging outflows, and black for affecting capital flows overall.

why the model identifies a decrease in τ^B is because the policy was reacting - and not very successfully - to inflation driving capital to other countries.

In 1957, new capital controls were introduced in response to concerns about capital outflows and their potential effect on bank reserve adequacy. This coincided with a significant increase in τ^B after that, consistent with the intention of the policy. In 1971, financial institutions were prohibited from accepting deposits or loans from non-residents, restricting capital inflows. These policies are not picked up by the model as they should have triggered a decrease in τ^B, but instead there is an increase. In 1979, the U.K. abolished all exchange and capital controls, encouraging capital flows, and after that τ^B declines, consistent with a policy that generally removes impediments to flows.

In summary, the model-inferred measures of impediments to international capital mobility align closely with the actual policies implemented by the U.S., France, Germany, and the U.K.. In the few instances where they do not, it is important to note that our de facto measure of capital controls is a net measure, where controls on outflows may be implemented to offset controls on inflows, and vice versa. These comparisons suggest that the model-inferred τ^B is reasonably capturing capital controls implemented during Bretton Woods.

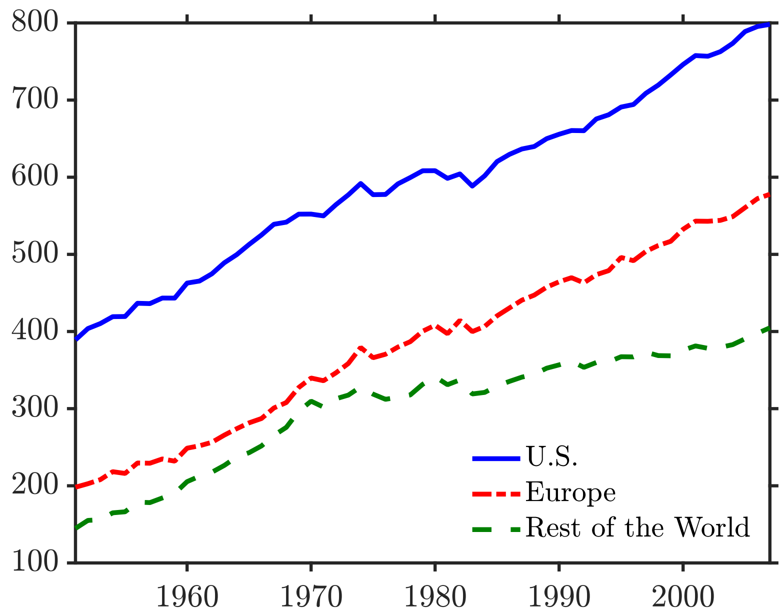
5.2 Productivity and Domestic Labor and Capital Market Distortions

This section presents productivity for the three regions and the model's inferred labor market and domestic capital market distortions.

Productivity in the Three Regions

Figure 7 shows total factor productivity (A_{jt}) for the three regions. The figure shows that during Bretton Woods, productivity grew 1.84 percent annually in the U.S., 2.7 percent in Europe, and 3.6 percent in the ROW. Bretton Woods was also a period of rapid real output growth, with an average annual growth rate of 3.7 percent for the United States, 4.6 percent for Europe, and 7.4 percent 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.

Figure 7: Total Factor Productivity

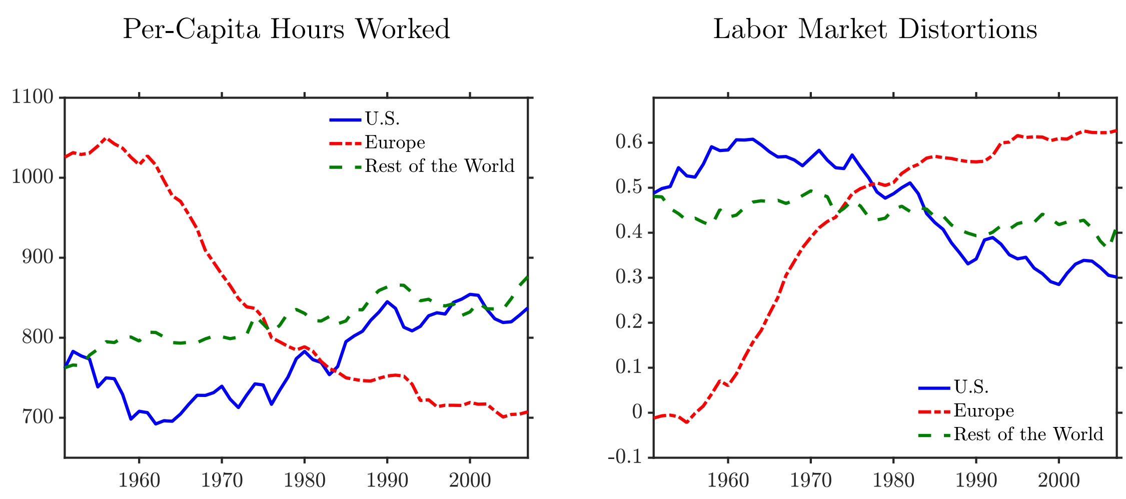


Domestic labor market distortions

Figure 8 reports the estimated labor market distortions τ^h (right panel) and per capita hours worked (left panel). Recall 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 of 0.4, for example, denotes a 40 percent tax rate on labor income. A value less than zero is interpreted as a subsidy to labor.

Regarding the importance of policies, studies of taxes on labor income and consumption in European countries coincide closely with the European domestic labor market distortion. Prescott (2002) and Ohanian et al. (2008) document that consumption and labor tax rates rose substantially between 1950 and the early 1980s in many European countries, and then were roughly stable on average after that. This comparison suggests that the model's inferred changes in distortions to labor markets plausibly coincide with significant labor market policy changes in Europe over the same period.

Figure 8: Hours Worked and Labor Market Distortions

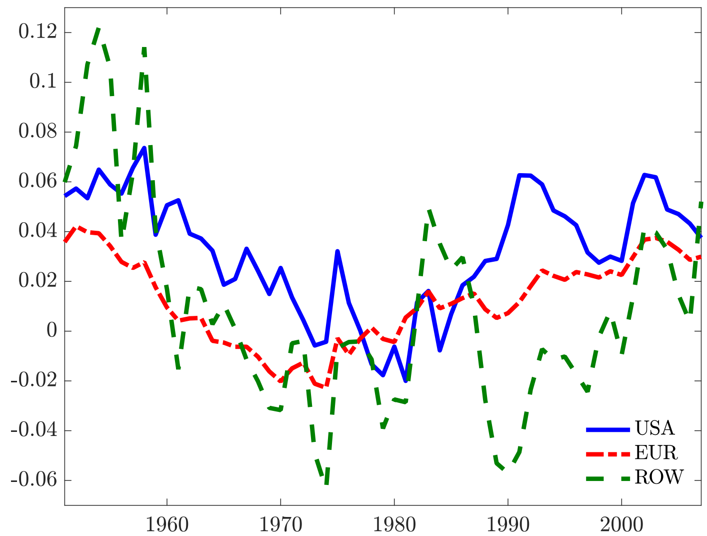


Domestic capital market distortions

Figure 9 presents the estimates of domestic capital market distortions τ^K. This distortion is identified from the Euler equation (13). This distortion may reflect capital income taxation, expropriation Aguiar et al. (2009), financial market imperfections Arellano et al. (2019), and changes in financial development Arellano et al. (2012).

Perhaps the most noteworthy aspect of Figure 9 is the trend decline in the distortion in all three regions that occurs between 1950-80, which may reflect financial market development and also deregulation of these markets.

Figure 9: Domestic Capital Market Distortions



6 Counterfactual Analysis

This section presents counterfactual analyses that exogenously change realizations of some of the model distortions. We begin with the main counterfactual, which evaluates how Bretton Woods capital controls affected the size of capital flows and the allocation of economic activity across regions. We therefore set the international capital market distortion (τ^B) for the U.S. and Europe to zero between 1950 and 1973, which roughly covers the Bretton Woods period. The process evolves stochastically after that. The model solution is recomputed so that agents' expectations are consistent with this change. All other distortion realizations remain the same.

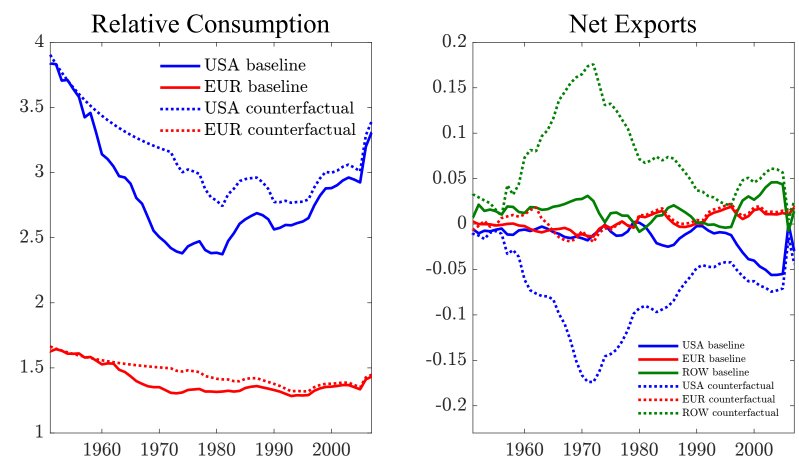
The goal of this counterfactual is to analyze what would have happened if global capital markets had been much more open during Bretton Woods, as they were during the "Golden Age" of capital flows before the Great Depression, when capital controls were largely absent and international capital flows were high.[4]

Recall the paths of the U.S. and European international capital control distortions are identified from the consumption paths of the U.S. and Europe relative to that of the ROW.

[4]We interpret this counterfactual reflecting capital control policies, given the significant use of capital controls during Bretton Woods and given the evidence presented above relating model-inferred policies to actual polices.

Therefore, implementing this counterfactual pins down these *relative consumptions*. The solution of the full equilibrium yields the absolute levels of these variables.

Figure 10: Counterfactual (No Bretton Woods) Relative Consumptions and Capital Flows



Figures 10 and 11 show the results of the counterfactual exercise. The left panel of Figure 10 shows the consumption paths for the U.S. and Europe relative to the ROW for the benchmark (which is also equal to the data), and the counterfactual. The counterfactual path for U.S. consumption relative to the ROW (dashed) is much higher than in the benchmark (solid), and more in line with standard consumption smoothing motives.

The upper left panel of Figure 11 shows the ratio of the absolute levels of consumption for each region under the counterfactual to their respective benchmark/data level. Thus, a value of 1.05 means that the variable in the counterfactual is five percent higher than the benchmark/data value. The lower left panel of that figure shows hours worked compared to their benchmarks. Figure 11 thus shows higher counterfactual consumption and lower hours worked for the U.S. during Bretton Woods, and lower ROW counterfactual consumption and higher ROW hours.

The planner's solution is informative for these results. Recall from the equivalence result between the planner and the competitive equilibrium that eliminating the positive U.S. international distortion means *increasing* the planner's Pareto weight for the U.S. relative to the ROW. Given the higher planner weight for the U.S., this means the planner allocates more consumption and less labor to the the U.S., and allocates less consumption and more hours worked to the ROW.

Figure 11: World Economy Without Bretton Woods

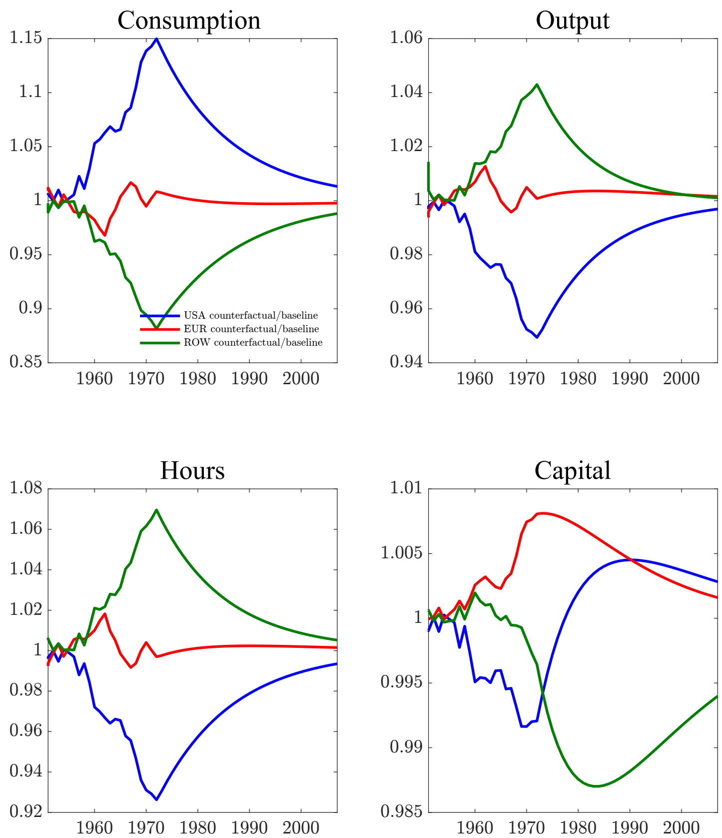


Figure 12: Effects of No Bretton Woods Capital Controls on World Output

Figures 10 and 11 also show the benchmark and counterfactual paths for Europe. Eliminating Europe's international distortion leads to relatively small changes in consumption and hours worked in the counterfactual, as Europe's international distortion is quite small. Even though Europe's consumption relative to the ROW rises, its absolute level falls modestly under the counterfactual compared to the benchmark as world output declines. Figure 12 shows that world output drops about 0.4 percent in the counterfactual, reflecting the U.S. producing less.

Table 3: Welfare Effects of Bretton Woods

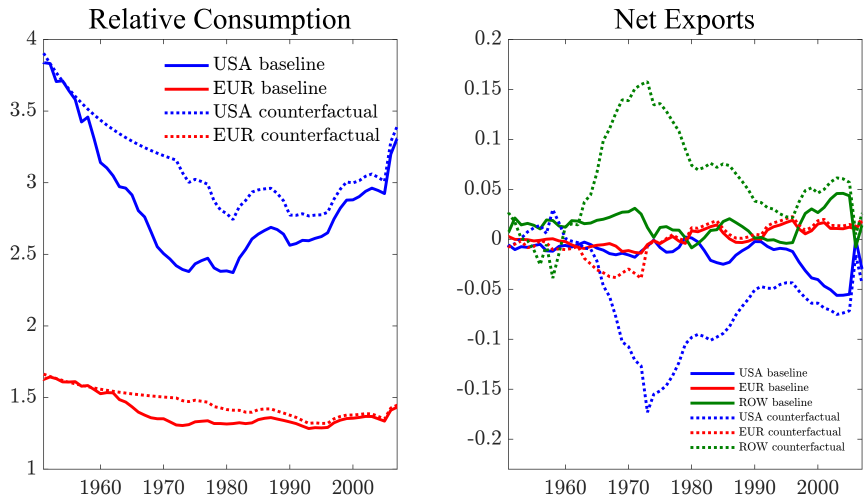
Region	Consumption Equivalent	
	1950-1973	1950-2007
	(1)	(2)
U.S.	-2.78%	-2.40%
Europe	-1.27%	-1.09%
Rest of the World	5.55%	4.80%

Notes: Column (1) presents the change in consumption equivalent after shutting down the international wedge for the period 1950 to 1973, 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).

We find that Bretton Woods capital controls had large welfare effects, particularly for the U.S. and the ROW. Table 3 calculates the perpetual consumption equivalent welfare changes under the counterfactual relative to the benchmark. The ROW has 5.55 percent higher welfare in consumption-equivalent units under Bretton Woods capital controls, while the U.S. has a 2.78 percent welfare loss and Europe has a 1.27 percent welfare loss under Bretton Woods capital controls.

To understand why setting the international distortions to zero (no Bretton Woods capital controls) raises U.S. welfare and reduces ROW welfare, recall that the negative of the international distortions ($-\tau_j^B$) is approximately equal to the innovation in the planner's Pareto weight. Thus, reducing τ_U^B corresponds to an increase in the planner's Pareto weight for the U.S., resulting in relatively higher U.S. consumption and lower US labor supply, and relatively lower ROW consumption and higher ROW labor supply.

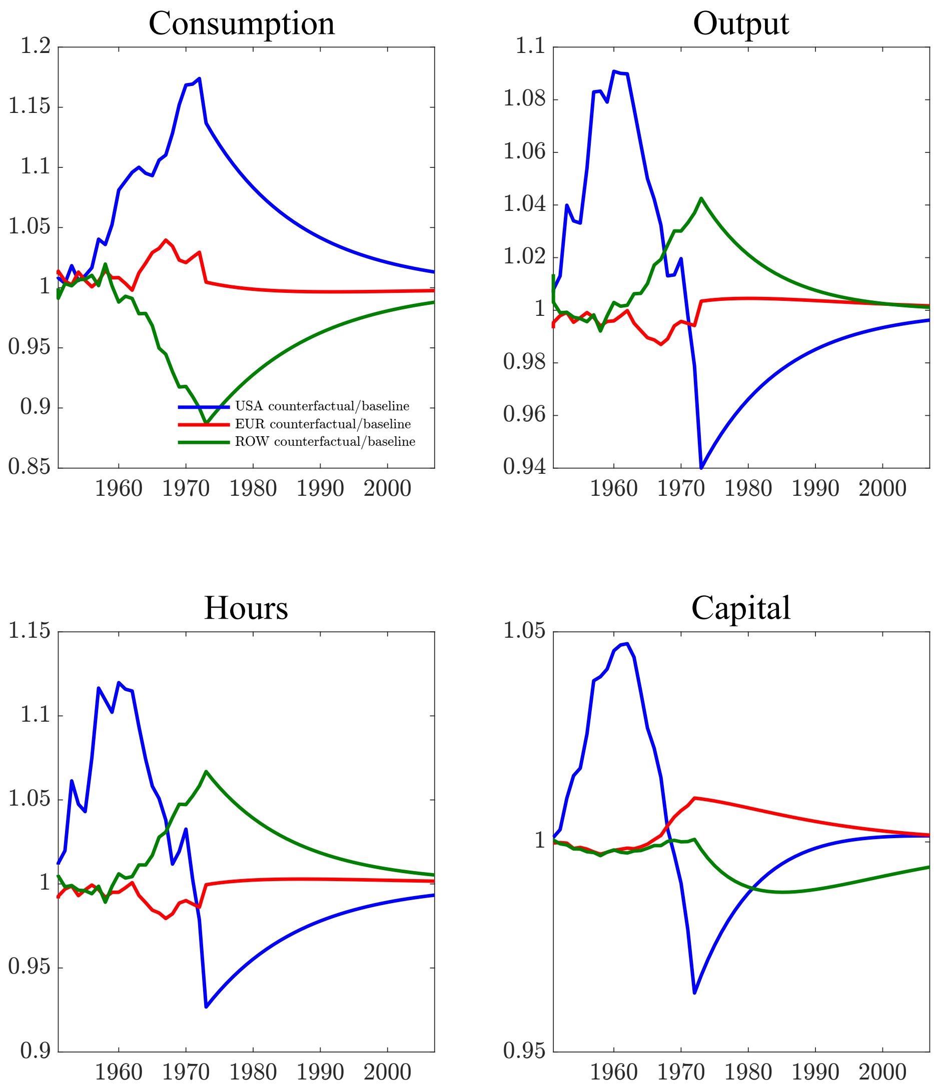
Figure 13: Counterfactual With No Capital Controls and No U.S. Distortions



An interesting feature of Figure 11 is the extent that the planner reduces U.S. labor in the counterfactual, which is enough to reduce world output. This is because the U.S. had sizable labor and domestic capital market distortions at that time (recall Figures 8 and 9 from the previous section.) To see how much these U.S. distortions disincentivized U.S. production, Figures 13 and 14 show the results for a counterfactual which shuts down not only international capital controls, but also sets the U.S. labor and domestic capital market distortions equal to zero from 1950 to 1973. With these distortions eliminated, the marginal conditions change enough so that the planner chooses to expand U.S. production, rather than contract production as in the previous counterfactual. Note in the right panel of Figure 13 that capital inflows from the ROW to the U.S. are delayed, given the large increase in U.S. production.

Finally, the large welfare loss for the U.S. under Bretton Woods raises the important question of why the U.S. had promoted these controls in the first place, which we discuss in the next section.

Figure 14: The World Without U.S. International and Domestic Distortions



7 Why Did the U.S. Want Capital Controls, Given Lower U.S. Welfare?

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 30-year periods in modern history, a three-decade span that included two world wars, the Spanish Flu 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 friendly governments, particularly developing countries, to protect against future hostilities with aggressor 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 would endanger these goals and that capital controls were needed to keep capital within ally and unalligned countries.

The evidence and discussion presented in this section provide context for interpreting the welfare results that show that the U.S. would have been significantly better off had the Bretton Woods capital controls not been adopted. We will describe how the U.S. was willing to adopt capital control policies that 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, which leads us to interpret the Bretton Woods capital controls as a tool to preserve economic and political stability in those countries.

We find that the implicit value of capital controls is large, and perhaps plausibly so, given the literature's documentation of the U.S.'s ambitious foreign policy goals, and given the size of U.S. military spending during Bretton Woods. To our knowledge, these welfare costs provide the first macroeconomic quantification of U.S. policy choices relating to postwar geopolitical stability within the literature.

7.1 U.S. and U.K. economic views of capital controls in the 1940s

The key concern for White was that capital flows could damage a country by draining it of investment funds, which in turn could destabilize the country's economy and its political stability. He viewed controls as fundamental for keeping capital in developing economies, which in turn would prevent those countries from aligning with hostile countries, notably Nazi countries and the USSR.

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 stability. Flights of capital, motivated either by prospect of 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.

The design of the Bretton Woods capital controls was based on White's and Keynes's views on capital flows during the 1920s and 1930s. Both White and Keynes agreed 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, including post-World War II reconstruction.

A primary goal of capital controls was promoting the economic development of poor nations. White viewed capital controls as protecting these countries from capital flight (International Monetary Fund 1996):

> 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 (International Monetary Fund 1996):

> 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).

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 were highly open economies that exhibited large output fluctuations outside of their control. Robert Triffin wrote (Helleiner 2014):

> 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.

7.2 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 (2014) writes:

> 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:

> 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.

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.

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. Boughton (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 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, motives that 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 security, then it would seem reasonable that the U.S. was willing to pay substantially for capital controls.

8 Summary and Conclusion

Little is known about the quantitative effects of Bretton Woods capital controls on the global economy 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 the Bretton Woods *de facto* capital controls within an open economy general equilibrium framework in which effective capital controls are measured using differences in consumption growth across regions. This allows us to bypass the significant difficulties emphasized within the literature of trying to directly measure these controls, assessing whether their implementation differed from their legal specification, and incorporating their multidimensional characteristics into a model economy.

The very large differences in observed consumption growth across regions during Bretton Woods identifies large capital controls in our model, which we find prevented a substantial amount of capital from flowing out of the ROW and into the U.S. We also find that capital controls raised welfare for the ROW, but substantially reduced welfare for the U.S.

This welfare finding raises an important question: why was the U.S. so keen on implementing international capital controls when their effect appears to be so sharply at variance with U.S. interests? We reviewed the historical political economy literature of that time, particularly the writings of Harry Dexter White, the primary architect of Bretton Woods, and found that the purpose of these controls was to promote political and economic stability in ally and unaligned countries, and that the U.S. valued this stability highly, given geopolitical tensions of that time period.

The cost of capital controls to the U.S. is considered here as an implicit U.S. investment that promoted U.S. interests in maintaining the political stability of foreign, friendly governments. This view is consistent with the expensive post-World War II U.S. military engagements, including the Korean War, the Vietnam War, the Cold War, and smaller interventions in Latin America and the Middle East, in which military spending averaged nearly 12 percent of GDP between 1950-1973.

These findings open a new avenue for research that integrates open economy macroeconomics with political economy considerations and global conflict. This type of research can provide a new perspective on U.S. international economic policies, with a focus on the provision of national defense, whose production includes both investments in military machinery and personnel, and investments in promoting global political and economic stability among friendly countries. This research can productively connect with research in the political science literature and in the novel geoeconomics literature of Clayton et al. (2023).

More broadly, the observed large consumption growth differences across regions during the Bretton Woods era that quantify capital controls in the model in this paper suggest the likelihood of sizable controls in other model environments that include a preference for consumption smoothing. This presents another interesting avenue for future research.

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Appendix

Model Solution and Computation

We begin by describing the pseudo social planner's problem used to compute equilibria, and prove its equivalence with the competitive equilibrium problem. We next show how we transform both problems into intensive form problems that are stationary. 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 Planner's 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 $T_t^{PSPP} = \sum_j \chi_{jt}^I \left(X_{jt} - Y_{jt} \right)$), 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 parameter restrictions

$$\begin{aligned}\chi^{H}_{jSS} &= 1/\left(1-\tau^{h}_{jSS}\right), \\ \rho^{H}_{j} &= \rho^{h}_{j}, \\ \sigma^{H}_{j} &= \sigma^{h}_{j}.\end{aligned}$$

For the social planner's consumption wedge, we normalize $\chi^{C}_{Rt} = \chi^{C}_{RSS} = 1$, while for $j = U, E$ we require

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

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

$$\varepsilon^{C}_{jt+1} = \rho^{\varepsilon^{C}}_{j}\varepsilon^{C}_{jt} + \sigma^{\varepsilon^{C}}_{j}\epsilon^{\varepsilon^{C}}_{jt+1},$$

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

$$\begin{aligned}1-\rho^{C}_{j} &= \frac{\psi_{j1}}{1+\psi_{j1}}, \\ \chi^{C}_{jSS} &= \psi_{j0}, \\ \rho^{\varepsilon^{C}}_{j} &= \frac{\rho^{B}_{j}}{1+\psi_{j1}}, \\ \sigma^{\varepsilon^{C}}_{j} &= \frac{\sigma^{B}_{j}}{1+\psi_{j1}}.\end{aligned}$$

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

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

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

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

Note that, compared to the competitive equilibrium problem, the formulation of this problem and the specification of the wedges are 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. This 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 in turn causes it to enter the planner's 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 planner's consumption wedge is autoregressive. As yet another example, we impose a specific relationship between the investment wedge and the consumption wedge. As a result of the unusual nature of this mapping to the planner's problem, we discuss the competitive equilibrium model in the paper.

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 concave. Hence, the necessary and sufficient conditions for an optimum include

$$
C_{jt} \ : \ \beta^t \chi_{jt}^C \frac{N_{jt}}{C_{jt}} = \lambda_t^{PSPP}, \qquad (16)
$$

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

$$
\begin{aligned}
K_{jt+1} \ : \ \mu_{jt}^{PSPP} = E \Bigg[& \lambda_{t+1}^{PSPP} \chi_{jt+1}^I \alpha \frac{Y_{jt+1}}{K_{jt+1}} \\
& + \mu_{jt+1}^{PSPP} \left(1 - \delta - \phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right) + \phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right) \frac{X_{jt+1}}{K_{jt+1}} \right) \Bigg]
\end{aligned} \qquad (18)
$$

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

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

To establish the mapping between the two problems, 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 construct the mapping, we first find a solution to the competitive equilibrium problem (CEP), and 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 CEP. For this, it is sufficient to show that 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 household's 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 household's 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

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

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 for labor 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 exactly 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 household's 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

$$
\begin{aligned}
r^K_{jt+1} &= \alpha \frac{Y_{jt+1}}{K_{jt+1}}, \\
P^K_{jt} &= \frac{1}{1-\phi'\left(\frac{X_{jt}}{K_{jt}}\right)}, \\
P^{*K}_{jt+1} &= \frac{1-\delta-\phi\left(\frac{X_{jt+1}}{K_{jt+1}}\right)+\phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)\frac{X_{jt+1}}{K_{jt+1}}}{1-\phi'\left(\frac{X_{jt+1}}{K_{jt+1}}\right)}, \\
1-\tau^K_{jt+1} &= \frac{\chi^C_{jt+1}}{\chi^C_{jt}}\frac{\chi^I_{jt+1}}{\chi^I_{jt}}, \qquad (23)
\end{aligned}
$$

where in the last line we substituted from (20). The first of these conditions is simply the FOC in choosing 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

$$
\ln\left(1-\tau^K_{jt+1}\right) = \ln\left(\chi^I_{jt+1}/\chi^I_{jt}\right) + \ln\left(\chi^C_{jt+1}/\chi^C_{jt}\right),
$$

so that after substituting for (23) and imposing the restrictions in (15) we obtain the evolution equation for the capital wedge in the CEP

$$
\ln\left(1-\tau^K_{jt+1}\right) = \left(1-\rho^K_j\right)\ln\left(1-\tau^K_{jSS}\right) + \rho^K_j \ln\left(1-\tau^K_{jt}\right) + \sigma^K_j \varepsilon^K_{jt+1}.
$$

Lastly, note that the resource constraint of the PSPP is equal to the sum of the budget constraints of the CEP 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

As discussed in Section 2.1 of the paper, the world economy follows 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 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 forms the basis for our numerical algorithm and parameter 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

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

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 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

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

Recall that there are two types of (representative) firms 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 firm's 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.

With transfers rebating 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 Planner's Problem

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

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

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

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

and the capital evolution equation is

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

The first order-conditions of this problem are

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

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

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

Imposing the “equilibrium” restriction on the wedges and additive shock yields

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

Changes in Net Foreign Assets from Policy Interventions

After the realization of the state variables at date t, the net foreign asset position of a country/region is implied by the country's budget constraint, and is given by:

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

Thus, after any policy intervention, the realized net foreign asset position will be related to net exports and the expected future asset position.

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

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

Substituting gives

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

The intensive form analog is then

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

so that

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

Solving this difference equation forward recursively yields:

$$\begin{aligned} b_{jt} &= -E_t \left\{ nx_{jt} + \beta \eta_{t+1} \frac{c_{Rt}}{c_{Rt+1}} nx_{jt+1} + \beta^2 \eta_{t+1} \eta_{t+2} \frac{c_{Rt}}{c_{Rt+2}} nx_{jt+2} + ... \right\} \\ &= -E_t \left\{ \sum_{s=0}^{\infty} \beta^s \left(\prod_{r=1}^{s} \eta_{t+r} \right) nx_{jt+s} \right\}, \end{aligned} \tag{24}$$

where

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

The Balanced Growth Path of the Deterministic Model

This section presents 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 provide further detail about why the portfolio adjustment costs are needed 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 in 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 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 r_{ss}^{W} is 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 is determined as

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

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, we have

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

which pins down the capital to output ratio as

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

All that remains is to pin down 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 is equal to the change in the level of net foreign assets—and 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 realized 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 balanced 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, have 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, a naive analysis of capital flows simply from the balanced growth will find that the labor wedge plays no role in impacting long-run capital flows.

Data and Methods

As noted in the paper, recovering the distortions requires data on 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. This section describe our data sources, data aggregation techniques, and sample definitions, and provide plots of the raw data used in our analysis.

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, and 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 are 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* are used for its member countries. For other countries, data from the World Bank's *World Development Indicators* (WDI) is our primary source. Data prior to 1960 are often scarce; our primary source is the World Bank's *World Tables of Economic and Social Indicators* (WTESI). The Groningen Growth and Development Center (GGDC) was a valuable source of data on hours worked. 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 span the years 1950 to 2008. The country-level data were not available from a single source; thus, they were 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 TFP 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 level of TFP.

Data Aggregation 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 were missing for a small number of years. More details on these cases are presented in the country-specific notes below; in general, missing data were 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.

For country-specific notes on data see the Appendix in Ohanian et al. (2018).

Conceptual Issues About Measuring Capital Flows

This paper uses 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). Here, we discuss the reasons for our approach in more detail.

There are several reasons for our approach: (1) net factor income is poorly measured;

(2) balance of payments data are limited by their focus on transactions data and their inconsistent treatment of transfers such as debt restructuring; (3) balance of payments data are not available for many countries prior to 1970 and sometimes have 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.

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, 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. A country's net foreign asset position can change for roughly three reasons: first, because of a transaction in which assets change hands or income is paid; second, because of capital gains and valuation effects; and third, because of a gift or transfer, such as foreign aid, a nationalization, or an expropriation, or because of 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 et al. (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. 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 et al. (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 the 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 has become traditional in the literature (1) to work with models that 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 et al. (1992). This is the approach we have adopted in this paper.

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

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

The start-of-period definition is

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

so that, recalling also that

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

we can write the current account as

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

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

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

The end-of-period definition is

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

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

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

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

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

as

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

Then we have a fourth measure of the current account:

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

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

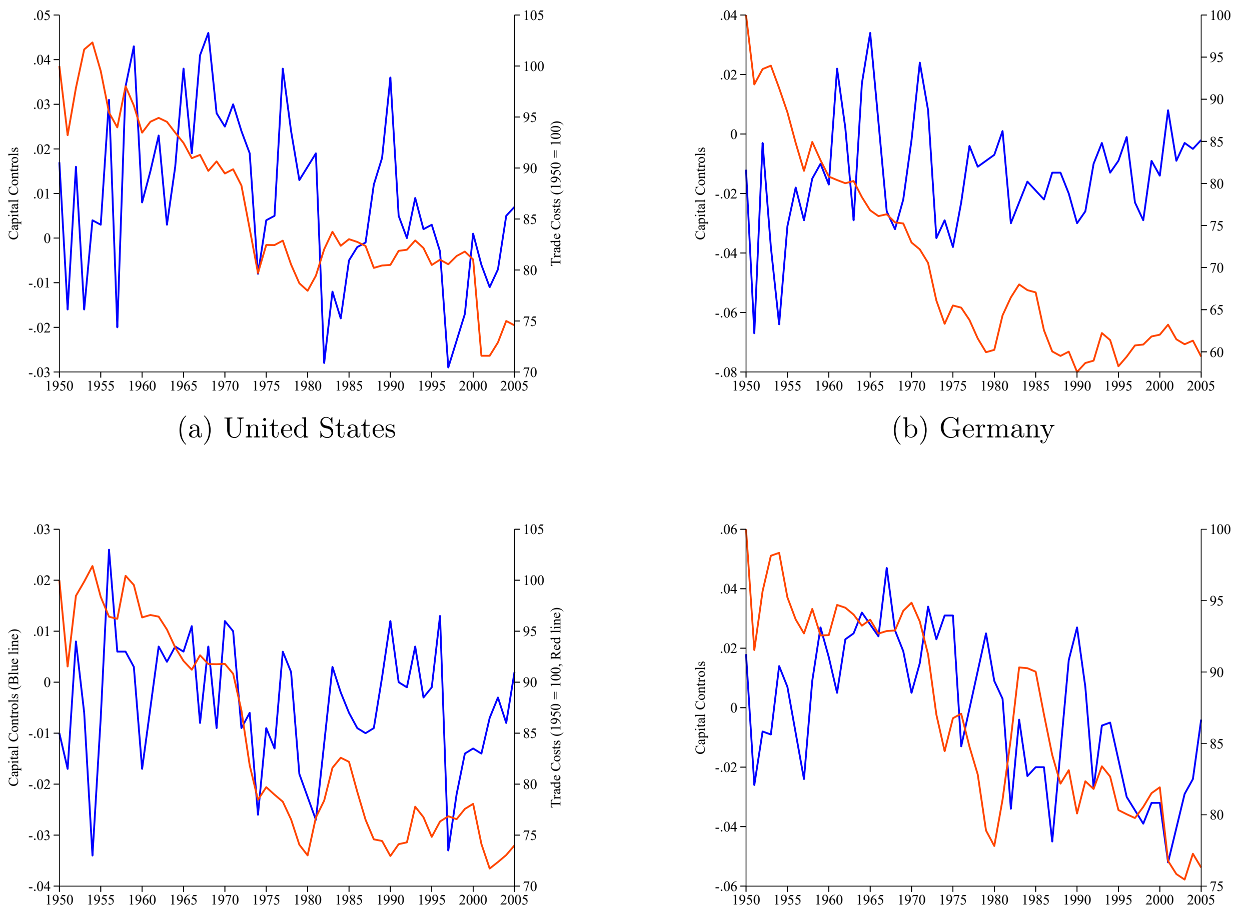
Capital Flows and Trade Costs

The international distortion works like a tax on foreign assets, shifting consumption across regions. Equation 8 shows that higher τ^B values leave countries worse off relative to the ROW in terms of consumption growth. In principal, these effects could also stem from changes in trade costs over time and across countries. In this section, we compare the capital distortions (τ^B) in our model with trade costs from Meissner and Novy (2011) to verify that indeed what we are capturing with our meassure of τ^B are capital controls and not trade costs.[5]

Each country's trade cost estimates are weighted by the GDP of its trading partners, using data from the World Bank Indicators, to construct a measure of total trade costs. Figure 15 shows the results for the United States, Germany, France, and the United Kingdom, where trade costs are represented by a red line and our measure of capital controls is depicted in blue. The figure shows that trade costs have been trending down over time and they are clearly different from our τ^B. If one computes the correlation between the two measures (once trade costs have been detrended) it ranges between -0.12 for Germany to 0.21 for France, with 0.03 and 0.07 in between for the United Kingdom and the United States respectively.

[5] Trade costs for 2001–2005 are from UNESCAP, following the methodology of Meissner and Novy (2011).

Figure 15: Capital Controls vs Trade Costs



(a) United States

(b) Germany

(c) France

(d) United Kingdom

Notes: The blue line represents τ^B over time. The red line represents the Trade Costs from Meissner and Novy (2011).