Long-Term Fundamentals of the 2008 Economic Crisis

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Abstract

The current economic crisis has long-term causes that are rooted in the economic dynamics of globalization. I construct a Solow-style endogenous model of capital accumulation, technological change, trade and foreign direct investment (FDI), based on myopic agents. Combining advanced technologies with low labor costs, FDI yields extraordinary profits that generate asymmetric innovation incentives that explain the following stylized facts. Globalization (a) increases the world economic growth rate; (b) is consistent with development, underdevelopment and miracle growth; (c) increases inequality in leading countries; (d) generates a transition path along which the interest rate diminishes if capital accumulates at a faster rate than technological change. Over the period 1980-2007, liberalization unleashed a wave of globalization, and the international sector experienced miracle growth. Profits rose to all time highs and global saving exceeded global investment. This savings glut or investment shortfall fueled a global housing appreciation, after which excessive risk in a deregulated financial market led to a financial meltdown. While restoring financial markets and reducing the housing market fallout are immediate priorities for the US, economic growth can only be recovered by restoring global investment. Lowering interest rates cannot generate very much investment, nor will consumption flows from fiscal spending. To stimulate the global economy, whole new economic sectors and technologies must be developed in advanced countries, and economic development deepened in underdeveloped countries. A global harmonization of taxes, which is eventually necessary anyway, is required to fund publicly provided goods, to balance incentives between local and international production, to reduce the polarization between developed and underdeveloped countries, to balance global markets with global governance, and to reinforce global cooperation. Developing the green energy sector is consistent with these aims.

Keywords:
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1. Introduction

The purpose of this article is to show that the economic crisis that began in 2008 has long-term causes that are rooted in the economic dynamics of globalization. I explain these dynamics both verbally and theoretically, constructing a model.[1] The latter is a Solow-style model of capital accumulation, technological change, trade and foreign direct investment (FDI) that reflects the main stylized facts of globalization. The model predicts the root of the crisis, paradoxically, the huge profits generated by FDI. These led to a global savings glut–or investment shortfall–that dramatically lowered long-term real interest rates, led to a housing bubble in many countries simultaneously, and finally destabilized the financial system. Thus the present crisis is the combination of a long-term crisis caused by insufficient investment, *overlaid* with the crash of the housing market and the consequent crash of the loosely regulated financial system.

The failure of the financial system is provoking a return to standard monetary and fiscal Keynesian policies: lowering interest rates to raise incentives for investment, and maintaining employment and consumption by spending money or giving tax breaks. However, since interest rates were low for the best of a decade, investment has already been saturated, so these policies will not be very effective in reviving investment, an essential component of the product.[2,3] Moreover, as the economy gets moving, it will again channel resources and profits to those sectors that had insufficient incentives to invest in the first place, when economic expectations were much better.

Instead, what has to be understood is why the huge amounts of investible funding deposited mostly in the developed world's financial system did not find its way to real investment in the first place.[4] Some possibilities are the following. First, in lagging countries, as stated in the World Investment Report (UNCTAD, 2008), "there are huge unmet investment needs for infrastructure" which "far exceed the amounts being invested by governments, the private sector and other stakeholders, resulting in a significant financing gap." There are also huge shortfalls in human capital investment; witness the Millennium Development Goals (MDGs), whose basic education and health goals may remain unmet. In both advanced and in lagging countries, there are significant investment shortfalls in publicly provided complements to private investment, such as infrastructure, education, health and science, due to more than two decades of low public spending associated with liberalization policies.

Second, in advanced countries, labor faces the competition of low salaries abroad that make investment less attractive. In this respect, the giant tax loophole enjoyed by transnational corporations (TNCs) through international tax havens significantly subsidizes international production at the expense of local production. Third, future real

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[1] The verbal explanation can be read independently of the model. To this end, although the model fundaments the explanation very closely, it is presented in the appendix.

[2] According to the Austrian business cycle theory, excessively low interest rates implemented by monetary policy result in low yield, poor investments and financial volatility. In this case, however, the low *long-term* interest rates are the consequence of real conditions that need to be addressed.

[3] For example, after its real estate crash, holding interest rates low did not promote investment in Japan's decade-long slump in the 1990's.

[4] Recall that saving for the future by some agents is impossible in the absence of corresponding investment opportunities for other agents.

prices of the main commodities used for production and consumption–raw materials, energy and food, are highly uncertain. The bubbles in these commodities that presented themselves as a final prelude to the financial crash were partly caused by the strong dependence of these prices on global growth expectations, because their demand rises significantly as more countries raise their standards of living. Finally, a series of institutional barriers exist for the flow of funding from the financial system to smaller private investors, especially in lagging countries.

The present explanation of the economic crisis is rooted in the core dynamics of economic growth under globalization. I therefore construct a model of economic growth incorporating the main aspects of long-term global dynamics, first, capital accumulation, a direct concern here because of its connection with the financial crisis. Second, technological change, since a decade of empirical and theoretical studies has it as the fundamental motor of economic growth.[5]

Next, the model incorporates the main components of globalization, which are trade and FDI. These allow production to be assigned according to comparative advantage, and technologies to flow across international boundaries. However, the international assignment of production implies also an international assignment of innovation. While in general technological transfer implies an "advantage of backwardness" generating convergence (Gerschenkron, 1952), I show that trade and FDI can focus innovation in leading countries, thus generating asymmetric innovation incentives, a "disadvantage of backwardness," that makes technological differences between advanced and lagging countries persist. The mechanisms are the following.

Trade will distribute production sectors across countries in proportion to aggregate productive capacity, selecting them according to comparative productivities. Thus, more advanced and larger countries will produce in and therefore innovate for a proportionally higher number of sectors. When there are innovation externalities between sectors, for example due to shared public goods such as scientific and educational infrastructure and to cross fertilization in sectoral knowledge production, this will generate asymmetric innovation incentives favoring advanced countries.

In the case of FDI, combining advanced technologies with low labor costs generates extraordinary profits. As we shall see, these TNC profits played a role in the savings glut. In addition, FDI generates asymmetric innovation incentives between advanced and lagging countries, by transferring innovation sectors from lagging to advanced countries. On the other hand, FDI generates technological spillovers that can increase technological absorption in host countries. Mayer-Foulkes and Nunnenkamp (2009) show over a sample of countries that outward US FDI contributes to convergence in developed countries, but to divergence in underdeveloped countries.

When trade and FDI generate sufficiently strong asymmetric innovation incentives favoring advanced countries, lower steady states appear that represent underdevelopment. Correspondingly, development is represented by higher steady states and miracle growth by changing from a lower to a higher steady state, a process that can be set off by changes in economic policies or circumstances.

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[5] See Aghion, Howitt and Mayer-Foulkes (2005), Howitt and Mayer-Foulkes (2005), and Mayer-Foulkes (2006), for extensive references.

Note that high FDI profits tend to concentrate income at the highest levels of the income distribution, and therefore tend to increase inequality in leading countries. On the other hand, when labor costs are cheaper, incentives for innovation are lower. It can therefore be expected that FDI impacts capital accumulation more than technological change.

Finally, the model includes economy-wide publicly provided goods, including institutional quality, a fundamental component of long-run economic growth (e.g. Acemoglu, Johnson and Robinson, 2004, Rodrik, 2007). Institutional quality has a fixed long-term component and also a component depending on the levels of institutional expenditure and innovation.

These elements are brought together in a Solow-style endogenous model of economic growth that explains the following stylized facts.

(a) Globalization increases the world economic growth rate.
(b) Development, underdevelopment and miracle growth can all coexist under globalization.
(c) Globalization increases inequality in leading countries.
(d) Along the transition path generated by the introduction of globalization, the global interest rate will diminish if capital per capita grows faster than technology.

By presenting the facts of the financial crisis, I further argue that as interest rates descended, instabilities emerged in the financial system that led to the financial meltdown. However, modeling this part of the process is beyond the scope of this paper.

Finally, the model allows constructing a global development policy generating balanced growth across countries and maximizing the world growth rate. The proposal is based on enhancing the provision of publicly provided goods. Funding can be generated through a global harmonization of value added taxes ending the tax loophole enjoyed by TNC's through off shore tax havens.

The rest of the paper is organized as follows. Section 2 discusses globalization. Section 3 gives a summarized account of the financial crisis and its historical setting, including the impact of globalization on the US economy. Section 4 discusses the global need for governance and publicly provided goods, Section 5 discusses the benefits of low interest rates and fiscal stimulus policies versus investment policies. Section 6 concludes. The Appendix presents the model.

2. Globalization

Globalization is not a new phenomenon. In fact, most of the history of modern economic growth occurred in the context of globalization. The "First Great Age of Globalization" lasted from about 1820 to 1914. With the advent of steam engine-based manufacturing and the Industrial Revolution, Great Britain turned to free trade, obtained raw materials in exchange for industrial products and become the "Workshop of the World". Britain also held huge investments in Africa, Asia, and Latin America. The process of globalization was interrupted from 1914 until 1945 because of the two World Wars and the Great Depression. During the postwar period a second stage of globalization emerged, this time

led by the United States, with an industrial supremacy based on electrically power-based mass production. In the postwar era trade and FDI first mainly expanded between the United States and Europe, but these accelerated worldwide in the 1980's.

The acceleration of globalization in the 1980's began with Ronald Reagan and Margaret Thatcher. Faced with the stagflation crisis of the 1970's and the first oil crisis, they restarted economic growth by freeing trade and investment. In addition, China's introduction of market mechanisms in its economy in December 1978, and the fall of the Berlin Wall in 1989, created a global market economy. As free trade and investment treaties proliferated, freer markets and a reduced government role in both developed and underdeveloped countries released a fresh wave of globalization.

Transnational corporations (TNCs) play a central role in the global economy. While aggregate world exports of goods and non-factor services reached U.S. $17 trillion dollars in 2007, aggregate sales of foreign affiliates of TNCs reached U.S. $31 trillion. At $6 trillion, the gross product of foreign affiliates of TNC's now reached 43.7% of US GDP, which is $15 trillion. The prominent role played by TNCs in globalization has raised their importance as well as their impact, especially on technology transfer, inequality, labor conditions, and the ecology. Thus, implementing global economic policies requires the capacity to regulate the role of TNCs on a global scale. This requires unprecedented global collaboration between governments.

The policies that strengthened markets and weakened government in the 1980's also raised inequality in the U.S. Using IRS tax data, Piketty and Saez (see web page) have shown that, while the bottom 90% has seen their income share drop from 66.8% in 1982 to 54.7% in 2006, the top 1%, 0.1% and 0.01% income brackets saw their income shares *multiply* by 2.3, 4.1 and 6.4 respectively (excluding capital gains!), see Figure 1.[6] The income shares of these income brackets were 45.3%, 18.0%, 8.0% and 3.4% respectively in 2006. The share of national income going to wages and salaries fell to 51.6% in 2006, its lowest recorded level, with data going back to 1929. The share of national income captured by corporate profits, in contrast, rose to its highest recorded level, 13.8% (Aron-Dine and Shapiro, 2007). Income inequality evokes Third World imagery ever more strongly in the US (e.g. Brooks, 2008).

Not since the Great Depression, have the highest income brackets held such a large share of US income. The corresponding shift in political power that liberalization policies brought on has led to a decline of the public role in research, education and health. Democracy in the US came to a relative low, as measured by the low responsiveness of public policy to urgent needs such as green energy research, or by the lack of independence of the press in the discussion of issues related to the Iraq war. Obama's election of course marks a revival of US democracy.

Globalization and economic growth

A brief review of how globalization works and why it is a potent force for economic growth is in order. Economic growth is the increase in the amount of the goods and services produced by an economy over time, public and private. Two decades of research on economic growth show that differences in per capita incomes between countries are

[6] Data from Emmanuel Saez' home page at http://elsa.berkeley.edu/~saez/TabFig2006.xls, read 11/10/2008.

mainly driven by differences in technological levels. Hence the engine of economic growth is technological change.[7] Globalization consists of the integration of national economies through trade and FDI. While migration was an important element of globalization in the 19th C, it has been restrained in the present wave of globalization. So, what are the driving forces behind globalization and how do they impact economic growth?

First, trade is driven by comparative advantage. Countries specialize in the sectors they are most productive at, given their technological levels, and thus increase their income by trading. This is a static effect that would soon reach equilibrium in the absence of technological change. Technological change itself is driven by the incentives for profits and market power that come with developing and owning new production techniques, product lines and so on. This market power tends to lead to the emergence of large corporations that subsist through sequential innovation. In addition to trade, globalization is driven by foreign direct investment. Firms invest abroad seeking cheap labor, cheap raw materials, new markets for their goods, and more efficient arrangements of production. When approximately equal partners such as European countries and the US engage in trade and FDI, countries specialize in those sectors for which they have a comparative or a technological advantage. Production takes place more efficiently and for larger markets. The incentives for innovation increase, thus raising not only the levels of production but also long-term economic growth. Economic well-being tends to grow in parallel across these countries.

When instead quite unequal partners engage in trade and FDI, specialization also occurs according to the costs of factors of production such as labor and capital. In these circumstances a polarized, asymmetric form of globalization emerges. Developed countries with high wages invest in underdeveloped countries, seeking low wages. Large multinational corporations emerge that obtain extraordinary profits as they purchase cheap labor and cheap resources in backward countries and sell their products in advanced countries. Because more workers are now using better technologies, overall production rises. In the model below we concentrate on cheap-factor-seeking FDI. The relative importance of trade and FDI is reflected in the numbers quoted above.

Polarized globalization leads to imbalances both in developed and underdeveloped countries. In developed countries, workers have now to compete with lower-salaried workers elsewhere, endangering the middle class, while capital and technology tend to receive higher returns, as noted above. On the other hand, underdeveloped countries competing with each other for the investments of TNCs that export their profits may find it hard to raise taxes for funding public goods. They may also find it hard to compete in innovation. Because advanced economies are large and innovate in many sectors, backward economies may remain technologically dependent, reaching an equilibrium technological lag constituting underdevelopment.[8] Indeed underdevelopment emerged simultaneously with modern economic growth in the context of globalization in the 19th century. Thus, it is possible for globalization to generate a

[7] The essence of economic growth is incorporating into practical life ever higher degrees of knowledge, so as to improve capacities and well-being, through private and public goods, such as a healthy environment.
[8] For a detailed exposition of this point of view of underdevelopment as equilibrium see Mayer-Foulkes (2007a, 2007b, 2008a 2008b), Mayer-Foulkes and Nunnenkamp (2008).

global economy that can remain persistently polarized into high and low steady states[9] even though it may be growing faster and generating more welfare than under autarchy.

Alternatively, when there is enough technological transfer, "miracle" growth may occur. Indeed, the majority of countries that attained industrialization and development did so through a prolonged period of high, sustained economic growth. Such are the cases of Denmark, Sweden, Italy, Japan, South Korea, Taiwan, Hong Kong, Singapore, Ireland, Germany in the 19th century, Western Germany after the War, Cyprus, Iceland, Spain, Malta, Portugal, Israel. In Wan's (2004) comparative case studies of the Asian Tigers' growth experiences, the reference convergence trajectories include at least two decades of growth higher than 5%, viewed explicitly as a transition to a higher stationary state. This possibility of miracle growth represents a hope for hundreds of millions of people for emerging from poverty. For this reason Wan considers the East Asian rise to development one of the mega-events of the 20th Century. However, some countries experienced periods of miracle growth without fully reaching development, such as Argentina, India, Nigeria, Brazil, and Mexico in the sixties and seventies. [10] What the outcome will for the current cases of China and India remains to be seen. If these countries can rise from poverty, the rest of the underdeveloped world would surely follow. When countries become equal partners, welfare rises, countries specialize in different sectors of production, and workers from advanced countries cease to face competition from low salaries. Also, more resources become available for innovation, so economic growth rises. This was the case in the relation between the Asian Tigers and the US.

Twenty five years of trade and investment liberalization have increased economic growth by allowing a higher specialization between advanced countries and by taking advanced technologies to lagging countries, increasing their productivity. Both processes raise capital accumulation and therefore increase economic growth. In fact, trade and investment liberalization have been so successful (at producing wealth, but not at distributing it) that they have generated miracle growth not only of countries such as China, but of the international sector itself. Recall that for twenty five years FDI grew at an average real rate of 14.6% a year, while worldwide exports grew at a rate of 6.2%, approximately doubling as a proportion of world GDP from, 14.5% in 1982 to 30.6% in 2006. Liberalization tapped a huge potential of economic growth, which surely is not exhausted, and without which economic growth can now hardly be contemplated. What, then, led to the present crisis?

3. The financial crisis

The economic expansion that began with Reagan's and Thatcher's liberalization in the 1980's occurred simultaneously with a technological expansion, particularly in the computer, communication, internet and related fields. This process met with a first slowdown when the "dot-com bubble" burst on March 10th, 2000. In an attempt to maintain economic growth, Alan Greenspan applied a low interest rate policy obtaining

[9] *Steady state* refers to an equilibrium trajectory in economic growth with an equilibrium rate of growth.
[10] See Pipitone (1995) for a historical case studies of Denmark, Sweden, Italy and Japan, Argentina, India, Nigeria, Brazil and Mexico.

mild results that worked through a housing expansion. A lengthy period of extraordinarily low interest rates then occurred, that led to a global housing bubble in the US, Britain, Australia, Italy, France, Spain, China, Russia, and many Eastern European countries (The Economist, 2005, EconomicReason, 2008). "According to estimates by The Economist, observing that the total value of residential property in developed economies rose by more than $30 trillion over the past five years, to over $70 trillion, an increase equivalent to 100% of those countries' combined GDPs," observed: "In other words, it looks like the biggest bubble in history."

A series of bubbles then appeared in relatively quick succession in financial markets, involving commodities, food and oil. Finally, the Dow Jones index lost 22% of its value between the 1st and 10th of October, and reached a low of 8,175.77 on October 27th that was 42.3% below its October 9, 2007 high of 14,164.53.[11] This was at least partially a financial derivatives crash that led to the collapse of US credit markets, the bankruptcy of multiple leading banking, brokerage and insurance firms, and the need for massive government intervention on the part of all leading industrial countries.

Impacts of globalization on the US economy

Since the present economic crisis is intimately related with the US financial system, to investigate the causes of the crisis, let us first ask in what ways the main indicators of the US economy have been affected by globalization from 1982 to 2007. Real US GDP grew at an average rate of 3.1% year, a pretty fast pace, and its relative size remained approximately constant at 28.8% of world GDP. The rate of investment was not strongly affected by inflows or outflows of foreign direct investment, in fact growing at a trend rate of 0.18% per year (Figure 2, data from WDI). Exports grew moderately. However, the US trade deficit ballooned, reaching 5.8% of GDP in 2005 and 2006.[12] Instead of buying US goods, foreigners, or TNC's, bought US equity.

Analyzing the problem, Bernanke (2005) defined it as a global saving glut. (In our model the "savings glut" will be represented by a lower steady state interest rate due to the presence of profits from FDI.) The United States, Spain, the United Kingdom, Australia, Italy and France experienced capital account inflows (and therefore current account deficits) that led to a substantial housing appreciation, while Japan and Germany–whose economies had been growing slowly despite very low interest rates, China, Middle Eastern Oil countries, other Euro countries, Korea, Canada, Taiwan, and Hong Kong lent money to the rest of the world.[13]

[11] Data from http://finance.yahoo.com/, read 11/4/08.

[12] Foreign direct investment inflows and outflows have recently been relatively volatile. However, their difference shows no trend and only exceptionally exceeded a net investment gain of 1.7% of GDP or net loss of 1.4%. Exports as a proportion of GDP rose significantly but only slowly from 8.6% to 11.1% (values along a linear trend). However imports grew from 9.4% to 15.3% of GDP (same; using WDI data).

[13] In 2004, the largest capital inflows were (billions): United States, $665.9, Spain $49.4, United Kingdom $46.9, Australia $39.6, Italy $13.7, Mexico $8.6 and France $5.1, while the largest outflows were: Japan $171.8, Middle Eastern Oil countries $116.4, Germany $104.3, China $55.5, Other Euro countries $40.8, Korea $27.6, Canada $25.9, Taiwan $19 and Hong Kong $16.

At the same time, corporate profits reached an all time high in the US and the UK,[14] and also for many corporations across the world. The World Investment Report highlights increased profits of foreign affiliates for 2007, notably in developing countries (UNCTAD, 2008, page 4). It explains that, "as TNCs in most industries had ample liquidity to finance their investments, reflected in high corporate profits, the impact (of sub-prime mortgage crisis that erupted in the United States in 2007) was smaller than expected. The aggregate profits of TNC's foreign affiliates reached $1,100 billion in 2007, with profit rates of about 7%, calculated as ratio of net income to total sales (ibid). These profits were increasingly generated in developing countries rather than in developed countries. About 30% were reinvested and the rest repatriated, in an amount that is remarkably close to the US capital account surplus.

The overall picture of high global corporate profits, high earnings for the top income levels, a falling participation of income for salaried workers in advanced countries, and transfers of 70% of affiliate profits to their home countries, is consistent with the role described above for FDI under polarized globalization.[15]

What is especially notable, however, and is one of the roots of the present financial crisis, is that this repatriated income was not invested. Instead it remained in the financial system of the developed world, tending to overvalue it, and feeding housing appreciation through many countries. In the US this process was accelerated by the low interest rate policy applied by Alan Greenspan following the "dot-com bubble." In fact the underlying low demand for capital was one of the factors which prolonged the period of low interest rates, since, as investment did not pick up, it was hard to raise interest rates without slowing the economy. Investment flowed towards housing because it was not attracted to production. Japan, which had already experienced its housing bubble, experienced a decade of low interest rates and low growth. Germany had low interests and low growth. The US had low interests and only housing growth, while corporations enjoying extraordinary profits paid down their debts, bought back their stock, and did not invest. The lack of investment was noted by Krugman (2007) in an editorial column, in reference to a "double disconnect:" "high profits haven't led to high investment, and rising productivity hasn't led to rising wages." Now, with the crisis, tens of trillions of dollars of saving, the sweat of millions of workers, has been wiped out.

The savings glut hypothesis is supported by an examination of US Treasury Bill interest rates minus inflation. Long-term interest rates, represented by the yields for 20 (and 30) year bonds, decreased significantly (the confidence levels for these coefficients are far better than the 1%), on average 15 (respectively 18) basis points per year, reaching about 1.6% in 2006 and 2007. This is consistent with a decrease of the returns to investment in the US over this period, and with the emergence of the saving glut during the last few years. Because economic growth and investment were intimately linked with globalization over this period, this means that, *under the present structure, global opportunities for investment were insufficient.* Now, short-term interest rates, represented by the yields for 6 (and one) month bonds reflect more closely their use as a policy

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[14] Aron-Dine and Shapiro (2007), Blanchflower (2008).

[15] Jaumotte, Lall and Papageorgiou (2008) use data showing inequality as measured by the Gini coefficient has risen in the United States, the United Kingdom, Italy and Japan, and, on average, in high income, upper middle income and lower middle income countries (this follows the World Bank classification).

instrument by the Fed. After 2001, lowering interest rates meant lowering them quite low, reaching negative real returns over the recessions of 1991 and 2001. Once they came back up again in 2006 and 2007, long-term interest rates did not go up, remaining at levels very close to short term bonds (Alan Greenspan's "conundrum"). Risky assets also reflected low interest rate spreads. However, the long-term trend in 20 year and 6 month real interest rates were approximately parallel, see trend lines in Figure 3.

Financial deregulation and the crash

In the setting of a savings glut with low interest rates, the lack of regulation of US financial markets generated a sequence of bubbles and then a turbulent financial crisis. But let us start this story from the inception of some crucial ideas.

Perfect markets are to the economist what Newton's laws are to the physicist, a simple paradigm that serves to analyze a remarkable variety of phenomena. However, the results require very strong assumptions: perfect competition, perfect knowledge, perfect foresight, complete markets, zero transaction costs, decreasing returns to production and consumption, and so on. Amongst the virtues of this paradigm is that its mathematical treatment is tractable. The existence of general equilibrium was rigorously established in Berkeley and Stanford in 1954 by Nobel Prizes Arrow and Debreu using complex mathematical techniques from differential geometry. However, demand and supply allow multiple equilibria, exhibit complex stability properties, and have limited mathematical tractability. As an approximation, the perfect markets paradigm has served well in the study of many aspects of the US economy, partly because of the US's large size and multifaceted competitiveness.

Imperfections tends to greatly complicate economic models and these are usually treated just one or two at a time. An example is Nobel Prize Lucas' (1972) islands model showing how rational expectations under imperfect information can deceptively mimic the empirical Phillips' curve negative correlation between inflation and unemployment, on which Keynesian macroeconomic policy was therefore arbitrarily based. In the face of global stagflation in the 1970s Lucas' Critique contributed to abandoning Keynesian policies in favor of market liberalization.

Paradoxically, the tremendous success of liberalization, which in fact has its roots in the economic forces generated by globalization, led to unparalleled perfect market hubris. Markets were simply best for anything; particularly financial markets, which test expectations and efficiency by the minute. Complex probabilistic mathematical models were developed to represent the pricing of derivatives[16]. Financial Engineering emerged as a new profession, "quants". One of its first stars was David Elliot Shaw, former computer scientist faculty at Columbia who founded a hedge fund company and made a fortune, ironically by exploiting *inefficiencies* in financial markets with the help of computer models. As the new financial "derivative products" gained ground and diversified, it was as if the perfect future markets for all commodities were coming out of Debreu's (1959) *Theory of Value* live into the stock market.[17]

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[16] Financial contracts such as futures, options and swaps based on the price of some financial asset or index. The Black–Scholes model prices such derivatives under assumptions such as efficient markets.

[17] In the Arrow-Debreu model mentioned above there exists a market for every time period and future prices for every commodity at all time periods and in all places.

Enter low interest rates and a lot of money chasing a limited investment portfolio (a savings glut), and the scenario was set for the emergence of a bubble.[18] According to the Bank of International Settlements (BIS), world's clearinghouse for central banks in Basel, Switzerland, the valuation of the world's derivatives grew exponentially from $72 trillion in June 1998 to $683 trillion in June 2008, in real terms multiplying by 5.8 and growing at an annual rate of 19.5% a year. This truly astronomical figure, a sum of "investors'" wagers, compares to: US annual GDP of about $15 trillion, US government's maximum legal debt of $9 trillion, world GDP of approximately $50 trillion, total value of the world's real estate estimated at about $75 trillion and total value of world's stock and bond markets at somewhat above $100 trillion. As far back as 2002, well-known investor Warren Buffet warned his shareholders at Berkshire Hathaway that the interlinked risks in the derivative markets, whose valuation was fraught with uncertainty, had created a ticking time bomb.[19]

When uncertainty clouded one of the main sets of assets underlying derivatives, sub-prime mortgages, the stage was set for disaster. The market in future assets and commodities lacked crucial ingredients such as information and transparency. The securities were impossible to evaluate and uncertainty grew rife. In addition, as they were sold, feedback loops embedded in their design and in market regulation, such as mark to market and mark to model bookkeeping, forced sales, computer sales and speculation in general, generated volatility and selloff. These instruments continue to pose an almost impossible challenge for the stability of the financial markets, and for the design of regulation.

Correlated risk, systemic risk, herd behavior in financial markets, risky behavior by financial managers egged on by competition with their rivals: these are all well known financial phenomena. Financial collapse has existed since the beginnings of credit in 16th century England! It was just not good for business to consider these problems![20] Under the risk of recession, and given the closeness of the Bush administration to big money, 'the market,' that is, Wall Street, was left to its own devices. But markets only exist when property rights are enforced, and in this more sophisticated context, under regulation and transparency, as illustrated by the Madoff[21] and Stanford frauds.

4. The global need for governance and publicly provided goods

Imbalances in the process of globalization have led economic growth to a halt. World savings accumulated in the financial markets of developed countries. However, even though gross domestic investment correspondingly rose, for example in the US, the rise in investment was not sufficient to meet the available funds.

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[18] This can only be a heuristic assertion. We lack a theory explaining how bubbles arise and burst, how they relate to regulation and low interest rates, and how realistic expectations of rising prices can set them off.
[19] This paragraph follows Farrell (2008), complementing some of his figures using BIS sources.
[20] Perhaps the Financial Engineer of the Year Award, established in 1993, should now be given to those who design regulation and transparency for the industry, and point out the way to stability.
[21] See for example "Mapping Bernard Madoff's $50bn 'fraud'" Times Online, February 6, 2009, http://business.timesonline.co.uk/tol/business/industry_sectors/banking_and_finance/article5677239.ece.

Yet, as noted above (UNCTAD, 2008), investments are clearly necessary in both underdeveloped and developed countries.

During the last few months before the crash in October, other problems became apparent. Given a scenario of positive economic growth, future scarcities in raw materials, energy and food are probable. There is great uncertainty over the prices these commodities might command in the near and long-term future. In fact, as investors fled the sinking financial ship into any market that promised to sustain value, volatility made the price signals for these commodities unreadable. This introduced even further uncertainty in investment.

Finally, the seriousness of the global ecological threats caused by the growing population and the growing use and abuse of natural resources, including global warming and a host of other problems, has reached new levels of urgency which require solid global cooperation.

In short, globalization has reached a bottleneck. Untrammeled market forces are not able anymore on their own to conduct economic growth. An economy run by TNCs was not able to generate enough investment. Investment now requires the goods that governments provide (I will refer to this set as *publicly provided goods*): infrastructure, education, health, law, institutions, science, equity, environmental sustainability and other global public goods. In short, global *governance*. This term acknowledges that these goods are not to be provided by a global government, but by the concert of nations.

Of course, publicly provided goods, which are indispensable, require funding. That is why there are only two inevitables, death and taxes. Corporations cannot anymore be allowed to benefit from the lawless no man's land that exists in between nations, evading taxes. In effect, the existence of this giant loophole subsidizes international at the expense of local production, contrary to the basic tenets of efficiency. Some sort of value added taxation, perhaps in tandem with rules of origin, must be put into effect. This should also be a progressive tax schedule, rewarding cheap labor with the resources needed to uplift the poor. This would tend to generate equal rather than polarized globalization, fund public goods reestablishing the conditions for investment, and balance the incentives for local and international production.[22] At the present it is impossible for countries–even the US–to levy such taxes on TNCs without facing the threat of their relocation or provoking their reorganization.[23] Only a global initiative can achieve this, increasing the resources of all governments, but hopefully also generating at least some global funds to be administered with global aims, an exercise that will lay the foundations for generating global public goods and serve to enhance global cooperation and peace.[24]

At the global level, TNCs simply adapt to their environment. What this means for taxes at the present time is illustrated by two examples, whose sources cannot be verified.

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[22] Underdevelopment is linked with low institutional development and a prolonged demographic transition, forming a part of polarized globalization. Conversely, policies leading to a more equal globalization will promote higher institutional development and slower population growth. See Mayer (2008a) for a more detailed discussion.

[23] Such a global initiative is a way of ending tax breaks to corporations sending jobs abroad, one of Obama's campaign promises, but doing so fairly across nations. Domestically, it would have a progressive redistributive impact, and would raise incentives for investment. Whether its short-term impact works towards expansion or contraction, this can be compensated by domestic policy.

[24] The kinds of agreements that are necessary for monitoring money flows to harmonize taxes will also be helpful in fighting crime and in generating security.

Mitsubishi UFJ Financial Group, one of 20 core member companies of the Mitsubishi Group, holding assets of around US$1.8 trillion in March 2008, consisted of 64 worldwide corporations of which 9 were registered in the Cayman Islands.[25] Halliburton consists of 272 corporations of which 16 are registered in Cayman Islands, 10 in other possible tax havens, and one is a "Tax Department."[26] A global tax system has to be designed whose incentives favor straightforward, transparent organization of TNCs.[27,28]

Closing the giant tax loophole for TNCs and increasing funding for publicly provided goods at the national and international levels constitutes a reform of globalization.[29] Globalization is not synonymous with extreme laissez-faire. Globalization needs to be reformed to establish a more normal relation between markets and governance at the global level. This will tend to open a panorama of investment and economic growth into the future, by providing the necessary public complements for investment.

Some lessons can be learnt on how such a project of reform would proceed from the history of the implementation of Reagan and Thatcher's liberalization policies in the 1980s. This fundamental policy change took shape throughout the policy spectrum. In November 1982, a ministerial meeting of the General Agreement on Tariffs and Trade (GATT, whose first round of negotiations was signed in 1947) proposed what became the Uruguay round of negotiations. This was launched in 1986, concluded in 1994, signed by 123 countries, and led to the creation of the World Trade Organization (WTO) in 1995. It was "the largest negotiation of any kind in history."[30] Concurrently, the Washington Consensus (a term coined in 1989) implemented the standard New Classical reform in any developing country that faced a crisis, recommending and imposing liberalization of trade and foreign direct investment, privatization, and deregulation. China also began introducing market mechanisms into its economy in December 1978. In addition, marked by the fall of the Berlin Wall in 1989, much of the socialist block dissolved. Thus, a global market economy emerged. The new horizons of trade and investment led to what amounts to miracle growth in the international economy.

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[25] See en.wikipedia.org/wiki/Mitsubishi_Group, en.wikipedia.org/wiki/Mitsubishi_UFJ_Financial_Group, read 11/28/2008. Sources listed: citing morganstanley.com and company's home page.

[26] See www.libertyparkusafd.org/lp/Hancock/Global%20Corporations%5CList%20of%20Halliburton%20subsidiaries%20-%20Wikipedia,%20the%20free%20encyclopedia.htm The information is claimed to originate in Wikipedia, but is not available there anymore.

[27] In fact the race to the bottom in terms of corporate taxes also exists within the US, where Delaware operates as a corporate haven. Delaware's laws give corporate management notable latitude in its powers to operate and control the corporation, frequently at the expense of the shareholders' ability to control the corporation. Delaware charges no income tax on corporations not operating within the state. (Information from http://en.wikipedia.org/wiki/Delaware_General_Corporation_Law, read 12/13/2008)

[28] Perhaps a carrot and stick strategy only granting contracts in infrastructure, health, education, and other publicly provided goods to transparently organized corporations would help. The World Investment Report (UNCTAD, 2008), not surprisingly, makes a case for transnational involvement in "the infrastructure challenge".

[29] Guo and Lansing (1995, a Federal Reserve Bank Working Paper) show that when monopoly power is higher, the optimal level for the taxation of capital income increases. They find for empirically plausible parameters of their model that the positive welfare effects of taxing monopoly profits exceed the negative effects due to disincentives on investment.

[30] Information from http://www.wto.org/english/thewto_e/whatis_e/tif_e/fact5_e.htm, the World Trade Organization web page, read 11/15/2008.

As in the case of liberalization, reforming globalization to eliminate the giant tax loophole enjoyed by TNCs and to fund the provision of public goods will entail long, complex negotiations. However, these will also generate the mechanisms of global cooperation and global governance that are indispensable for establishing environmentally sustainable economic growth.

5. Low interest rates and fiscal stimulus versus investment

Recognizing that the economic crisis was caused by a shortfall in investment under low long-term interest rates is crucial. The present crisis is the combination of a long-term crisis caused by insufficient investment *overlaid* with the crash of the housing bubble and the consequent crash of the loosely regulated financial system. The long-term crisis is the result of liberalization policies successful at creating wealth but not at distributing it, which produced miracle growth in the international sector, and an extraordinary level of profits, that under the present arrangements of the world economy did not find investment opportunities. The short-term crisis was caused by instabilities originated in the consequent savings glut, which, combined with deregulation in the financial markets, led to a housing bubble and to highly leveraged investments. In turn, the financial crash is now provoking a cascade of consequences.

The failure of the liberalized market system is provoking a *return to the standard monetary and fiscal Keynesian policies* in the US, lowering interest rates to raise the incentives for investment and stimulating consumption by spending money or giving some kind of tax break. Bernanke is proposing the combination of both policies to prevent deflation.

However, the diagnosis of the crisis implies that *these policies will not be very effective*, for several reasons. Recall that all possible investment under very low interest rates, and under much lower uncertainty than today, has already been carried out. The long-term investment shortfall obeys real reasons.[31] While these may not be fully understood, they include the following. First, future real prices of the main commodities used for production and consumption, raw materials, energy and food, are highly uncertain. These prices strongly depend on the global growth scenario, because as more countries lift their standards of living, their demand rises. Second, in advanced countries, labor faces the competition of low salaries abroad. A giant tax loophole for TNCs in effect subsidizes international production at the expense of local production. Third, both in lagging and in advanced countries, there is a shortfall in investment in infrastructure, education, health and science. These goods are usually provided from public funding. Thus, holding interest rates low is not very likely to promote investment. It didn't in Japan's decade-long slump in the 1990's (that occurred after its real estate crash).

Turning to consumption stimulus package, recall Milton Friedman's criticism of Keynesian policies. According to the "permanent income hypothesis," except for the very poor, consumption decisions are based on long-term income expectations rather than on

[31] According to the Austrian business cycle theory, excessively low interest rates implemented by monetary policy result in low yield, poor investments and financial volatility. This describes the housing bubble quite well. However, the low *long-term* interest rates of the last few years are the consequence of real conditions that need to be addressed.

current income. That is why the first stimulus package had a limited impact and was saved rather than consumed. Also, while firms may respond to additional demand with additional production, this does not mean they will invest. Yet the sum total of national income is consumption plus investment. Thus, so long as investment is low and expected to continue low, permanent income, and therefore consumption, will be low. Under the permanent income hypothesis, the Keynes consumption multiplier does not work. However, there is an investment multiplier. Permanent income will rise when investment is revitalized, raising future income expectations, and with it consumption. A consumption fiscal package will not be very effective for jump-starting the economy, because it does not address the causes of the investment shortfall. Similarly, public investment in roads will only work in so far as it promotes investment, and in so far as it employs the very poor (also providing an employment policy).

The problem with these policies proposals is two-fold. First, US economists are focused on the US as if it were an independent economy, without fully considering its insertion and role in and the impact of the global economy. Second, economists are focused on the short-term impact and dynamics of the financial crisis, without considering its long-term causes. Of course, the credit freeze and leverage levels in financial markets are posing high risks that are snowballing and must be met, but these will diminish if a clearer way towards economic growth emerges and the economy starts moving again. If things went really smoothly it could even be possible to recuperate some of the paper losses in the financial system, representing a mass of savings.

Now, while it is true that countries must follow their national self-interest in seeking to restart their economies, if the present crisis generates a globalization backlash tending to restrict trade and investment, this could lead to a further implosion of the economy. The world economy *is* now, by and large, a single economy.

Thus, what really needs to be stimulated is the global economy. This can only be done through promoting the development of whole new economic sectors and technologies in advanced countries, deepening economic development in underdeveloped countries, and reforming globalization to achieve the new levels of governance that are required to meet challenges in infrastructure, education, health, science and sustainability.

The US must strengthen its economy in full cognizance of its international economic role as provider of innovation, one of its traditional strengths. The sector that most urgently requires support is green energy. The US dependence on fossil fuels is now strategically untenable, expensive, and environmentally unsustainable (Gore, 2006). The energy sources for economic activity have been critical at different times, such as the introduction of the steam engine for the Industrial Revolution, the emergence of electrically powered mass production for mass consumption in the US, the oil crisis in the 1970's. At the present time, the development of green energy is imperative for sustainable economic growth.

Supporting investment in green energy just happens to be consistent with all of the necessary ingredients for US economic policy.[32] It promotes investment in new sectors of the economy, such as green transportation and housing; it promotes low and middle class employment; it has the potential to promote technology exports throughout the world; and it solves an urgent problem of environmental sustainability. Ironically, the

[32] See also Al Gore New York Times Op Ed Nov 9, 2008: "Here is the good news:"

first thing that is required is to *withdraw* subsidies from fossil fuel, channeling them instead towards clean energy sources. The US currently spends more than $35 billion a year to subsidize fossil fuels. Over the industrial countries overall, these subsidies have been estimated at $250 billion a year. Gelbspan's proposal, *Toward A Real Kyoto Protocol*, includes a subsidy switch towards clean energy; the creation of a large fund to transfer clean energy technologies to developing countries; and raising the Kyoto Fossil Fuel Efficiency Standard by 5 percent per year.[33] Reforming globalization as suggested here, to begin with by closing the giant tax loophole benefiting TNCs, would provide such funding, as well as necessary groundwork in international cooperation.

Supporting investment in green energy is also consistent with revitalizing the role of science in the US economy. The privatization of the university has weakened a traditional link between public and private investment that was key to the scientific and technological revolution in the US.[34] In an era as complex as the present one, public knowledge on technological alternatives for the economy in general and on sustainability in particular, supporting innovation as well as informed public decision making, are crucial. This is especially true in the face of corporate lobbying that can severely distort such decisions. For example, Congress suppressed funding for satellite Triana, which was to obtain invaluable information on global warming. The satellite had already been built when US$50 million were withheld from NASA's budget to cancel its launching (Street, 2008). Likewise, deceptive scientific research funded by corporations has clouded the implications of global warming for years (Gelbspan, 1997, 2005). The same occurred in the debate over the dangers of smoking. At the present time, the consumer cannot choose between alternative energy sources for transportation. Big corporate interests in oil have severely distorted US national policies and priorities.

If any doubts should remain as to the market's ability to regulate environmental stability, let Alan Greenspan's 'shocked disbelief' at the present financial meltdown serve as a warning for the potential consequences of leaving the arctic meltdown in the hands of unfettered self-interest. Ominously, as the ice melts, shipping magnates, oil and gas companies, and countries are already fighting each other for sea routes and oil fields emerging in the Northwest Passage as the ice melts (Lobel, 2008). The need for developing global governance can hardly be overstated.

Supporting the development of green energy is not the only project that public policy can seed to generate investment and technologies for whole new sectors of the economy. In its universities, the US has a tremendous innovation infrastructure that can lead to the development of new economic sectors generating sustainable solutions for both advanced and developing countries. Wireless infrastructure for cities. The air car based on compressed air. The water car based on hydrogen combustion. Solar power for multiple purposes including compressed air and hydrogen. Sustainable mechanized agriculture. Bringing urban quality to rural living, from the rural communities in the Midwest to China and India, for export. The US can enlist its young engineers and scientists and build on the active technology policy that has existed since first President

[33] See http://www.heatisonline.org/contentserver/objecthandlers/index.cfm?id=6320&method=full, Gelbspan's web page, for this data and information as well as further discussion (read 11/23/2008).
[34] See Brown (2000) for one example of discussion of this topic.

Bush's 1990 *US Technology Policy* and President Clinton's *Economic Report of the President* in 1994 (Link and Scott, 2001).

These policies are complementary with China's 4 trillion yuan (US$586 billion) stimulus package announced November 9 to be spent on upgrading infrastructure, particularly roads, railways, airports and the power grid; on raising rural incomes via land reform; and on social welfare projects such as affordable housing and environmental protection (Maidment, 2008). In effect the measure counteracts China's slump in exports by deepening its domestic economy. Provincial governments later announced additional spending of 10 trillion yuan (US$1.5 trillion) that emphasize rural infrastructure (Hornby, 2008). Demand will be generated for improved rural productivity and quality of life that could be supplied by green US technology. In fact, lifting productivity, and therefore salaries, in India and China is almost a prerequisite for harmonic global integration.

Given that the long-term cause of the present crisis is a shortfall in investment, income expectations and therefore economic growth require a global public investment plan of a magnitude sufficient to generate substantial flows of private investment. This will be the case even if the global plan consists of a sum of independent national plans, which may be more or less coordinated, together with a global plan for raising the provision of publicly provided goods. As discussed above, these actions require an emphasis on sustainable economic growth.

The housing market, the financial system and jobs are currently the center of attention and priority of US economists. Designing appropriate policies is a challenging and complex process that is beyond the expertise of this author. However, ignoring the long-term origins and global context of the crisis, and thinking of the US as an isolated economy will lead to pursuing ineffective policies. Specifically, the implementation of low interest rates and fiscal policies promoting consumption will only replicate the prolonged slump that took place in Japan after the collapse of its real estate market.

6. Conclusions

The present financial crisis resulted from a long-term decline in long-term interest rates. As interest rates declined, investment resources flowed towards real estate rather than production, and housing bubbles were generated in a series of countries. Combined with deregulation, instability was generated in financial markets. When the US housing bubble burst, uncertainties in the sub-prime mortgage market derailed a leveraged market. Thus, the present crisis is the combination of a long-term crisis caused by insufficient investment *overlaid* with the crash of the housing bubble and the consequent crash of a loosely regulated, over-leveraged financial system.

While restoring credit, seeking the softest possible landing for the housing market, and minimizing the impact of the financial meltdown are clearly the immediate priorities, designing the adequate policies to achieve these aims requires taking the global setting and long-term causes of the crisis into account. Because interest rates have been low for so long, lowering them will not generate very much investment. Similarly, consumption flows emanating from fiscal spending will not generate very much investment. So long as investment remains low, so will expected income and therefore economic activity. This is

the core reason for the possibility of an "L-shaped" recession along the lines of the Japanese slump in the 1990's.[35]

What must be kept in mind therefore is to promote global investment. While the free market policies governing globalization have been very successful in generating wealth (although not in distributing it), it is crucial to recognize that an investment shortfall was generated nevertheless. This means that something other than market forces is needed in the global arrangements of production to generate investment. The only other player is government, and what are needed are the goods that government provides. Challenges in infrastructure, education, health, science and sustainability, raw materials, energy, food, equity and other global public goods must be met.

To stimulate the global economy, whole new economic sectors and technologies must be developed in advanced countries, and economic development deepened in underdeveloped countries. Developing the green energy sector is consistent with all of these aims, with the need for an adequate energy supply, with revitalizing the role of science, and with sustainability. From this point of view, Obama's American Recovery and Reinvestment Plan is just a beginning.

The pendulum has swung. While globalization has produced twenty five years of global economic growth under free market policies, now it requires global governance. Indeed, it could well happen, not so far in the future, that public goods (such as environmental sustainability) rather than private goods, are the main components of welfare.

Global integration is not equivalent to *laissez faire*. Restoring investment for sustainable, global economic growth requires establishing a normal balance between markets and governance, ensuring an adequate supply of publicly provided goods. A global harmonization of taxes is required to fund these goods, to balance the incentives between local and international production, and to generate mechanisms for global cooperation and peace. Bold steps are required to reform globalization so as to reduce the imbalances it generates, both between and within countries, and to promote equality, welfare, sustainability and governance. The world awaits US leadership for setting the global economy on course towards higher levels of cooperation, as an equal partner in the concert of nations.

[35] Recent Nobel prize winner Krugman explicitly warns of this possibility (Reuters Mon Dec 8, 2008).

Figure 1. Factor by which Income Share of Higher Income Brackets was Multiplied from 1970 to 2006

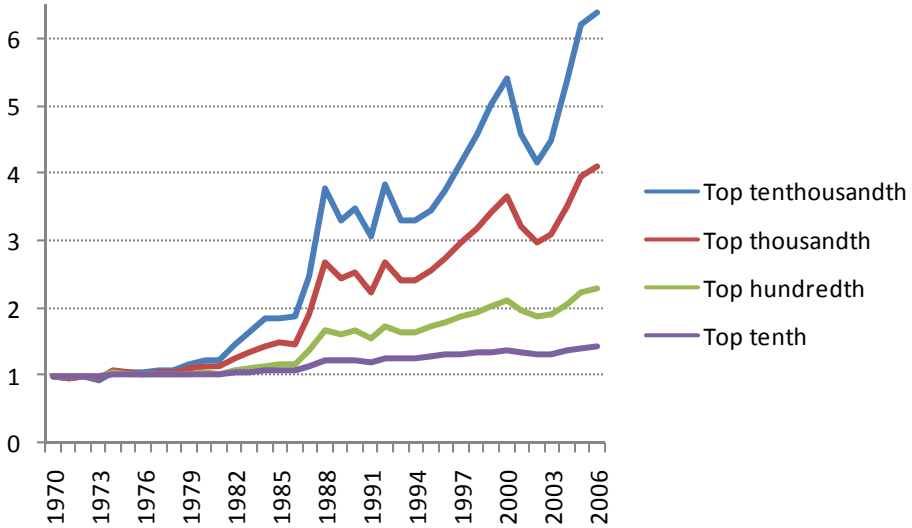


Figure 2. US Gross Domestic Investment, Imports, Exports, FDI Inflows and FDI Outflows as Percentage of GDP, 1980-2007 (trend lines added)

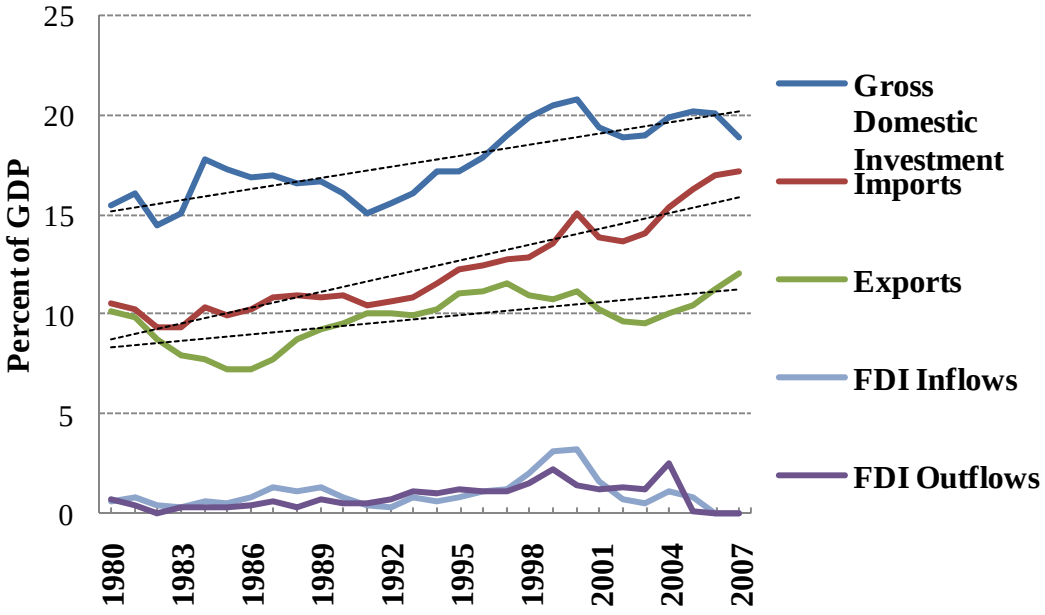
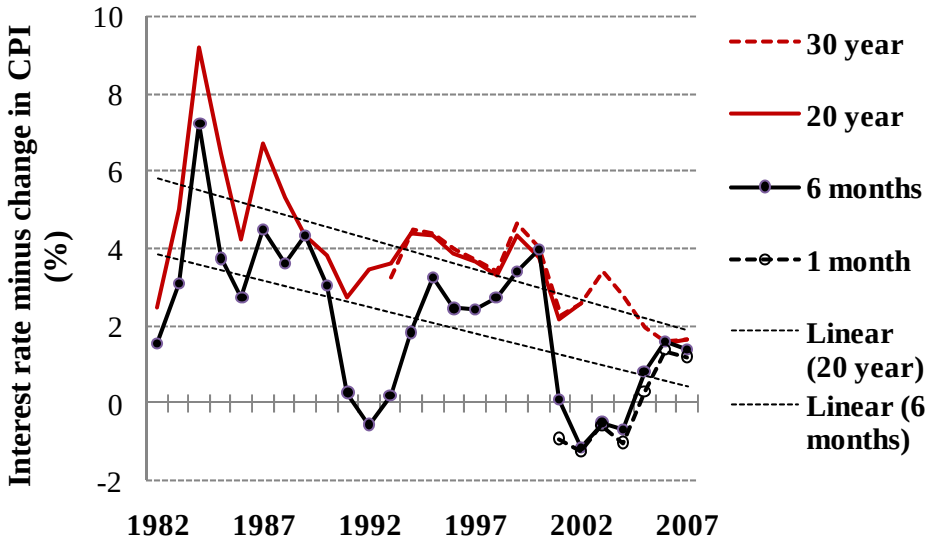


Figure 3. Real US Treasury Interest Rates According to Term, 1982-2007
Trendlines added for 20 year and 6 month Bonds



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7. Appendix. The model

The Schumpeterian model presented here builds on a series of papers. These first introduce endogenous technological change in the theory of economic growth (Aghion and Howitt, 1992); then show that technological transfer can induce convergence (Howitt, 2000); and finally go on to address problems generating divergence and underdevelopment. These include human capital thresholds for R&D can separate implementing from R&D countries into convergence clubs and explain long-term divergence (Howitt and Mayer-Foulkes, 2002); financial development can determine technological absorption rates and also explain long-term divergence (Aghion, Howitt and Mayer-Foulkes, 2005). The present paper moves beyond closed economies and includes trade and direct investment. It demonstrates that convergence clubs and divergence can arise based on the standard assumptions of the theory of endogenous technological change, without assuming market failures or increasing returns.

A series of assumptions are made in the model for the sake of simplicity. We consider a two-country model, a leading developed country and an underdeveloped country with a lower technological level. Next, because we want to analyze the long-term behavior of the interest rate, we include both technological levels and capital in the model, making it a two state variable model. For this reason we opt for writing a continuous Solow-style model. This has the advantage of making the model accessible to non-specialists in endogenous technological change. We show, though, that the Solow-style model is endogenous in that it can be derived from myopic preferences generating saving and infinitesimal foresight generating technological change. Because we analyze trade and FDI, we use a continuum of goods (called sectors), something that is also common in endogenous growth models seeking to smooth innovation probabilities. However, here we also abstract from uncertainty in innovation, again to reduce the complexity of the model. Since the main motor of the effect we are looking at is FDI, we do away with comparative advantage in trade. However, it would not be hard to include this in the analysis, by introducing a gradient of productivity fixed effects across sectors, moving in opposite directions for the two countries, as is done in Mayer-Foulkes (2007c). We comment on the implications that would arise from including it.

Another change from more standard models in technological change is that rather than postulating a leading technological edge we take the leading country's technology as the leading edge that a more backward country can adopt. This eliminates another state variable. We understand innovation as a wide spectrum of activities, beginning with adoption at the lower end of the spectrum and taking the form of R&D at the top level. Technological change is costly in proportion to the technological level, so that a constant steady state rate of growth is possible, obtained by expending a constant proportion of income on innovation. More backward countries enjoy the "advantage of backwardness" consisting of adopting more advanced technologies (Gerschenkron, 1952). This generates convergence. However, when technological adoption is also proportional to resources divergence may result.

One of the properties of these models of technological change is that they generate two types of steady state divergence. The first is divergence in levels, when there is an equilibrium lag in technological levels. The second is divergence in growth rates, when this lag becomes larger, the lagging country growing at a slower rate than the leading country.

7.1. **Production.** Economy 1 and Economy 2 produce a continuum of tradeable goods indexed by $i \in [0,1]$, where each i refers to a sector.

There is a single innovator in each sector who invests in innovation, innovates with certainty, and becomes a national or world monopolist, under autarchy or trade, producing in the presence of a competitive fringe. The character of domestic innovation races will be described below. Under trade, however, there will be no international innovation races, because when comparative advantage assigns production it will also assign an advantage in innovation competition.

On the subset of sectors $[0, \bar{\xi}^{FDI}]$ it is feasible to conduct cheap-factor-seeking FDI. We assume that on these sectors innovators from Economy 1 producing in Economy 2 will out compete domestic producers from both countries, the reverse not holding for innovators from Economy 2.[36]

Under autarchy all goods are domestically produced and each economy produces in all sectors. We return to this case presently.

Under free trade and FDI, in every sector innovators produce monopolically supplying world consumption and investment. FDI production on sectors $[0, \xi^{FDI}]$ (with $\xi_t^{FDI} < \bar{\xi}^{FDI}$) is carried out by Economy 1 innovators in Economy 2. Domestic production in Economy 1 is on sectors $[\xi_t^{FDI}, \xi_t^{FDI}+\xi_{1t}]$, and on set $[\xi_t^{FDI}+\xi_{1t}, 1]$ in Economy 2. Let $\xi_{2t} = 1 - \xi_t^{FDI} - \xi_{1t}$. Then Economy 2 produces and innovates domestically on set $[1-\xi_{2t}, 1]$, and

$$\xi_t^{FDI} + \xi_{1t} + \xi_{2t} = 1. \tag{7.1}$$

I refer to the variables ξ_{1t}, ξ_{2t}, ξ_t^{FDI} as sectoral measures of the domestic and FDI sectors. It will turn out that if Economy 2's population is large enough, then $\xi_{2t}^{FDI} = \bar{\xi}^{FDI}$. Otherwise, FDI will only be possible for a restricted set of sectors with $\xi_{2t}^{FDI} < \bar{\xi}^{FDI}$, employing all of the working population of Economy 2, a case I refer to as "Dominated by FDI."

The production function for domestically produced goods in sectors $\eta \in [\xi_t^{FDI}, 1]$ in Economy j is the Cobb-Douglass:

$$y_{jt}(\eta) = k_{jt}(\eta)^{\alpha} \left(Q_{jt}^{\beta} A_{jt}^{1-\beta} l_{jt}(\eta) \right)^{1-\alpha}.$$

Here $y_{jt}(\eta)$ is the amount produced in sector η, $k_{jt}(\eta)$ is the amount of physical capital (a composite good to be defined below) employed in the sector, Q_{jt} is an economy level public good, A_{jt} is the technological level of the given economy, and $l_{jt}(\eta)$ is labor employment. Observe that assuming that there are different technological levels in each economy implicitly assumes that mastering foreign technologies and adapting them to the local environment is costly.

The production function for FDI (produced by innovators from Economy 1 in Economy 2) is:

$$y_t^{FDI}(\eta) = k_{2t}^{FDI}(\eta)^{\alpha} \left(Q_{2t}^{\beta} A_{1t}^{1-\beta} l_{2t}^{FDI}(\eta) \right)^{1-\alpha}.$$

The domestic and FDI productivities are

$$B_{jt} = Q_{jt}^{\beta} A_{jt}^{1-\beta}, \quad B_{2t}^{FDI} = Q_{2t}^{\beta} A_{1t}^{1-\beta}.$$

[36] FDI, denoting investment, is usually understood as carried out by a single firm. However, the definition here includes the case when innovators from Economy 1 subcontract production to firms in Economy 2, innovators retaining their profits. Intermediate cases can also be dealt with.

Definition 1. *Define the productivities*

$$B_{jt} = Q_{jt}^{\beta} A_{jt}^{1-\beta}, \quad B_{2t}^{FDI} = Q_{2t}^{\beta} A_{1t}^{1-\beta}.$$

and the relative state variables

$$a_t = \frac{A_{2t}}{A_{1t}}, q = \frac{q_2}{q_1},$$
$$b_t = \frac{B_{2t}}{B_{1t}} = \frac{Q_{2t}^{\beta} A_{2t}^{1-\beta}}{Q_{1t}^{\beta} A_{1t}^{1-\beta}} = q^{\beta} a_t,$$
$$b_t^{FDI} = \left(\frac{B_{2t}}{B_{2t}^{FDI}}\right)^{1-\alpha} = \left(\frac{Q_{2t}^{\beta} A_{2t}^{1-\beta}}{Q_{2t}^{\beta} A_{1t}^{1-\beta}}\right)^{1-\alpha} = a_t^{(1-\beta)(1-\alpha)},$$
$$\lambda = L_2/L_1.$$

Here each economy has population L_j, assumed to be fixed. Since it is assumed that $A_{2t} \leq A_{1t}$, it follows that $a_t \leq 1$ and $b_t^{FDI} \leq 1$. Hence FDI is feasible, since $B_{2t} < B_{2t}^{FDI}$.

Proposition 1. *Given wages w_{jt} and interest rate r, the private cost of each unit of domestic good η is:*

$$z_{jt}(\eta) = \frac{r^{\alpha} \left(w_{jt}/B_{jt}\right)^{1-\alpha}}{\alpha^{\alpha} \left(1-\alpha\right)^{1-\alpha}}. \tag{7.2}$$

The ratio of capital to labor is:

$$\frac{k_{jt}(\eta)}{l_{jt}(\eta)} = \frac{\alpha w_{jt}}{(1-\alpha)\, r}. \tag{7.3}$$

We suppose that public goods are supplied in proportion to the technological level, whether they are institutions or services. Institutional quality is the result of continual innovation adapting to conditions changing with the arrival of new technologies. Services need to be provided in proportion to the technological level to be effective. Thus

$$Q_{jt} = q_j A_{jt}, \tag{7.4}$$

where q_j is a constant.

Each domestic sector produces monopolically (with or without a competitive fringe) with a mark up $\chi > 1$ selling at a price:

$$p_{jt}(\eta) = \chi z_{jt}(\eta), \tag{7.5}$$

This is a common assumption in models of endogenous technological change.

The competitive fringe for FDI producers from Economy 1 in Economy 2 are domestic producers in Economy 1.[37]

[37]For example, assume that the FDI producer is large; that she has innovated specifically for production in Country 2; and finally that her fringe competitors are small and would have to innovate for production in Country 1. Also, note that if the price where proportional to A_{2t}, the level of production would tend to infinity as $A_{2t}/A_{1t} \to 0$ (the case of divergent equilibria, see below) something that seems unrealistic. Intermediate cases with less than full profits could be posed leading to similar results.

Wages are proportional to domestic productivity: from equations (7.5) and (7.2) it follows that

$$w_{jt} = (1-\alpha)\left(\frac{\alpha^{\alpha}}{\chi r^{\alpha}}\right)^{\frac{1}{1-\alpha}} B_{jt}. \tag{7.6}$$

Assume capital markets are perfect, so that capital investment is assigned optimally according to (7.3). Hence production levels are:

$$y_{jt}(\eta) = \left(\frac{\alpha w_{jt}}{(1-\alpha)\, r}\right)^{\alpha} B_{jt}^{1-\alpha} l_{jt}(\eta) = \chi \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{jt} l_{jt}(\eta), \tag{7.7}$$

using expression for wages (7.6).

7.2. **Trade and FDI.** Under trade and FDI, production responds to global demand, and global prices are formed. Let the instantaneous consumer subutility function C_t for an agent consuming $c_t(\eta)$ units of sector η goods, $\eta \in [0,1]$, be the Cobb-Douglass:

$$\ln(C_t) = \int_0^1 \ln(c_t(\eta))\, d\eta. \tag{7.8}$$

Suppose also that investment uses a composite good with the same kernel as consumption, so that the composition of consumption and investment demand are equal. Then aggregate world expenditure across sectors is some constant x_t.

Comparative advantage can be introduced in the model (see Mayer-Foulkes, 2009) by introducing a fixed sectoral productivity effect that decreases along η for Economy 1 and increases for Economy 2. Then comparative advantage combines with technological advantage to determine some equilibrium $\eta = \xi_t^{FDI} + \xi_{1t}$ on $[\xi_t^{FDI}, 1]$ so that sectors on $[\xi_t^{FDI}, \xi_t^{FDI} + \xi_{1t}]$ are produced in Economy 1 while sectors in $[\xi_t^{FDI} + \xi_{1t}, 1]$ are produced in Economy 2. Trade thus increases aggregate productivity and consequently also makes more resources available for innovation.

However, the present model emphasizes the role of FDI, so for the sake of simplicity comparative advantage is not introduced, first, to eliminate mathematical complexity, and second, so as not to make assumptions about the relation between comparative advantage and FDI. (We can still imagine there is a small fixed sectoral productivity effect that decreases along η for Economy 1 and increases for Economy 2.)

We now work out how production is allocated across the two economies.

Proposition 2. *Prices and quantities of production are constant across sectors.*

Proof. The boundary $\xi_t^{FDI} + \xi_{1t}$ of the set of domestic sectors is determined endogenously and would shift to the right or to the left if p_{1t} were different to p_{2t} (by attracting more domestic sectors into production in the economy offering the cheaper price) except possibly in the boundary cases $\xi_{1t} \in \{0, 1 - \xi_t^{FDI}\}$. Now $\xi_{1t} > 0$, because otherwise labor in Economy 1 would not be employed (leading to very low and attractive wages), so the only boundary case is $\xi_{1t} = 1 - \xi_t^{FDI}$, when all labor in Economy 2 is employed in the FDI sector. In this case employment in domestic production in Economy 2 is not competitive with employment in FDI sectors, so there is no domestic supply and there is no price p_{2t}. Without loss of

generality we can set $p_{2t} = p_{1t}$.[38] Now similarly p_t^{FDI} cannot be more than p_{1t}, otherwise FDI sectors would loose their markets to domestic sectors in Economy 1. On the other hand, the competitive fringe for FDI sectors is in Economy 1, so p_t^{FDI}will be at least p_{1t}. Hence $p_t^{FDI} = p_{1t}$. It follows that all prices p_{1t}, p_{2t}, p_t^{FDI} are equal. We therefore set them as numeraire,

$$p_{1t} = p_{2t} = p_t^{FDI} = 1.$$

Since expenditure is constant across sectors, it now also follows that production quantities are equal, and equal to expenditure:

$$y_{1t} = y_{2t} = y_t^{FDI} = x_t.$$

□

Proposition 3. *The amount of labor $l_{jt}(\eta)$ assigned to production in either domestic or FDI sectors is constant across each type of sector in each economy.*

Proof. First consider domestic sectors. Aggregate expenditure is:

$$\begin{aligned} y_{jt}(\eta) &= \chi \frac{r^{\alpha}\left(w_{jt}/B_{jt}\right)^{1-\alpha}}{\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}} \times \chi \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{jt} l_{jt}(\eta) \\ &= \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{jt} l_{jt}(\eta) = x_t, \end{aligned} \tag{7.9}$$

using expression (7.6) for wages. Hence in each economy $l_{jt}(\eta)$ is constant across domestic sectors. Now consider FDI sectors. Aggregate expenditure in FDI sectors is:

$$\begin{aligned} y_t^{FDI}(\eta) &= \chi \frac{r^{\alpha}\left(w_{1t}/B_{1t}\right)^{1-\alpha}}{\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}} \\ &\quad \times \left(\frac{\alpha w_{2t}}{\left(1-\alpha\right) r}\right)^{\alpha} B_{2t}^{FDI(1-\alpha)} l_{2t}^{FDI}(\eta) \\ &= \chi \frac{w_{1t}^{1-\alpha} w_{2t}^{\alpha}}{1-\alpha} \left(\frac{B_{2t}^{FDI}}{B_{1t}}\right)^{1-\alpha} l_{2t}^{FDI}(\eta) \qquad (7.10) \\ &= \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{2t}^{\alpha} \left(B_{2t}^{FDI}\right)^{1-\alpha} l_{2t}^{FDI}(\eta) = x_t. \qquad (7.11) \end{aligned}$$

The last line uses (7.6). It follows that $l_{2t}^{FDI}(\eta)$ is constant across FDI sectors. □

Notation 1. *In view of the constancy of prices and quantities across sectors of the same type, we now eliminate η from much of the notation, as follows. $l_{1t}(\eta) = l_{1t}$ for domestic sectors in Economy 1, $\eta \in [\xi_t^{FDI}, \xi_t^{FDI} + \xi_{1t}]$. $l_{2t}(\eta) = l_{2t}$ for domestic sectors in Economy 2, $\eta \in [1 - \xi_{2t}, 1]$, $l_{2t}^{FDI}(\eta) = l_t^{FDI}$ for FDI sectors$\eta \in [0, \xi^{FDI}]$, and similarly for other variables.*

[38]Note if all sectors are involved in FDI then wages are not fully defined domestically, and neither is the home technological level. We will assume below that home knowledge does continue to exist and follows the same dynamics, although other assumptions are possible.

Corollary 1. *The ratios between expenditure, wage payments, capital payments, domestic profits and FDI profits are either fixed or depend on the relative state variables,*

$$w_{jt}l_{jt} = \frac{1-\alpha}{\chi}x_t, \tag{7.12}$$

$$rk_{jt} = \frac{\alpha}{\chi}x_t, \tag{7.13}$$

$$\pi_t = \left(1-\frac{1}{\chi}\right)x_t, \tag{7.14}$$

$$\pi_t^{FDI} = \left(1-\frac{b_t^{FDI}}{\chi}\right)x_t. \tag{7.15}$$

Similarly the ratios between employment levels $l_{1t}, l_{2t}, l_t^{FDI}$ are given by

$$l_{1t} = b_t l_{2t}, \quad l_t^{FDI} = b_t^{FDI} l_{2t}. \tag{7.16}$$

Proof. Expression (7.12) follows from (7.6) and (7.9). Hence domestic profits levels can be written

$$\pi_t = y_{1t} - w_{1t}l_{1t} - k_{1t}r = \left(\frac{\chi}{1-\alpha} - 1 - \frac{\alpha}{1-\alpha}\right) w_{1t}l_{1t} = \left(1-\frac{1}{\chi}\right)x_t,$$

while FDI profits are

$$\pi_t^{FDI} = y_t^{FDI} - w_{2t}l_t^{FDI} - k_{2t}r = \left(1-\frac{b_t^{FDI}}{\chi}\right)x_t.$$

For the labor ratios divide equation (7.9) for $j=2$ by the same expression for $j=1$, and by expression (7.11). □

Definition 2. *We refer to domestic profit levels as normal profits. Let Extraordinary profits of FDI are the difference between FDI and domestic profits,*

$$\pi_t^{Extra} = \pi_t^{FDI} - \pi_t = \frac{\left(1-b_t^{FDI}\right)x_t}{\chi}.$$

Remark 1. *The labor market clearing equations, setting demand equal to supply, are:*

$$\xi_{1t}l_{1t} = L_1, \tag{7.17}$$

$$\xi_{2t}l_{2t} + \xi_t^{FDI}l_{2t}^{FDI} = L_2. \tag{7.18}$$

These two equations complete the instantaneous description of the economy. Note that it follows that employment levels can be expressed as functions of the sectoral measures ξ_{1t}, ξ_{2t}; using ratios (7.16),

$$l_{1t} = \frac{L_1}{\xi_{1t}}, \quad l_{2t} = \frac{L_2}{\xi_{2t} + \xi_t^{FDI}b_t^{FDI}}, \quad l_{2t}^{FDI} = \frac{b_t^{FDI}L_2}{\xi_{2t} + \xi_t^{FDI}b_t^{FDI}}. \tag{7.19}$$

Proposition 4. *International assignment of production. The sectoral measures ξ_t^{FDI}, ξ_{1t}, ξ_{2t} of domestic production and FDI depend on relative productivities*

and working populations as follows:

$$\begin{aligned} \xi_t^{FDI} &= \min\left[\frac{\lambda b_t}{\lambda b_t + b_t^{FDI}}, \bar{\xi}^{FDI}\right], \\ \xi_{1t} &= \frac{1-\left(1-b_t^{FDI}\right)\xi_t^{FDI}}{1+\lambda b_t}, \\ \xi_{2t} &= \frac{\lambda b_t - \left(b_t^{FDI}+\lambda b_t\right)\xi_t^{FDI}}{1+\lambda b_t}. \end{aligned} \tag{7.20}$$

Note that if Economy 2 is too small or backward, it will be dominated by FDI, that is, all of its labor will be employed by FDI. This occurs when its relative population, institutional and technological levels λ, q, a_t are low, satisfying

$$\lambda q^{\beta} a_t^{1-(1-\beta)(1-\alpha)} < \frac{\bar{\xi}^{FDI}}{1-\bar{\xi}^{FDI}}. \tag{7.21}$$

Economy 2 is dominated by FDI if its relative technological level satisfies

$$a_t \leq \bar{a}^{FDI}\left(\lambda, q, \bar{\xi}^{FDI}\right) \equiv \left(\frac{\bar{\xi}^{FDI}}{\lambda q^{\beta}\left(1-\bar{\xi}^{FDI}\right)}\right)^{\frac{1}{1-(1-\beta)(1-\alpha)}}. \tag{7.22}$$

Introduce the "FDI multiplier"

$$\Phi_t^{FDI} = \frac{1}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)} > 1. \tag{7.23}$$

These results can be written

$$\begin{aligned} l_{1t} &= \left(1+\lambda b_t\right)\Phi_t^{FDI} L_1 \\ l_{2t} &= \frac{\left(1+\lambda b_t\right)\Phi_t^{FDI} L_2}{\lambda b_t} \\ l_{2t}^{FDI} &= \frac{\left(1+\lambda b_t\right)\Phi_t^{FDI} b_t^{FDI} L_2}{\lambda b_t} \end{aligned} \tag{7.24}$$

$$\xi_{1t} = \frac{1}{\left(1+\lambda b_t\right)\Phi_t^{FDI}} \tag{7.25}$$

$$\xi_{2t} = \frac{\lambda b_t}{\left(1+\lambda b_t\right)\Phi_t^{FDI}} - b_t^{FDI}\xi_t^{FDI} \tag{7.26}$$

Proof. To solve for ξ_{1t} and ξ_{2t}, obtain

$$\xi_{1t}\lambda b_t = \xi_{2t} + b_t^{FDI}\xi_t^{FDI}$$

from (7.16) and (7.9), and solve as a simultaneous equation with (7.1). Expression Φ_t^{FDI} is introduced by substitution. The last inequality expresses that total FDI employment has to be less than L_2:

$$\begin{aligned} \xi_t^{FDI} l_{2t}^{FDI} &= \frac{\left(1+\lambda b_t\right)\Phi_t^{FDI} b_t^{FDI}\xi_t^{FDI} L_2}{\lambda b_t} \leq L_2 \\ &\Leftrightarrow \left(1+\lambda b_t\right)\Phi_t^{FDI} b_t^{FDI}\xi_t^{FDI} \leq \lambda b_t \\ &\Leftrightarrow \left(1+\lambda b_t\right) b_t^{FDI}\xi_t^{FDI} \leq \lambda b_t\left(1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)\right) \\ &\Leftrightarrow b_t^{FDI}\xi_t^{FDI} \leq \lambda b_t\left(1-\xi_t^{FDI}\right) \end{aligned}$$

This implies (7.20). It is equivalent to $a_t^{(1-\beta)(1-\alpha)}\xi_t^{FDI} \leq \lambda q^\beta a_t \left(1-\xi_t^{FDI}\right)$, which implies (7.21). □

7.3. **Aggregate Variables.** We give here some simplified expressions for aggregate variables. Recall that Gross Domestic Product is the aggregate of local production. In Economy 2 this includes what we have called domestic production as well as production by FDI. Gross National Product adds FDI profits to Economy 1's GDP and deducts them from Economy 2's GDP.

Proposition 5. *Expressions for aggregate variables. Aggregate domestic production in Economy 1 is*

$$Y_{1t}^{GDP} = \xi_{1t} y_{1t} = \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{1t} L_1. \tag{7.27}$$

Aggregate world product and aggregate sector expenditure have the same expression

$$Y_t^{World} \equiv x_t = \frac{1}{\xi_{1t}}\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} B_{1t}L_1 = \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} (1+\lambda b_t)\,\Phi_t^{FDI} B_{1t}L_1. \tag{7.28}$$

Hence also

$$Y_{2t}^{GDP} = (1-\xi_{1t})\,x_t = \left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} \left((1+\lambda b_t)\,\Phi_t^{FDI} - 1\right) B_{1t}L_1. \tag{7.29}$$

Aggregate profits and capital are

$$\begin{aligned} K_t &= \left(\frac{\alpha}{\chi r}\right)^{\frac{1}{1-\alpha}} (B_{1t}L_1 + B_{2t}L_2), \\ \Pi_t &= \left(\Phi_t^{FDI} - \tfrac{1}{\chi}\right)\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} (1+\lambda b_t)\, B_{1t}L_1 \end{aligned} \tag{7.30}$$

The interest rate can be written in terms of aggregate capital as follows:

$$r = \frac{\alpha}{\chi}\left(\frac{B_{1t}L_1 + B_{2t}L_2}{K_t}\right)^{1-\alpha}. \tag{7.31}$$

Aggregate profits can be written as a function of aggregate capital,

$$\Pi_t = \left(\Phi_t^{FDI} - \tfrac{1}{\chi}\right) K_t^\alpha\, (1+\lambda b_t)^{1-\alpha}\, (B_{1t}L_1)^{1-\alpha}. \tag{7.32}$$

Similarly aggregate FDI profits, as well as domestic and world products, can be expressed in terms of aggregate capital.

$$\begin{aligned} \Pi_t^{FDI} &= \frac{\xi_t^{FDI}\left(1-\chi^{-1}b_t^{FDI}\right)}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)} K_t^\alpha\, (1+\lambda b_t)^{1-\alpha}\, (B_{1t}L_1)^{1-\alpha}, \\ \Pi_t^{Extra} &= \frac{\chi^{-1}\xi_t^{FDI}\left(1-b_t^{FDI}\right)}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)} K_t^\alpha\, (1+\lambda b_t)^{1-\alpha}\, (B_{1t}L_1)^{1-\alpha}, \\ Y_t^{World} &= \Phi_t^{FDI} K_t^\alpha\, (1+\lambda b_t)^{1-\alpha}\, (B_{1t}L_1)^{1-\alpha}, \\ Y_{1t}^{GDP} &= K_t^\alpha\, (1+\lambda b_t)^{-\alpha}\, (B_{1t}L_1)^{1-\alpha}, \\ Y_{2t}^{GDP} &= \left((1+\lambda b_t)\,\Phi_t^{FDI} - 1\right) K_t^\alpha\, (1+\lambda b_t)^{-\alpha}\, (B_{1t}L_1)^{1-\alpha}. \end{aligned} \tag{7.33}$$

Since profits from FDI are part of Economy 1's national income,

$$\begin{aligned} Y_{1t}^{GNP} &= Y_{1t}^{GDP} + \Pi_t^{FDI} \\ &= \left(1 + (1+\lambda b_t)\frac{\xi_t^{FDI}\left(1-\chi^{-1}b_t^{FDI}\right)}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)}\right) K_t^{\alpha}\left(1+\lambda b_t\right)^{-\alpha}\left(B_{1t}L_1\right)^{1-\alpha}, \\ Y_{2t}^{GNP} &= Y_{2t}^{GDP} - \Pi_t^{FDI} \\ &= \left((1+\lambda b_t)\frac{1-\xi_t^{FDI}\left(1-\chi^{-1}b_t^{FDI}\right)}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)} - 1\right) K_t^{\alpha}\left(1+\lambda b_t\right)^{-\alpha}\left(B_{1t}L_1\right)^{1-\alpha} \end{aligned}$$

Alternatively

$$Y_{2t}^{GNP} = \left(1 - \left(1-\tfrac{1}{\chi}\right)\tfrac{b_t^{FDI}\xi_t^{FDI}(1+\lambda b_t)\Phi_t^{FDI}}{\lambda b_t}\right)\left(\tfrac{K_t}{B_{1t}L_1+B_{2t}L_2}\right)^{\alpha} B_{2t}L_2 \tag{7.34}$$

Proof. For (7.27) use (7.9). From this expression, (7.28) is obtained again using (7.9) and also (7.25). The expressions for sectoral expenditure and aggregate world product Y_t^{World} are the same since the total sectoral measure is 1. For (7.29) also use (7.25). Aggregate capital is:

$$\begin{aligned} K_t &= \xi_{1t}k_{1t} + \xi_{2t}k_{2t} + \xi_t^{FDI}k_{2t}^{FDI} \\ &= \frac{\alpha}{(1-\alpha)\,r}\left(\xi_{1t}w_{1t}l_{1t} + \xi_{2t}w_{2t}l_{2t} + \xi_t^{FDI}w_{2t}l_{2t}^{FDI}\right) \\ &= \frac{\alpha}{(1-\alpha)\,r}\left(w_{1t}L_1 + w_{2t}L_2\right). \end{aligned}$$

Now use (7.6). Using (7.14) and (7.15),

$$\begin{aligned} \Pi_t &= \xi_{1t}\pi_t + \xi_{2t}\pi_t + \xi_t^{FDI}\pi_t^{FDI} = \pi_t + \xi_t^{FDI}\left(\pi_t^{FDI} - \pi_t\right) \\ &= \left(1-\tfrac{1}{\chi}\right)x_t + \xi_t^{FDI}\tfrac{1}{\chi}\left(1-b_t^{FDI}\right)x_t \\ &= \left[1-\tfrac{1}{\chi}\left(1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)\right)\right]\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}\left(1+\lambda b_t\right)\Phi_t^{FDI}B_{1t}L_1 \\ &= \left[1-\tfrac{1}{\chi\Phi_t^{FDI}}\right]\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}\left(1+\lambda b_t\right)\Phi_t^{FDI}B_{1t}L_1 \end{aligned}$$

using (7.28) and (7.23), from which follows (7.30). Note

$$\begin{aligned} &\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}\left(1+\lambda b_t\right)B_{1t}L_1 = \\ &= \left(\tfrac{K_t}{B_{1t}L_1+B_{2t}L_2}\right)^{\alpha}\left(1+\lambda b_t\right)B_{1t}L_1 \\ &= \left(\tfrac{K_t}{B_{1t}L_1+B_{2t}L_2}\right)^{\alpha}\left(1+\lambda b_t\right)B_{1t}L_1 \\ &= K_t^{\alpha}\left(\tfrac{B_{1t}L_1}{B_{1t}L_1+B_{2t}L_2}\right)^{\alpha}\left(1+\lambda b_t\right)\left(B_{1t}L_1\right)^{1-\alpha} \\ &= K_t^{\alpha}\left(1+\lambda b_t\right)^{1-\alpha}\left(B_{1t}L_1\right)^{1-\alpha} \end{aligned}$$

Observe now that

$$\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}} = \left(\frac{K_t}{B_{1t}L_1+B_{2t}L_2}\right)^{\alpha},$$

and therefore

$$\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}(1+\lambda b_t)\,B_{1t}L_1 = K_t^{\alpha}\,(1+\lambda b_t)^{1-\alpha}\,(B_{1t}L_1)^{1-\alpha}\,. \tag{7.35}$$

Now (7.32) follows. Now consider aggregate FDI profits.

$$\begin{aligned}\Pi_t^{FDI} &= \xi_t^{FDI}\pi_t^{FDI} = \xi_t^{FDI}\left(1-\frac{b_t^{FDI}}{\chi}\right)x_t\\ &= \xi_t^{FDI}\left(1-\frac{b_t^{FDI}}{\chi}\right)\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}(1+\lambda b_t)\,\Phi_t^{FDI}B_{1t}L_1\\ &= \frac{\xi_t^{FDI}\left(1-b_t^{FDI}/\chi\right)}{1-\xi_t^{FDI}\left(1-b_t^{FDI}\right)}\left(\frac{\alpha}{\chi r}\right)^{\frac{\alpha}{1-\alpha}}(1+\lambda b_t)\,\Phi_t^{FDI}B_{1t}L_1.\end{aligned}$$

Using (7.35), (7.33) follows. the expression for Π_t^{Extra} is derived similarly, and the aggregate capital expression for Y_{jt}^{GDP} also uses (7.35). The expressions for the national products follow directly, using (7.23). For the alternative expression for Y_{2t}^{GNP}, observe using (7.12), (7.6) that

$$\begin{aligned}Y_{2t}^{GNP} &\equiv w_{2t}L_2 + K_{2t}r + \xi_{2t}\left(1-\frac{1}{\chi}\right)x_t\\ &= \left(L_2+(\chi-1)\,\xi_{2t}l_{2t}\right)\left(\frac{\alpha^{\alpha}}{\chi r^{\alpha}}\right)^{\frac{1}{1-\alpha}}B_{2t}\end{aligned}$$

where $\xi_{2t}l_{2t}$ is substituted using (7.24), (7.26) and $\left(\frac{\alpha^{\alpha}}{\chi r^{\alpha}}\right)^{\frac{1}{1-\alpha}}$ using (7.31). □

7.4. **Capital accumulation.**

7.4.1. *Myopic saving.* Recall we defined a subutility function C_t for consumption. Now we define capital as a good which results from the combination of a quantity $k_t(\eta)$ of goods in all sectors, yielding an amount K_t of capital according to:

$$\ln(K_t) = \int_0^1 \ln\left(k_t(\eta)\right)d\eta. \tag{7.36}$$

When a firm invests, it maximizes (7.36) just as the consumer maximizes (7.8), demanding the same expenditure of each good. Therefore the composition of demand remains unaltered. As we have seen, all prices are equal and therefore the quantities of capital inputs $k_t(\eta)$ demanded are also equal. Since prices are 1, a unit of capital is obtained by purchasing and combining a unit of each sector's good, at a unit cost, because

$$\ln(1) = \int_0^1 \ln(1)\,d\eta, \quad \int_0^1 p_t(\eta)k_t(\eta)d\eta = \int_0^1 1\times 1 d\eta = 1.$$

Suppose first that agents are myopic and decide on consumption and saving each instant according to the utility function

$$U_t = C_t^{1-\kappa}S_t^{\kappa}.$$

The utility function describes myopic agents with a preference for saving for the future. It is worth mentioning that this utility function is the continuous analogous of the altruistic utility function often used in discrete intergenerational models.

When U_t is maximized subject to an income Y_t, agents consume and save according to:

$$C_t = (1-\kappa)\, Y_t,\ S_t = \kappa Y_t.$$

7.4.2. *The Solow model for capital.* We have shown that optimization by our myopic agents generates the standard savings assumption in the Solow model. Now, we would ideally prefer to think of a situation where savings out of profits might be higher than savings out of labor. This would entail using more complex instantaneous utility functions in which consumption and savings decision might depend on income and might also be different between consumers and firms. This would entail keeping tab of income levels and income distributions, as well as property.

For simplicity we assume that, on average, a fixed proportion s^Y of aggregate world income Y_t^{World}, and a fixed additional proportion $s^\Pi \geq 0$ of extra profits Π_t^{Extra} are saved. Hence we obtain a Solow model for capital,

$$\begin{aligned} K_t' &= \left[s^Y + s^\Pi \chi^{-1} \xi_t^{FDI}\left(1-b_t^{FDI}\right)\right] \\ &\quad \times \Phi_t^{FDI} K_t^\alpha \left(1+\lambda b_t\right)^{1-\alpha} \left(B_{1t}L_1\right)^{1-\alpha} - \delta K_t. \end{aligned} \tag{7.37}$$

By contrast, under autarchy, represented by $\lambda = 0$, $\bar{\xi}^{FDI} = 0$, so $\Phi_t^{FDI} = 1$, $\xi_t^{FDI} = 0$, the national income and Solow model are given by

$$\begin{aligned} Y_{1t}^{Aut} &= K_t^\alpha \left(B_{1t}L_1\right)^{1-\alpha}, \\ K_t' &= s^Y K_t^\alpha \left(B_{1t}L_1\right)^{1-\alpha} - \delta K_t. \end{aligned}$$

Theorem 1. *Solow model without technological change. Equilibrium aggregate capital under 1) free trade and FDI and 2) autarchy are:*

$$K^* = \left(\frac{\left[s^Y + s^\Pi \chi^{-1} \xi_t^{FDI}\left(1-b_t^{FDI}\right)\right]\Phi_t^{FDI}}{\delta}\right)^{\frac{1}{1-\alpha}} \left(1+\lambda b_t\right)\left(B_{1t}L_1\right) \tag{7.38}$$

$$K^{Aut*} = \left(\frac{s^Y}{\delta}\right)^{\frac{1}{1-\alpha}} \left(B_{1t}L_1\right) \tag{7.39}$$

The corresponding equilibrium interest rates are:

$$\begin{aligned} r^* &= \frac{\alpha\delta}{\left(\chi s^Y + s^\Pi \xi_t^{FDI}\left(1-b_t^{FDI}\right)\right)\Phi_t^{FDI}}, \\ r^{Aut*} &= \frac{\alpha\delta}{\chi s^Y}. \end{aligned}$$

and satisfy

$$r^* < r^{Aut*}.$$

Proof. The steady state is obtained as usual. The expressions for the interest rates follows directly from (7.31) and (7.38), (7.39). The inequality follows from $\Phi_t^{FDI} > 1$, $\xi_t^{FDI}\left(1-b_t^{FDI}\right) > 0$. □

The difference in interest rates is larger the higher the FDI multiplier and the higher the savings on extra profits s^Π are. If Economy 1 and Economy 2 join together in globalization, the steady state interest rate will decrease. This would not happen in the absence of FDI. If the savings rate from extra profits is decreased,

for example through taxes, the difference in interest rates will decrease. The income can be used to increase the steady state capital level by increasing B_{1t} and B_{2t}.

7.5. **Technological change.**

7.5.1. *Innovation competition.* In this section we model technological change under infinitesimal foresight, because this yields a Solow-style model. We will construct an equilibrium for innovation competition under which the incumbent is forced to innovate by the presence of competition, and then remains as monopolist.

Over a time period Δt, the incumbent can invest $s_t A_{1t} \Delta t$ units of resources in R&D (or technological absorption) to obtain a technological level

$$A_{1t+\Delta t}^{1-\alpha} = A_{1t}^{1-\alpha} \left(1 + R\left(s_t\right) \Delta t\right),$$

where R is an innovation function that is increasing in s_t and has decreasing returns starting at infinity and tending eventually to zero, thus satisfying $R\left(0\right) = 0$, $R'\left(s_t\right) > 0$, $R''\left(s_t\right) < 0$ for $s_t \geq 0$ and $\lim_{s_t \to \infty} R'\left(s_t\right) = 0$. Multiplication of s_t by A_{1t} represents the fishing out effect.

Consider first an incumbent in Economy 1 that is not subject to competition. Because costs will be inversely proportional to $A_{1t}^{1-\alpha}$, her profit flow at time $t + \Delta t$ is:

$$\Pi_{t+\Delta t}\left(s_t\right) = \left(1 - \frac{B\Delta t}{\chi(1 + R(s_t))}\right) x_t - A_{1t} s_t \Delta t$$

According to expressions (7.14) and (7.15) for profits, B is 1 for domestic producers and b_t^{FDI} for FDI producers.

Remark 2. *The profit flow $\Pi_{t+\Delta t}\left(s_t\right)$ has a unique maximum at an investment rate $s_t = s^*\left(B\right)$ which is increasing in cost factor B. There is also a unique maximum level $s^{\max}$ beyond which innovation investment is not profitable.*

Proof. Observe that $\Pi'_{t+\Delta t}\left(s_t\right) = \frac{B x_t \Delta t}{\chi}(1 + R(s_t))^{-2} R'(s_t) - A_{1t}\Delta t$, from which it is easy to see $\Pi'\left(s_t\right) < 0$. The maximum profit flow at $t + \Delta t$ occurs when $(1 + R(s_t))^{-2} R'(s_t) = \frac{\chi A_{1t}}{B x_t}$. Since the LHS decreases from ∞ to 0 as s_t goes from 0 to ∞, and has negative derivative, $\Pi'_{t+\Delta t}\left(s_t\right)$ has a unique maximum $s^*\left(B\right)$ which is increasing in B (as well as dependent on market size). There is also a unique value $s^{\max} > s^*\left(B\right)$ at which $\Pi_{t+\Delta t}\left(s^{\max}\right) = 0$ and after which profits become negative. □

Corollary 2. *FDI innovators have less incentives to innovate than domestic innovators.*

Proof. Cost factor B for domestic innovators is 1, which is larger than $b_t^{FDI} = a_t^{(1-\beta)(1-\alpha)} < 1$, the FDI producers' cost factor. □

This conclusion is remarkable. Even though FDI producers have higher profits, they have lower innovation incentives, since they face lower costs. While this conlusion follows from very general principles, it nevertheless depends on the somewhat simple assumptions made herein about FDI production. For example, FDI producers might innovate to adapt their production to unskilled labor, to transportation, and so on.

For the sake of simplicity, we present a model in which FDI producers innovate at the same rate as domestic producers. This eliminates keeping track of a technological level for FDI. This can be obtained endogenously as follows.

Consider now innovation competition by the competititve fringe. Suppose the actions of the innovator are visible to its competitors, and suppose that given an expenditure level s_t there is a probability $P(s_t)$ that another innovator will invest any amount $s_{1t} > s_t$ units and win the competition race against the incumbent. Assume probability $P(s_t)$ is given by:

$$P(s_t) = \begin{cases} 0 & s_t \geq s_0 \\ \Psi > 0 & s_t < s_0 \end{cases}$$

We could let Ψ be decreasing in s_t but this will make no difference. For investment levels above s_0, the incumbent has an absolute advantage.

Proposition 6. *Suppose* $s^*\left(b_t^{FDI}\right) < s_0 < s^*(1)$. *Domestic innovators will choose the optimal level of innovation investment while FDI innovators will opt for* s_0. *For* $s_0 \in [s^*(1), s^{\max}]$, *both types of innovators will invest* s_0 *and obtain a rate of technological change of* $\frac{1}{1-\alpha}R(s_0)$.

For simplicity we therefore assume innovator competition is tough enough that domestic and FDI innovators invest at the same rate, $s_0 \in [s^*(1), s^{\max}]$.

7.5.2. *Technological change in the two economies.* We have shown conditions under which innovators with infinitesimal foresight choose a constant, Solow-style rate of technological change, given an innovation function. We now consider other factors affecting the rate of technological change, to obtain the following two-economy Solow-style model.[39]

$$\begin{aligned} \frac{A'_{1t}}{A_{1t}} &= q_1 g_1(a_t) + \theta_1 \xi_t^{FDI} \tau_1 \frac{\pi_t^{Extra}}{x_t}, \\ \frac{A'_{2t}}{A_{2t}} &= q_2 g_2(a_t) + \xi_t^{FDI}\left(\theta_{weak}^{FDI} + \theta_{strong}^{FDI} \tau_2 a_t^{-1}\right) \frac{\pi_t^{Extra}}{x_t}. \end{aligned}$$

Here

$$\begin{aligned} g_1(a_t) &= \gamma_0 - \gamma_1(1 - a_t) \\ g_2(a_t) &= \gamma_0 + \gamma_2(1 - a_t). \end{aligned}$$

The terms $q_j g_j(a_t)$ represent the rates of technological change for innovators operating at normal profit levels in a public goods context q_j.[40] We assume that $g_j(a_t)$ are functions of the relative technological level a_t to include the costless transfer of ideas. This is assumed to operate in both directions. In the case of Economy 1, the transfer will be larger the more advanced Economy 2 is, so $g_1(a_t)$ is an increasing function, which becomes more meaningfull as a_t approaches 1. In the case of Economy 2 $g_2(a_t)$ is a decreasing function in a_t, generating a larger transfer the larger the technological lag, and therefore a convergence effect, the *advantage of backwardness* (Gerschenkron, 1952). In the case of Economy 1, we allow positive externalities of FDI on technological change, although our previous results imply these are likely to be small. Specifically, we suppose FDI increases overall technological change in proportion to $\pi_t^{Extra}/x_t = \chi^{-1}\left(1 - b_t^{FDI}\right)$ and to

[39] Having shown that a Solow-style model of technological change can be microfundamented fundamented, it is pointless to write out the innovation functions R that yield these results.

[40] We do not include her innovation externalities that could result from the sectoral measures ξ_{1t}, ξ_{2t}, so as to keep the model simple. Thus some of the effects alloted here to publicly provided goods could result through other externalities.

the measure ξ_t^{FDI} of FDI sectors involved. In the case of Economy 2, FDI firms increase domestic technological change (a) through knowledge externalities and (b) through direct or indirect impacts on innovation. Both types of effects might be proportional either to A_1 (and therefore to the production flow produced by FDI) or to A_2. We refer to these as strong and weak FDI effects, with coefficients θ_{strong}^{FDI}, θ_{weak}^{FDI}. Some literature argues that FDI externalities depend on local levels of assets, and are therefore weak. Finally, τ_2 is a transfer variable representing some porportion of FDI profits dedicated to technological change. It could for example be the result of a value added tax policy.

Observe that $\gamma_0 - \gamma_1 > 0$ can be thought to represent the autarchic growth rate, without the higher resources available through the operation of comparative advantage and through closer contact between the two economies, as well as market size effects. In turn, γ_0 represents the free trade growth rate for the two economies, trading together when their technological levels are equal. Thus $\gamma_1 < \gamma_0$ represents the growth rate gain from free trade.

Remark 3. *The differential equation for the relative technological level a_t is*

$$\frac{a_t'}{a_t} = H(a_t) \equiv (q_2 - q_1)\gamma_0 + q_2\gamma_2(1 - a_t) + q_1\gamma_1(1 - a_t) + \left(\theta_{weak}^{FDI} + \theta_{strong}^{FDI}\tau_2 a_t^{-1} - \theta_1\tau_1\right)\frac{1 - a_t^{(1-\beta)(1-\alpha)}}{\chi}\xi_t^{FDI} \tag{7.40}$$

This dynamical system allows for several types of steady states, even between economies with identical parameteres. For the next theorem, we explore different types of steady states that can exist. We fix $\tau_1, \tau_2 \in (0, 1)$ to let qualitative variations be represented by θ_1, θ_{weak}^{FDI}, θ_{strong}^{FDI}.

Theorem 2. *Multiple steady states in technological change. The dynamical system for the relative technological level a_t can have different types of steady states and catch up. Identical economies need not converge absolutely.*

(1) For economies with identical parameters, $a^* = 1$ is a steady state unless FDI externalities in Economy 1 are strong enough, in which case a lagging economy with parameters identical to the leading economy will converge to a steady state $a^* < 1$.

(2) Divergence in growth rates. Consider the case when a_t is small enough, so that the economy is dominated by FDI. Economy 2 will diverge in growth rates if its provision of public services is sufficiently poor, convergence is sufficiently low, there are no strong FDI effects and the weak effects are sufficiently low, namely

$$H(0) = q_1(\gamma_0 - \gamma_1) + \theta_1\tau_1\chi^{-1}\xi_t^{FDI} - \left\{q_2(\gamma_0 + \gamma_2) + \theta_{weak}^{FDI}\chi^{-1}\xi_t^{FDI}\right\} < 0$$

Then $a^* = 0$ is a steady state, and the equilibrium growth rate of Economy 2 is lower than Economy 1's by $|H(0)|$. When Economy 2 diverges in growth rates, for Economy 1 the steady state is equivalent to autarky.

(3) Divergence in levels.

(3.1) Example. Suppose (a) that convergence and FDI effects are high enough that if initially Economy 2 is not dominated by FDI, it will not become so, that is, $H\left(\bar{a}^{FDI}\left(\lambda, q, \bar{\xi}^{FDI}\right)\right) > 0$, see (7.22), and (b) that Economy 2 is worse in its provision of public goods than Economy 1, so

$$H(1) = (q_2 - q_1)\gamma_0 < 0.$$

Then a unique stable steady state $a^* \in (\bar{a}^{FDI}\left(\lambda, q, \bar{\xi}^{FDI}\right), 1)$ *exists, for which Economy 2 is not dominated by FDI.*

(3.2) It is possible for an economy with identical parameters to the leading economy to have a positive steady state that is dominated by FDI from Economy 1.

(3.3) At a positive steady state $a^* < 1$*, Economy 2 grows at the same rate as Economy 1 but experiences a permanent technological lag. The world growth rate rises to* $q_1 g(1) + \tau_1 \theta_1 \xi_t^{FDI} \pi_t^{Extra}/x_t$*. Due to the presence of FDI, profits become a higher component of income.*

(4) Catch up. If Economy 2 has better institutions then Economy 1, it can overtake it and become the leader.

(5) Under strong FDI effects, there is no divergence in growth rates.

Proof. (1) Given two economies with identical parameters, it is clear that $H(1) = 0$. However, if

$$H'(1) = -q_2\gamma_2 - q_1\gamma_1 - \left(\theta_{weak}^{FDI} + \tau_2\theta_{strong}^{FDI} - \theta_1\tau_1\right)(1-\beta)(1-\alpha)\frac{1}{\chi}\xi_t^{FDI}$$

is positive, as occurs if θ_1 is large enough, and Economy 2 initially lags behind Economy 1, with $a_0 < 1$, a_t will converge to a steady state value $a^* < 1$.

(2) Observe that when there are no strong FDI effects

$$\lim_{a_t \to 0} H(a_t) = (q_2 - q_1)\gamma_0 + q_2\gamma_2 + q_1\gamma_1 + \left(\theta_{weak}^{FDI} - \theta_1\tau_1\right)\frac{1}{\chi}\xi_t^{FDI}.$$

If this is negative then $a^* = 0$ is a steady state. As $a_t \to 0$, $\xi_t^{FDI} \to 0$, $\xi_{1t} \to 0$ and $\xi_{2t} \to 0$. The equation for technological change for Economy 1 tends to its autarkic version $\frac{A'_{1t}}{A_{1t}} = q_1 g(1)$.

(3.1) On the interval $(\bar{a}^{FDI}\left(\lambda, q, \bar{\xi}^{FDI}\right), 1)$ $H(a_t)$ is concave, has an initial positive value, and a negative final value. Therefore equation $H(a^*) = 0$ has a unique solution.

(3.2) In the case of identical parameters, $\lim_{a_t \to 0} H(a_t) = q_2\gamma_2 + q_1\gamma_1 > 0$. Now $\lambda = q = 1$ so $\bar{a}^{FDI} = \left(\bar{\xi}^{FDI}/\left(1 - \bar{\xi}^{FDI}\right)\right)^{\frac{1}{1-(1-\beta)(1-\alpha)}}$. For θ_1 large enough (it helps if θ_{weak}^{FDI}, θ_{strong}^{FDI} are small) $H\left(\bar{a}^{FDI}\right) < 0$.

(4)

$$\lim_{a_t \to 1} H(a_t) = (q_2 - q_1)\gamma_0$$

If this is positive and initial a_t is high enough, Economy 2 overtakes Economy 1.

(5) In this case $\lim_{a_t \to 0} H(a_t) = \infty$. □

Corollary 3. *Any harmonized tax proposal generating technological change in Economy 2 in proportion to FDI profits eliminates divergence in levels, generating balanced growth in the world economy.*

Proof. The hypothesis implies harmonized taxes generate strong FDI effects. □

7.6. **The full model.** We now consider the joint dynamics of capital and technology. Define first, for any variable X_t the deflacted "per effective unit of labor" variable $\hat{X}_t = X_t/(B_{1t}L_1 + B_{2t}L_2)$, typically used in the Solow model with technological change.

Proposition 7. *Expressed in terms of per effective labor units, the interest rate is*

$$r = \frac{\alpha}{\chi}\hat{K}_t^{\alpha-1}. \tag{7.41}$$

Proof. (7.41) follows from (7.31). □

We turn now to the capital accumulation equation, substracting taxes τ_1, τ_2 levied on FDI profits.

Lemma 1. *The deflacted differential equation for capital accumulation is*

$$\frac{\hat{K}_t'}{\hat{K}_t} = \left[s^Y + (1-\tau_1-\tau_2)\, s^{\Pi}\chi^{-1}\xi_t^{FDI}\left(1-b_t^{FDI}\right)\right]\Phi_t^{FDI}\hat{K}_t^{\alpha-1} - \delta - \hat{g}\left(a_t\right) \tag{7.42}$$

where

$$\hat{g}\left(a_t\right) = \frac{q_1 g\left(1\right) + \lambda q^{\beta} a_t q_2 g\left(a_t\right) + \left(\theta_1 \frac{1-a_t^{(1-\beta)(1-\alpha)}}{\chi} + \lambda q^{\beta}\theta\left(a_t\right)\right)\xi_t^{FDI}}{1+\lambda q^{\beta} a_t}$$

Proof. Differentiating the quotient defining $\hat{K}_t$,

$$\hat{K}_t' = \frac{\left[s^Y+(1-\tau_1-\tau_2)s^{\Pi}\chi^{-1}\xi_t^{FDI}\left(1-b_t^{FDI}\right)\right]\Phi_t^{FDI}K_t^{\alpha}(1+\lambda b_t)^{1-\alpha}(B_{1t}L_1)^{1-\alpha}-\delta K_t}{B_{1t}L_1+B_{2t}L_2} - \hat{g}\left(a_t\right)\hat{K}_t$$

where

$$\begin{aligned}
\hat{g}\left(a_t\right) &= \frac{\left(B_{1t}L_1+B_{2t}L_2\right)'}{B_{1t}L_1+B_{2t}L_2} \\
&= \left[q_1 g_1\left(a_t\right) + \theta_1\xi_t^{FDI}\tau_1\frac{\pi_t^{Extra}}{x_t}\right]\frac{1}{1+\lambda b_t} \\
&\quad + \left[q_2 g_2\left(a_t\right) + \xi_t^{FDI}\left(\theta_{weak}^{FDI} + \theta_{strong}^{FDI}\tau_2 a_t^{-1}\right)\frac{\pi_t^{Extra}}{x_t}\right]\frac{\lambda b_t}{1+\lambda b_t}.
\end{aligned}$$

□

We now show conditions under which globalization leads to lower interest rates due to the presence of FDI.

Theorem 3. *Lower interest rates under globalization. Suppose Economy 2 has a steady state a^* that diverges only in levels. Under globalization, the steady state value for deflacted aggregate capital is:*

$$\hat{K}^* = \left(\frac{\left[s^Y + (1-\tau_1-\tau_2)\, s^{\Pi}\chi^{-1}\xi_t^{FDI}\left(1-b_t^{FDI}\right)\right]\Phi_t^{FDI}}{\delta+\hat{g}\left(a^*\right)}\right)^{\frac{1}{1-\alpha}},$$

where

$$\hat{g}\left(a^*\right) = q_1 g_1\left(a^*\right) + \theta_1\xi_t^{FDI}\tau_1\chi^{-1}\left(1-\left(a^*\right)^{(1-\beta)(1-\alpha)}\right),$$

while under autarky it is

$$\hat{K}^{A*} = \left(\frac{s^Y}{\delta+q_1 g_1\left(0\right)}\right)^{\frac{1}{1-\alpha}}.$$

The steady state interest rate is lower under globalization than under autarchy when the contribution of FDI to new technologies is less than its contribution to capital

formation, for example if the growth rate gain from free trade is less than depreciation, that is, $\gamma_1 < \delta$, and

$$\frac{\theta_1 \tau_1}{\delta + q_1 g_1(0)} < \frac{(1-\tau_1-\tau_2)\, s^{\Pi}}{s^{Y}}.$$

Proof. At the steady state a^*, $\frac{A'_{1t}}{A_{1t}} = \frac{A'_{2t}}{A_{2t}}$, so either of the two rates of technological change serves as deflaction term $\hat{g}(a^*)$. Writing * on the steady state values, and choosing $\frac{A'_{1t}}{A_{1t}}$,

$$\hat{g}(a^*) = q_1 g_1(a^*) + \theta_1 \xi^{FDI*} \tau_1 \chi^{-1} \left(1 - (a^*)^{(1-\beta)(1-\alpha)}\right),$$

The interest rate diminishes under globalization if

$$\left[1 + \frac{s^{\Pi} \chi^{-1} \xi^{FDI*} \left(1 - b^{FDI*}\right)}{s^{Y}}\right] \Phi^{FDI*} > 1 + \frac{\gamma_1 a^* + \theta_1 \tau_1 \chi^{-1} \xi^{FDI*} \left(1 - b^{FDI*}\right)}{\delta + q_1 g_1(0)}.$$

Assuming $\gamma_1 < \delta$, since $\Phi_t^{FDI} > 1$, (**??**) is implied by

$$\begin{aligned} &\Leftarrow \quad \frac{s^{\Pi} \chi^{-1} \xi^{FDI*} \left(1 - b^{FDI*}\right)}{s^{Y}} > \frac{\theta_1 \chi^{-1} \xi^{FDI*} \left(1 - b^{FDI*}\right)}{\delta + q_1 g_1(0)} \\ &\Leftarrow \quad \frac{(1-\tau_1-\tau_2)\, s^{\Pi}}{s^{Y}} > \frac{\tau_1 \theta_1}{\delta + q_1 g_1(0)}. \end{aligned}$$

□

Corollary 4. *When the innovation externalities of cheap-factor-seeking FDI are small in Economy 1, and the growth rate gain from free trade is less than depreciation, that is, $\gamma_1 < \delta$, then the interest rate under globalization is lower than under autarchy, $r^* < r^{A*}$. Moreover, taxes levied on FDI profits increase the interest rate (making the financial system more stable).*

Proof. In this case $\theta_1 = 0$. Apply Theorem (3). □

7.7. **Harmonized Taxes for Economic Development.** We have already seen that a harmonized tax proposal generating technological change in Economy 2 will generate balanced growth in the world economy as well as increase the interst rate, tending to stabilize the financial system. We now show other benefits such a policy might have through funding publicly provided goods and through enhancing technological change. In what follows recall that both technology transfer from Economy 2 to Economy 1 and the externalities of cheap-factor-seeking FDI on innovation in Economy 1 are weak effects.

Theorem 4. *Any harmonized tax proposal resulting in:*

(1) A rise in the supply of publicly provided goods in Economy 2, or an increase in the strong effects of FDI, raises the steady state a^* of Economy 2.

If technology transfer from Economy 2 to Economy 1 is stronger than the externalities of cheap-factor-seeking FDI on innovation in Economy 1, as a^* rises, so does the world growth rate.

(2) A rise in the supply of publicly provided goods in Economy 1, or an increase in FDI externalities on research in Economy 1, will diminish the steady state a^* of Economy 2.

The impact on the growth rate of Economy 1 will be positive unless technology transfer from Economy 2 to Economy 1 is sufficiently high.

Proof. (1) $\frac{da^*}{dq_2} > 0$ because $\frac{dH(a_t)}{dq_2} > 0$. $\frac{da^*}{d\tau_2} > 0$ because $\frac{dH(a_t)}{d\tau_2} > 0$. (2) $\frac{da^*}{dq_1} < 0$ because $\frac{dH(a_t)}{dq_1} < 0$. $\frac{da^*}{d\tau_1} < 0$ because $\frac{dH(a_t)}{d\tau_1} > 0$. Observe also that $\frac{\partial \hat{g}(a^*)}{d\theta_1} > 0$, while $\frac{\partial \hat{g}(a^*)}{\partial q_1} = \frac{dg_1(a^*)}{da^*}\frac{da^*}{dq_1} < 0$, because $\frac{dg_1(a^*)}{da^*} > 0$ and $\frac{da^*}{dq_1} < 0$. □

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