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Development and Underdevelopment in the Globalizing Economy

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Abstract

A Schumpeterian (technological) theory of development and underdevelopment in an open global economy with technology transfer, trade and investment is presented. While free trade provides a powerful force for convergence, foreign direct investment (FDI), whose global product surpasses trade volume, may counteract that force. While free trade generates (through access to world markets) powerful incentives for production and innovation that may result in the updating of technologically dependent countries, foreign direct investment results in asymmetric incentives favoring the technological leaders, which may be strong enough to induce persistently unequal and even divergent equilibria. Whereas incentivized by cheap labor or market-seeking, foreign investment provides leading countries' innovators with lower salaries, higher profits, and consequently greater incentives for innovation. On the other hand, its presence in technologically dependent countries inhibits their potential for innovation (up to the extreme of eliminating it, as in the banana republic), counteracting its possible benefits.

Resumen

Se presenta una teoría Schumpeteriana (tecnológica) del Desarrollo y del Subdesarrollo en el contexto de una economía globalizada y abierta, que toma en cuenta el comercio, la inversión y la transferencia tecnológica. El libre comercio puede generar poderosas fuerzas económicas hacia la convergencia. Sin embargo la inversión extranjera directa, cuyo producto global es mayor al volumen del comercio, puede contrarrestar estas fuerzas. Mientras que el libre comercio genera a través del acceso a los mercados mundiales fuertes incentivos a la producción y la innovación, cuyo resultado puede ser la actualización de los países tecnológicamente dependientes, la inversión extranjera directa genera incentivos asimétricos que favorecen a los líderes tecnológicos, que pueden ser lo suficientemente fuertes para inducir equilibrios persistentemente desiguales e incluso divergentes. Ya sea que esté incentivada por la mano de obra barata o por la busca de mercados, la inversión extranjera provee a los innovadores de los países líderes salarios más bajos, ganancias más altas, y consecuentemente mayores incentivos para la innovación. En cambio, su presencia en los países tecnológicamente dependientes inhibe su potencial de innovación (al extremo de eliminarlo, como en la república bananera), contrarrestando sus posibles beneficios.

1. Introduction

This paper presents a Schumpeterian theory of *development* and *underdevelopment* in an open global economy with technology transfer, trade and foreign investment. In this context, which has characterized globalization both in the last few decades and in the historical long-term, unequal or divergent technological levels may persist between economies differing only in their relative status.

Most theories of both economic growth and trade imply that free trade and investment across countries will lead to equalization in growth rates and productivity levels. However, these predictions bear fruit unevenly. On the one hand, trade has been associated with the emergence of industrialization and modern growth in Britain, Western Europe and North America since its origins; with convergence episodes such as the development of Japan and the Asian tigers; with rapid convergence in Europe in the second half of the 20th Century; and with China's recent growth. On the other, in the very context of world trade and increasing globalization in which economic growth originated, a great divergence of incomes has taken place,[1] characterized by large technological differences across countries.[2] The underdeveloped world has been left behind. The process of divergence has continued through the second half of the 20th Century.[3] For whole blocks of countries, recent policies for globalization, liberalizing trade and investment, have been far less successful than economists had expected in light of the theory. This unequal pattern of effects that trade and investment have on economic growth can be account for in terms of club-convergence,[4] modelling the concepts of development and underdevelopment as steady states.

The first step towards our Schumpeterian framework puts together the arguments for convergence into a basic model incorporating trade. I show that in the autarchic and free commerce regimes,[5] so long as innovation competition is

[1] Pritchett (1997) estimates that the proportional gap in per-capita GDP between the richest and poorest countries worsened by a factor of five between 1870 and 1990. Similarly, according to Maddison (2001) this gap grew from 3 in 1820 to 19 in 1998.

[2] A large number of empirical studies attribute cross-country differences in per-capita GDP to differences in productivity (Easterly and Levine, 2001; Klenow and Rodríguez-Clare, 1997; Knight, Loayza and Villanueva, 1993; Islam, 1995; Caselli, Esquivel and Lefort, 1996; Prescott, 1998; Hall and Jones, 1999; Feyrer, 2001).

[3] The proportional per-capita income gap between Mayer-Foulkes' (2002) richest and poorest convergence groups grew by a factor of 2.6 between 1960 and 1995, and between Maddison's (2001) richest and poorest groups by a factor of 1.75 between 1950 and 1998.

[4] (Baumol, 1986; Durlauf and Johnson, 1995; Quah, 1993, 1997; Mayer-Foulkes, 2002, 2003.)

[5] Free commerce refers to the free trade of domestically produced goods, excluding foreign

balanced, identical countries will converge. The basic mechanism works as follows. Free commerce defines a "level playing field" between countries, making home wages proportional to home technological levels. Innovation in both lagging and leading countries, broadly understood to include technological adoption, is costly and responds to the same incentives for world profits. However, innovation investment aimed at achieving proportional productivity jumps, which in principle are proportionally costly,[6] obtains higher than proportional returns in lagging countries, because of their access to the advanced contemporary knowledge of the leading countries (technology transfer). This mechanism, Gerschenkron's (1952) *advantage of backwardness* in technological change, leads to convergence. In this limited context only country-specific differences in size, institutions and other characteristics will lead to persistent inequality and divergence. Free trade with a large partner will provide powerful incentives for innovation that can lead to increased growth and convergence.[7]

Trade has played a major role in modern economic growth since its origins. It forms a major strand in Maddison's (2001) description of the economic ascension of Western Europe through Venice, Portugal, the Netherlands and Britain, from the year 1000 to the present. Cotton exports in late 18th and early 19th Century England, widely recognized as the Industrial Revolution's leading sector, rose from 6% of total British exports in 1784-6 to a peak of 48.5% in 1834-6 (Chapman, 1999). The growth of this sector and the incentives for its increased productivity were directly linked with imports of cheap raw materials from India at this initial juncture of the Great Divergence (Broadberry and Gupta, 2005). More recently, the rapid growth of Germany, Israel, Cyprus, Spain, Portugal, Malta, Ireland and Iceland were intimately linked with trade. More spectacularly, the development of Japan and the East Asian countries was also inextricably linked with trade. I discuss below why recent convergence episodes from relatively lower income levels required policies promoting industrial coordination and infant industry to access the benefits of trade and realize the advantage of backwardness.

The second step of our framework incorporates not just trade, but also mechanisms generating *asymmetric innovation incentives* favoring the leading economies and generating persistent inequality and divergence. I mainly consider labor- and

investment. "Free Trade" has included this latter ingredient favoring leading countries (see below) since its origins. Note that commerce is an essential condition for FDI, unless all profits are to be exported in kind.

[6]This is the *fishing out* effect.

[7]Convergence here is absolute convergence or catch-up.

market-seeking foreign direct investment (FDI). A distinguishing feature of FDI is that its profits constitute incentives for innovation for the original investors, unlike credit or other financial (indirect) investments. Labor-seeking FDI allows leading country innovators to take advantage of lower wages in lagging countries. This yields supernormal innovation profits for leading countries only, undermining the "level playing field" and counteracting convergence. It also introduces an asymmetrical element in innovation competition, because firms performing FDI can afford higher wages than their local competitors, and can therefore threaten to price them out. This leads to *innovation crowding out.* I show that if technological spillovers from FDI are not too high and depend on the local technological level, as empirical studies have shown,[8] then multiple steady states will arise between identical countries. Thus, persistent inequality and divergence are possible, independently of institutional, geographic or other differences between countries.

Market-seeking FDI occurs when products must be sold where they are produced. Leading country innovators can produce in lagging countries and enjoy higher profits than at home, because of the lower wages, while innovators from countries lagging too far behind do not have the technological level to set up business in leading countries because of their high wages. For this class of goods, *unequal innovation incentives* result. Only leading countries can enjoy world profits when they innovate. Again, if technological spillovers from FDI are not too high, multiple steady states arise.

Two additional asymmetrical mechanisms will be formally analyzed.. The first is the *colonial diktat*, the typical trade monopoly conditions imposed by colonial powers on their colonies so as to provide raw materials and to prevent industrial competition from the colony (Bairoch, 1997). These conditions also imply persistent inequality and divergence between identical countries, and are enough to explain the emergence of underdevelopment. The second is the need for *NIC-style policies.* These may be indispensable in the contemporary period to access the benefits of trade and realize Gerschenkron's (1952) advantage of backwardness.

The presence of asymmetric incentives to innovation linked with trade and investment explain why both Britain and the US espoused "Free Trade" only

[8]Determinants of the intensity of FDI spillovers include: a sufficiently qualified labor force (Borensztein et al., 1998; Blonigen and Wang, 2004), not too large a technological gap (De Mello, 1997), a sufficient level of economic development (Blomström et al., 1994; Mayer and Nunnenkamp, 2005), sufficient financial development (Alfaro et al., 2001) and openness to trade (Balasubramanyam et al., 1996).

after they gained industrial supremacy.[9]

The Schumpeterian analysis presented here builds on a series of papers first introducing endogenous technological change in the theory of economic growth (Aghion and Howitt, 1988, 1992), then showing that technological transfer can induce convergence (Howitt, 2000) and going on to address problems of development including divergence: 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. Convergence clubs arise when differences in relative technological levels result in sufficiently strong asymmetric incentives for innovation. This explains underdevelopment *without assuming increasing returns.*

By incluiding FDI, the model goes beyond much of the theoretical analysis of the impact of trade on innovation and economic growth (Helpman, 1993; Eaton, Gutierrez, and Kortum, 1998; Eaton and Kortum, 2001, 2003, 2004). Rodriguez and Rodrik (1999) "find little evidence that open trade policies — ... lower ... barriers to trade — are significantly associated with economic growth". In his survey on international technology diffusion Keller (2004) finds international diffusion neither inevitable nor automatic, requiring domestic investments.

The model of development and underdevelopment assumes, as a stylized fact, that foreign direct investment has played a substantial role in international economic exchange, in close association with trade. To give empirical evidence for this assumption, I summarize some of the main features of globalization.

The process of globalization is divided by historians into two periods. The "First Great Age of Globalization" proceeded during the 19th and early 20th Century. Great Britain became its undisputed champion. With the advent of steam engine based manufacturing, Great Britain turned to free trade for obtaining raw

[9] "... the decision, on the part of Great Britain [with the repeal of the Corn Laws in 1846], to abandon ... colonial policy ... in favor of free-trade, should be understood as resulting from (i) a technology shock, (ii) the escalating cost of imperial wars, and (iii) the emergence of British transnational corporations. The steam engine rendered Great Britain's 18th century colonial empire redundant" (Beaudreau, 2004).

"US opposition to free trade, a staple of 19th and early 20th century ... foreign policy, metamorphosed itself into unwavering support from 1934 on [when Roosevelt signed the Reciprocal Trade Agreements Act]. The latter, like in the United Kingdom a century earlier, was founded on industrial supremacy, specifically on electric power-based mass production, which ... contributed to ... the birth of American industrial supremacy" (Bseaudreau, 2004).

materials and to sell its industrial products. Free trade became a more efficient policy for enrichment than colonialism (Beaudreau, 2004; Semmel, 1970). Two main mechanisms exploited the technological asymmetry between Great Britain and its colonies. The first, described more fully and modelled below, was the imposition of the colonial diktat. The second was the presence of large scale FDI, a major actor by the end of the 19th Century.[10] Investments in the colonial and dependent countries were a source of super profits, due to extremely cheap labor and raw materials. In his 1916 *Imperialism the Highest Stage of Capitalism*, Lenin criticized the vast accumulations of capital invested abroad at a far higher rate of return than in the home country. British assets abroad amounted to between 124 and 180% of its GDP in 1914. Taking British investment as a whole, between 1865 and 1914, approximately as much went to underdeveloped Africa, Asia, and Latin America (29.6%) as to the UK itself (31.8%) (Ferguson, 2003). Svedberg (1978) estimates that some 44 to 60% of the $19 billion of accumulated investment in developing countries in 1913-14 consisted of foreign direct investment.

The process of globalization was broken between 1914 and 1945 by the two world wars and the global depression, as well as a change in hegemony. A second stage of globalization emerged in the post-war period, headed by the United States. By 1960, the US owned almost half of the world's outward stock of FDI. Between 1950 and 1970, the stock of US manufacturing direct investment in Europe increased almost fifteen fold, while between 1970 and 1993 both US direct investment abroad and direct investment in the US increased fivefold (Graham, 1995). Foreign investment may be a stronger force for globalization then trade. All modern "free trade" agreements are agreements for free commerce *and* investment, allowing for the full scope of globalization to proceed. FDI has grown enormously since the 1980's.[11] Worldwide outflows have increased nearly 29% a year on average from 1983 to 1998, three times the growth of world exports. Even so, FDI has not reached the relative levels that characterized the first period of globalization. US. direct investment position abroad was about 13.6% of GDP in 2001,[12] much less than the corresponding British position in 1914. The following figures give a rough idea of the current relative importance of trade and FDI.

[10] The East India Company was chartered in London in 1600. By 1899 giant corporations such as the United Fruit Company controlled 90 per cent of US banana imports; Royal Dutch/Shell accounted in 1914 for 20 per cent of Russia's total oil production. Standard Oil of New Jersey, Singer, International Harvester, Western Electric, and by 1914, Ford Motor Company had major producing facilities outside the United States (Beaudreau, 2004).

[11] Data on FDI from UNCTAD (1999) unless stated otherwise.

[12] US Bureau of Economic Analysis data on a historical-cost basis.

Aggregate world exports amounted to US $7 trillion, while aggregate sales from foreign affiliates of transnational corporations (TNCs) amounted to US $11 trillion.[13] Two thirds of world trade is TNC-related. Intra-firm trade alone amounts to one third. A quarter of global output is produced by TNCs , one third of it in host countries. Approximately 26.3% of US FDI in 2000 and of global FDI in 1998[14] flowed to the underdeveloped world, where approximately 21.2% of world income was generated in 1999.[15] On the other hand, most R&D is undertaken by TNCs in the home or in developed countries.

Foreign direct investment has been a salient economic feature since the advent of trade and industrialization. Production networks form an important component of international exchange and globalization, as stressed by Beaudreau (2004). What is shown in this paper is that the resulting asymmetric incentives for innovation generate persistent inequality and divergence, that is, *underdevelopment.*

Our model adds two elements to single-economy models explaining the emergence from stagnation to modern economic growth, such as Galor and Weil (2000) and Galor and Moav (2002). The first is the crucial role of trade in raising the incentives for technological change and triggering economic growth. The second is the simultaneous emergence of development and underdevelopment.

The model shows the existence of two types of lower steady states. The lowest type represent lagging economies with lower growth rates than the leading economy, accounting for long-term divergence and for contemporary semi-stagnant economies, as in Sub Saharan Africa. Any policy improving the innovation rate, either directly or indirectly, will have growth effects. Middle steady state economies maintain a fixed relative lag in relation to leading countries, policy improvements yielding level effects. These explain a not sufficiently well-recognized stylized fact, the persistence of middle income levels. For example, the average per-capita

[13]Today, TNC's are truly huge. Quoting Anderson and Cavanagh (2000), "Of the 100 largest economies in the world, 51 are now global corporations; only 49 are countries." "The combined sales of the world's Top 200 corporations are far greater than a quarter of the world's economic activity." "The Top 200 corporations' combined sales are bigger than the combined economies of all countries minus the biggest 9; that is, they surpass the combined economies of 182 countries." TNC's have spread their activities widely across the globe. For example, the Swiss electrical engineering giant ABB has facilities in more than 100 nations. Royal Dutch/Shell has offices in 64 countries and refines in 34. Cargill, the largest US grain company, operates in 59 countries with 105,000 employees. ICI, Britain's leading chemical company, employs 36,000 people in 55 countries at 200 sites. (Data from the companies' web pages).

[14]The proportions of FDI outflows due to Western Europe, the US and Japan are 68.3, 22.3, and 4.0% (UNCTAD, 1999).

[15]Author's calculation from the World Bank database.

income relative to the US of 19 Latin American countries actually decreased between 1960 and 1999 from 0.25 to 0.20.[16] The relative level 0.20 represents a lag of around 80 years to the US, assuming what would seem an impossible catch up rate of 2% per year *above* the US growth rate. The importance of this middle income persistence tends to be neglected. It is believed that, since these countries grew at an average rate of 1.5% instead of 2.1%, it must be just a matter of fine tuning to get at least parallel growth, which is deemed to be a sufficient objective. The point, however, is that if a trap is maintaining the level difference, or the divergence, unlocking it would lead to miracle growth and enormous welfare gains. Ignoring it, on the contrary, may doom economic policies.

"The acceleration and then deceleration of East Asian growth is one of the mega-events of the 20th Century", suggesting that "for all developing economies, ... 'fully developed' status is within reach". This remark contextualizes Wan's (2004) detailed comparative analysis of East Asian growth experiences. His benchmark catch-up path includes a two-decade period of growth rates above 5%, explicitly understood as a transition to a higher steady state. Thus, the experiences of Japan, Korea, Taiwan, Hong Kong and Singapore constitute strong empirical evidence that development and underdevelopment are distinct steady states. The policies these countries applied throw light on the barriers they surmounted and the economic forces they harnessed. Japan and Korea, the largest countries,[17] concentrated on the creation of large industrial firms with scale economies. They used trade to integrate with the US production chain and were careful to gain technological transfer. Both avoided depending on FDI and promoted innovation rather than imitation, attaining dominance in the supply of new product lines. Japan depended on domestic saving. Some separation in government economic powers helped it to maintain efficiency in the support of carefully selected and changing infant industries. Korea was more authoritarian and more dependent on foreign saving, leading to some inefficiencies and financial instabilities. Taiwan concentrated on small and medium enterprises subcontracting from FDI regulated for an emphasis on technology transfer, integrating with the Japan-US production chain. Backward integration with technological absorption was closely promoted. In effect the local portion of what would be FDI, as well as the backward link-

[16]Of the 19 countries for which the World Bank database has relevant data, the relative position of Argentina, Belize, Bolivia, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Jamaica, Paraguay, Peru, Trinidad and Tobago, Uruguay and Venezuela worsened, while that of Brazil, Dominican Republic, Mexico and Panama advanced slightly.

[17]In 1999 the East Asian populations were, in millions: Japan, 126.6; Korean Republic, 46.8; Taiwan, 21.9; Hong Kong, 6.9; Singapore, 3.2.

ages, were locally owned. This form of 'subcontracted' FDI transfers innovation incentives to the local firms. In Japan, Korea and Taiwan, reliance on FDI was avoided. Cheap labor favored and even subsidized local firms rather than FDI.

Hong Kong's manufacturing growth was triggered by trade, itself driven by natural advantages including Hong Kong's position as an outlet for China and its well located harbor.. Cheap food imports from China also played a role. Singapore, the smallest of these countries, is an exception in that its economic policy was to use low wages and taxes, and an excellent location, to attract FDI. It relies on an authoritarian regime including 'bonded scholars' to keep its human capital cheap, with income rising on the basis of human capital accumulation.

In Japan, Korea, Taiwan and Hong Kong, specific policies or natural advantages were indispensable to harness trade to drive capital accumulation and technology transfer. Realizing Gerschenkron's (1952) advantage of backwardness may be subject to barriers requiring the application of public policies to surmount.

To highlight the plausibility of innovation crowding out and unequal innovation incentives due to FDI, world motor vehicle production and consumption in 1998 is examined (Table 1). Automobiles represent a fairly mature product with a not particularly impressive rate of innovation.[18] Many middle income countries are quite capable of engineering and producing a line of automobiles; however, to do this facing the competition of established and advanced producers may be impossible. What does Table 1 show? Those countries in Europe and North America that developed the automobile continue to produce and trade it, both with each other and with other countries. In contrast, the new producers, mainly Japan and Korea, do not import automobiles. These countries developed their capabilities in automobile production by promoting their exports and performing a full import substitution, eliminating competition from FDI in automobiles. On the other hand, Latin American countries that supposedly "substituted for imports" by allowing FDI in automobiles,[19] did not develop their own industries.

Discussion on the role of institutions usually places emphasis on how these improve the incentives for investment and innovation through, for example, property rights and effective contractual arrangements. What becomes apparent in the history of development and through the model, though, is the important role that institutions play in recognizing and implementing policies favoring the country's own *long-term self-interest.* This requires coordination and agreement amongst a country's various sectors, and has often necessitated manipulating trade incen-

[18]Yet, 78% of world sales are due to ten corporations (three from the US) (Najera, 1998).

[19]Since 1916 in Argentina (Ford home page) and 1920 in Mexico (Soto-Rodríguez, 2002).

tives to access the advantage of backwardness. In the US, the implementation of the American System required a high tariff to protect American industries from British industrial supremacy.[20] Similarly Japan, and later Korea and Taiwan, were jealously concerned with their technological independence, and devised economic policies that ensured their technological capabilities and independence. These governments were able to take leading, credible roles in the implementation of these policies. By contrast, in Latin America rent-seeking elites were not effectively concerned with the dependency that resulted from FDI.[21,22]

The rest of this article is organized as follows. First, I introduce the basic framework, including innovation, production and consumption. Next, I close the model in turn for the cases of autarchy, free commerce, labor-seeking FDI and market-seeking FDI, proving the stated results. Colonial diktat and NIC-style policies are discussed in the section of free commerce. Conclusions follow.

2. The basic framework

The Schumpeterian growth model is cast in a simple discrete-time framework following Acemoglu, Aghion and Zilibotti (2002), Howitt and Mayer-Foulkes (2005) and Aghion, Howitt and Mayer-Foulkes (2005). The model will cover the autarchic case, free commerce and labor- and market-seeking FDI. In the autarchic case there are m countries which make use of each others' technological ideas; once commerce is included (an essential condition for FDI), $m = 2$ for simplicity.

There is a continuum of tradeable general goods indexed by $i \in [0, 1]$, produced with labor and used for consumption and innovation. Each country has a fixed population L_j, $j = 1, ..., m$ consisting of a continuum of individuals living for two periods and endowed with one unit of labor services in the second period. A continuum of individuals $i \in [0, 1]$ is born each generation who may attempt to

[20] The American System advanced by Henry Clay and others after 1812 for industrial-technological progress, promoted trade between North, South and West through transportation improvements. The South, having access to markets for its cotton, had no incentives to join the System, one of the causes of the Civil War (Spannaus and White, 1996; Salisbury, 1992).

[21] The degree to which a country puts into place policies effectively promoting its self-interest may be orthogonal to whether it is democratic or autocratic, partly explaining Barro's (1991) weak findings for democracy as a variable promoting economic growth.

[22] Political scientists have proposed that countries which have faced the extreme organizational necessities of war have developed stronger institutions. This may be one reason why East Asian and Western European countries, as well as the US, have stronger institutions that effectively pursue their self-interest, as compared to, for example, Latin America.

manage a research firm for innovation on the i^{th} good during the first period of their life. Generation t has an intertemporal linear utility function[23]

$$U_t = u_{1t} + \beta u_{2t+1},$$

where $0 < \beta < 1$ and each period's utility is Cobb-Douglass,

$$u_{kt} = \exp[\int_0^1 \log\left(c_{kt}\left(i\right)\right) di].$$

$c_{kt}(i)$ is the amount of good i consumed in period k and time t. The real interest rate is given by $1 + r = \beta^{-1}$.

2.1. General goods, productivity and innovation

The economy has infinitely many small producers who can produce any good i at a generally available productivity level A_t, according to the production function:

$$Y_t(i) = \varphi A_t L_t(i), \tag{2.1}$$

where $L_t(i)$ is the labor used to produce good i, and φ is a fixed productivity effect that may include institutional, geographic and other factors.

Technological change is costly. At time $t-1$, the i^{th} innovator may attempt a technological jump of magnitude $\Gamma > 1$, so as to produce good i with labor productivity ΓA_t. In the autarchic case, innovators will decide to innovate according to their expected profit. In the open case, this decision will be embedded in an innovation competition game defining who wins the race, she or her competing i^{th} analogue in the other country. When she succeeds (innovates), she will form a large national or world monopoly which will be the i^{th} incumbent firm at time t. Let $\mu_t(i)$ be the probability that if she attempts to innovate she succeeds. Then:

$$A_t(i) = \left\{ \begin{array}{cc} \Gamma A_t & \text{with probability } \mu_t(i), \\ A_t & \text{with probability } 1 - \mu_t(i). \end{array} \right\}$$

Goods i for which an innovation has just occurred are produced according to the Leontief production function:

$$Y_t(i) = \varphi \chi \Gamma A_t \min\left[L_t(i), \frac{P_t(i)}{\chi\Gamma - 1}\right], \tag{2.2}$$

[23]Linear utility implies people are indifferent between investing in any country. Thus, by assuming δ is the same across countries, perfect indirect (financial) investment can be allowed with no change in the analysis.

where $P_t(i)$ is a public good necessary to produce the recently innovated i^{th} good and χ is an efficiency parameter associated with the combination of private and public goods, which must satisfy $\chi\Gamma > 1$. The public input in production function (2.2) is plausible because technological change often requires a public input, such as roads, railroad tracks, airports, the electricity distribution network, the "internet superhighway", new regulations, and so on. It is mainly introduced to simplify the model by making aggregate labor demand neutral to the innovation rate; for this reason, the ratio of public to private labor is set at $\chi\Gamma - 1$.[24] Its presence also allows the discussion of the impact of χ, public efficiency in relation to innovation. Public goods are produced according to the production function

$$P_t(i) = L_t^P(i). \tag{2.3}$$

Suppose that public labor is allocated in the optimal ratio:

$$L_t^P(i) = (\chi\Gamma - 1) L_t(i).$$

Then the privately perceived production function for innovated goods is analogous to the one for competitive goods,

$$Y_t(i) = \varphi\chi\Gamma A_t L_t(i), \tag{2.4}$$

except that its technological level ΓA_t is higher, the efficiency parameter χ is present, and society as a whole pays (through lump sum taxation) for $L_t^P(i)$ additional units of labor. Recall that the incumbent faces a competing fringe of small producers with production function (2.1) at technological level A_t.

The incumbent's specific knowledge disappears at her death,[25] but general knowledge diffuses during production within each country, so next period's shared technological level is:

$$A_{t+1} = (1 + \mu_t(\Gamma - 1)) A_t. \tag{2.5}$$

2.2. Consumer and producer optimization

The Cobb-Douglass utility for each period implies that consumers dedicate an equal expenditure to each good i. Competitively produced goods are sold at their

[24] The Leontief production function simplifies the analysis of public inputs in the case of FDI.

[25] Alternatively, it could be assumed that by the next period her specific knowledge is outdated, or that the set of general goods $i \in [0, 1]$ is irrelevant to consumption and innovation, having been replaced through technological progress with a new set of general goods.

cost $p_t = w_t/(\varphi A_t)$. Innovative producers face competition at this price, and a constant consumer expenditure. Therefore they minimize costs by reducing production to the minimum level compatible with price p_t. Innovators make a profit so long as $\chi\Gamma > 1$, the assumption made above. Goods will also be demanded for research, in the same proportional structure as for consumption, as shown below. Hence, all goods are produced at the same price and in the same quantity $Y_t(i) = Y_t = B_t/p_t$, where B_t is the aggregate expenditure on consumption and research, equal to nominal GNP. Real aggregate demand B_t/p_t depends on whether the economy is closed or open, and on the presence of labor- or market- seeking FDI. Observe that real wages are $w_t/p_t = \varphi A_t$.

2.3. Research

At the end of period $t-1$, production will be allocated between consumption and investment in research. Introduce an index j for countries. Innovative firms will have access to a knowledge level A_{jt}, resulting from the previous knowledge level A_{jt-1} and from the diffusion of the new knowledge level ΓA_{jt-1} at a rate μ_{jt-1} during production. Let the R&D investment needed to obtain a technological jump Γ at any given rate μ_{jt} in any sector i be governed by:

$$\mu_{jt} = \Psi(\frac{\psi(a_{jt})N_{jt-1}}{A_{jt}}), \tag{2.6}$$

where research intensity N_{jt-1} is given by the Cobb-Douglass production function:

$$N_{jt-1} = \exp[\int_0^1 \log(N_{jit-1})di].$$

Here $N_{jt-1}(i)$ is the quantity of good i used for research. It follows that consumption and research demand for goods i are proportional. Investment in innovation simply transfers some constant proportion of the consumption of each good to innovation, and $N_{jit-1} = N_{jt-1}$. In (2.6) the division by A_{jt} recognizes the "fishing-out" effect: the resources needed to obtain a technological jump Γ are proportional to the knowledge level. Suppose there is a single technological leader, country 1, and let $a_{jt} = A_{jt}/A_{1t} < 1$ be the relative technological level of country j with respect to the leader. Lagging countries face an innovation function identical to the one faced by the leader at previous levels of development, except for the convergence term $\psi(a_{jt})$. Through technological diffusion, the presence of the leading country's technological level A_{1t} reduces the resources that country j

needs to invest in order to achieve this jump Γ. This is Gerschenkron's (1952) "advantage of backwardness", represented by the decreasing function:

$$\psi(a_{jt}) = \psi_0 - (\psi_0 - \psi_1)\, a_{jt}. \tag{2.7}$$

For the function Ψ yielding the final probability of innovation (2.6) I chose

$$\Psi(n) = 1 - (1+n)^{-1}. \tag{2.8}$$

This satisfies $\Psi(0) = 0, \Psi < 1, \Psi' > 0, \Psi'' < 0,\ \Psi'(n) = (1+n)^{-2} = (1 - \Psi(n))^2$. The fact that Ψ is bounded will allow examining the effects of country size.

Innovators in each sector choose $\mu_{jt} \geq 0$ to maximize the expected real payoff:

$$\frac{\mu_{jt}\pi_{jt}}{(1+r)\,p_{jt}} - N_{jt-1} = \Psi\left(\frac{\psi(a_{jt})N_{jt-1}}{A_{jt}}\right)\pi_{jt} - N_{jt-1}. \tag{2.9}$$

The interior first order maximization condition can be written:

$$\left(1-\mu_{jt}\right)^2 \psi(a_{jt})\frac{\beta\pi_{jt}}{p_{jt}A_{jt}} = 1. \tag{2.10}$$

3. Autarchy

Consider country j with no trade. Labor demanded privately in competitive, and privately and publicly in innovative sectors (indices 'C', 'I' and 'P') amounts to:

$$L_{jt}^{\mathrm{C}} = \frac{Y_t}{\varphi_j A_{jt}} = \frac{B_t}{\varphi_j A_{jt} p_t},\ L_{jt}^{\mathrm{I}} = \frac{Y_t}{\varphi_j \chi_j \Gamma A_{jt}} = \frac{L_{jt}^{\mathrm{C}}}{\chi_j \Gamma},\ L_{jt}^{\mathrm{P}} = \frac{\chi_j\Gamma - 1}{\chi_j \Gamma} L_{jt}^{\mathrm{C}}. \tag{3.1}$$

Each sector i demands a total of L_{jt}^{C} units of labor. Market clearing for labor thus implies $L_j = L_{jt}^{C} = B_{jt}/\left(\varphi_j A_{jt} p_{jt}\right)$, which fixes aggregate income in country j at:

$$Y_{jt} = \frac{B_{jt}}{p_{jt}} = \varphi_j A_{jt} L_{jt}. \tag{3.2}$$

Real profits obtained by the i^{th} incumbent firm in each innovative sector are:

$$\frac{\pi_{jt}}{p_{jt}} = Y_{jt} - \frac{w_{jt}Y_{jt}}{p_{jt}\varphi_j\chi_j\Gamma A_{jt}} = \pi_j \frac{B_{jt}}{p_{jt}},$$

where the profit share is $\pi_j = 1 - [\chi_j\Gamma]^{-1} > 0$. The first order interior conditions for innovation are given by:

$$\left(1-\mu_{jt}\right)^2 \Omega(a_{jt}) = 1, \tag{3.3}$$

where the *effective innovation incentives* (corrected for the fishing out effect and convergence) are $\Omega(a_{jt}) = \psi(a_{jt})\beta\pi_j\varphi_j L_j$, a decreasing function of a_{jt}. Define:

$$f(\Omega) = \max\left[1 - \frac{1}{\sqrt{\Omega}}, 0\right].$$

The function f solves (3.3), is zero for $\Omega \leq 1$ and is strictly increasing thereafter. The innovation rate μ_{jt} (which must be nonnegative) is given by:

$$\mu_{jt}(a_{jt}) = f\left(\Omega_{jt}(a_t)\right). \tag{3.4}$$

In the case of the leading country, $a_{1t} = 1$ so μ_{1t} is a constant, which I assume is positive. Country 1's growth rate, also the autarchic growth rate, is given by:

$$g_1^{\mathrm{A}} = \frac{A_{1t+1}}{A_{1t}} - 1 = \mu_1(\Gamma - 1)$$

('A' for autarchy). g_1^{A} is increasing but bounded in the population level L_{1t}.

3.1. Lagging countries

The relative technological level a_{jt} of a lagging country follows the dynamics:

$$a_{jt+1} = \frac{A_{jt+1}}{A_{1t+1}} = \frac{\left[1+\mu_{jt}(a_{jt})(\Gamma-1)\right]A_{jt}}{\left[1+\mu_1(\Gamma-1)\right]A_{jt}} = \frac{1+\mu_{jt}(a_{jt})(\Gamma-1)}{1+\mu_1(\Gamma-1)}a_{jt}.$$

It is convenient to study these dynamics in the relative growth form[26]

$$\frac{a_{jt+1}}{a_{jt}} = H_j^{\mathrm{A}}(a_{jt}) \equiv \frac{1+\mu_{jt}(a_{jt})(\Gamma-1)}{1+\mu_1(\Gamma-1)}.$$

Country j converges in growth rates to country 1 if it tends to a steady state $H_j^{\mathrm{A}}(a_j^*) = 1$ at which its innovation rate $\mu_{jt}(a_j^*) = \mu_1$ equals the leader's. A

[26] The phase diagram can be viewed in the $(a_{jt}, a_{jt+1}/a_{jt})$ plane. Trajectories are mapped following the function $H_j^{\mathrm{A}}(a_{jt})$ and then rectangular hyperbolas to the $a_{jt+1}/a_{jt} = 1$ line.

divergent steady state $a_j^* = 0$ occurs if $H_j^{\mathrm{A}}(0) < 1$, yielding a negative relative growth rate for country j. If instead $H_j^{\mathrm{A}}(1) > 1$, country j will overtake country 1 once it approaches it. Now, $H_j^{\mathrm{A}}(\cdot)$ is decreasing and continuous because $\Omega(\cdot)$ and $\psi(\cdot)$ are, and is strictly decreasing unless $\mu_{jt}(a_{jt}) = 0$, in which case $H_j^{\mathrm{A}}(a_{jt}) < 1$. Hence the solutions to $H_j^{\mathrm{A}}(a_j^*) = 1$ are unique.

The analysis of autarchy obtains findings analogous to Aghion, Howitt and Mayer-Foulkes (2005), now including an overtaking result. Although credit constraints for innovation have been excluded for simplicity, their comparative statics are similar to those for χ, public efficiency for innovation.

Proposition 1. Under autarchy, countries fall into three groups.

(1) $H_j^{\mathrm{A}}(1) > 1$. Country j will overtake country 1.

(2) $H_j^{\mathrm{A}}(1) \leq 1$ and $H_j^{\mathrm{A}}(0) \geq 1$. Country j converges in growth rates to country 1. A unique steady state $0 \leq a_j^* \leq 1$ exists given by $H_j^{\mathrm{A}}(a_j^*) = 1$. At this steady state $\mu_j^* = f\left(\psi(a_j^*)\pi_j\varphi_j L_j\right)$. Marginal rises in productivity effects φ_j and χ_j, or in population size L_j, will result in marginal positive level effects.

(3) $H_j^{\mathrm{A}}(0) < 1$. In this case the steady state is $a_j^* = 0$. Country j diverges in growth rates from country 1. The growth rate is $\mu_j^*(\Gamma - 1) < g_1$, with $\mu_j^* = f\left(\psi_0\pi_j\varphi_j L_j\right)$. In this case marginal rises in productivity effects φ_j and χ_j, or in population size L_j, will result in positive growth effects.

Proof. Everything is clear except for the derivation of the growth rate when $a_j^* = 0$: $\lim_{t\to\infty} G_{jt} \equiv \lim_{t\to\infty} A_{jt+1}/A_{jt} - 1 = (1+g_1)\lim_{t\to\infty}(a_{t+1}/a_t) - 1 = (1+g_1)H^{\mathrm{A}}(0) - 1 = \mu_j^*(\Gamma-1) < g_1$.■

In the autarchic case, identical economies have the same steady states independently of their initial conditions, Galor's (1996) definition of convergence, which now also means "converging" to a divergent steady state. To study identical economies, set $\chi_j = \varphi_j = L_j = 1$. Then $\pi_j = \pi = 1 - \Gamma^{-1}$.

Proposition 2. Under autarchy,

(1) Identical countries have the same steady states.

(2) If a country has a higher steady state, it must have higher fixed productivity effects φ_j or χ_j or a higher population L_j.

Proof. (1) Since country j is identical to country 1, $H_j^{\mathrm{A}}(1) = H_1^{\mathrm{A}}(1) = 1$, so the unique steady state is $a_j^* = 1$. (2) This follows from Proposition 1.■

4. Free commerce

Consider two countries 1 and 2 trading domestically produced general goods, with labor and investment immobile. Write a_t for a_{2t}.

4.1. Innovation

In the autarchic case a single innovator is assigned to the i^{th} good in each country. In effect this abstracts from the problem of domestic innovation races. In the multi-country case the problem of innovation competition must be addressed. Since the concern is not with the particular nature of innovation races, but with their long-term effects on economic growth, I simply assume that nature assigns a subset of sectors with measure ω_j to innovators from country j, with $\omega_1 + \omega_2 = 1$. Several scenarios can be examined with this assumption. First, identical countries can be assigned $\omega_1 = \omega_2$. Alternatively, endogenous assignments $\omega_j(a_t)$ can be considered. Finally, situations will emerge when innovators from the leading country would clearly win a price war against innovators from the lagging country; the competition situation *after* innovation is enough to determine the innovation race winner. In this case $\omega_1 = 1$ and $\omega_2 = 0$ can be assumed.

4.2. Production, consumption and commerce

Suppose that as a result of the innovation process each country j has innovated on a measure $\omega_j \mu_j \geq 0$ of sectors. Also suppose, for definiteness, that each country is the unique producer on a measure $\xi_j \geq 0$ of competitive sectors, so that

$$\sum\nolimits_{j=1}^{2} \left(\omega_j \mu_{jt} + \xi_{jt}\right) = 1. \tag{4.1}$$

Goods are consumed in equal aggregate quantities Y_t and at the same price p_t.

4.2.1. Both countries produce competitive goods

Suppose each county can meet the world demand for its innovative goods. Labor demands (3.1) hold in each country with aggregate world expenditure B_t instead of B_{jt}. Each sector i demands L_{jt}^{C} units of labor. Market clearing for labor implies

$$L_j = \left(\omega_j \mu_{jt} + \xi_{jt}\right) L_{jt}^{C}, \text{ where } L_{jt}^{C} = B_t / \left(\varphi_j A_{jt} p_{jt}\right).$$

Applying (4.1), aggregate real world expenditure is:

$$Y_t = \frac{B_t}{p_t} = \sum\nolimits_{k=1,2} \varphi_k A_{kt} L_k. \tag{4.2}$$

The assumption of trade balance is implicit in the model. Each country consumes each good in proportion to its income. Real profits are $\pi_{jt}/p_t = \pi_j \sum_{k=1,2} \varphi_k A_{kt} L_k$. Solving for ξ_{jt} and writing $\phi = \varphi_2/\varphi_1$, competitive sectors have measures:

$$\begin{aligned} \xi_{1t} &= \tfrac{1}{1+\phi a_t \frac{L_2}{L_1}} - \omega_1 \mu_{1t} \geq 0, \\ \xi_{2t} &= \tfrac{1}{1+\phi^{-1} a_t^{-1} \frac{L_1}{L_2}} - \omega_2 \mu_{2t} \geq 0. \end{aligned} \tag{4.3}$$

4.2.2. One country produces only innovated goods

When country 2 cannot meet the world demand for goods it has innovated in, $\xi_{2t} < 0$ in equation (4.3). It thus specializes in producing innovated goods. Country 1 must produce any shortfall in their supply competitively. Suppose country 2 distributes its labor equally amongst its $\omega_2 \mu_{2t}$ innovative sectors. Taking account of the need for public labor, its aggregate product is $Y_{2t} = \varphi_2 A_{2t} L_2$, and aggregate world expenditure (4.2). Innovations in country 1 continue to yield sector profits $\pi_{1t} = \pi_1 B_t$, while those in country 2 now yield $\pi_{2t}/p_t = \pi_2 \varphi_2 A_{2t} L_2 / (\omega_2 \mu_{2t})$, production being less than world demand. When country 1 specializes, the same expressions hold with indices 1 and 2 interchanged. Both countries cannot specialize in producing innovated goods since $\omega_1 \mu_{1t} + \omega_2 \mu_{2t} < \omega_1 + \omega_2 = 1$.

4.3. The two-country dynamics

In the case when neither of the countries specializes in producing innovated goods, the effective innovation incentives in (3.3) are:

$$\begin{aligned} \Omega_{1t}(a_t) &= \psi_1 \beta \pi_1 (\varphi_1 L_1 + \varphi_2 a_t L_2), \\ \Omega_{2t}(a_t) &= \psi(a_t) \beta \pi_2 \left(\varphi_1 a_t^{-1} L_1 + \varphi_2 L_2\right). \end{aligned}$$

Hence the innovation rates are $\mu_{jt}(a_t) = f(\Omega_{jt}(a_t))$. While $f(\cdot)$ and $\Omega_{1t}(\cdot)$ are increasing functions, $\Omega_{2t}(\cdot)$ is decreasing. Thus $\mu_{1t}(\cdot)$ is increasing and $\mu_{2t}(\cdot)$ is decreasing.

If country 1 specializes in producing innovative goods, the interior first order condition for the innovation rate is:

$$\frac{(1-\mu_{1t})^2 \psi_1 \beta \pi_1 \varphi_1 L_1}{\omega_1 \mu_{1t}} = 1,$$

the condition for country 2 remaining unchanged. Thus for country 1

$$\mu_{1t}(a_t) = f_0\left(\frac{\psi_1\beta\pi_1\varphi_1 L_1}{\omega_1}\right),$$

where $\mu = f_0(x)$ is the unique solution to $(1-\mu)^2 x = \mu$.subject to $0 \leq \mu \leq 1$. It follows from (4.3) that country 1 specializes if

$$\omega_1 f_0\left(\frac{\psi_1\beta\pi_1\varphi_1 L_1}{\omega_1}\right) \geq \frac{1}{1+\phi a_t \frac{L_2}{L_1}}. \tag{4.4}$$

This occurs if the condition $a_t \geq a_1^{\text{Spec}}$ is met, where a_1^{Spec} solves (4.4) for equality.

When instead country 2 specializes in innovative goods, its innovation rate is:

$$\mu_{2t}(a_t) = f_0\left(\frac{\psi(a_t)\beta\pi_2\varphi_2 L_2}{\omega_2}\right).$$

f_0 is increasing so $\mu_{2t}(a_t)$ is decreasing as before. Country 2 specializes if:

$$\omega_2 f_0\left(\frac{\psi(a_t)\beta\pi_2\varphi_2 L_2}{\omega_2}\right) \geq \frac{1}{1+\phi^{-1} a_t^{-1} \frac{L_1}{L_2}}. \tag{4.5}$$

The LHS of (4.5) is decreasing in a_t, while the RHS is increasing. Also, as $a_t \to 0$, the LHS is positive while the RHS tends to zero. Hence country 2 specializes below some $a_2^{\text{Spec}} > 0$. Since both countries cannot specialize, $a_2^{\text{Spec}} < a_1^{\text{Spec}}$.

Summarizing, the two-country dynamics are given by:

$$\frac{a_{t+1}}{a_t} = H^{\text{F}}(a_t) = \frac{1+\omega_2\mu_{2t}^{\text{F}}(a_t)(\Gamma-1)}{1+\omega_1\mu_{1t}^{\text{F}}(a_t)(\Gamma-1)}$$

('F' for free commerce). The innovation rates $\mu_{1t}^{\text{F}}(a_t)$ and $\mu_{2t}^{\text{F}}(a_t)$ are given by:

$a_t \in [0,1] \cap$	$\mu_{1t}^{\text{F}}(a_t)$
$[0, a_1^{\text{Spec}}]$	$f\left(\psi_1\beta\pi_1\left(\varphi_1 L_1 + \varphi_2 a_t L_2\right)\right)$
$[a_1^{\text{Spec}}, \infty]$	$f_0\left(\frac{\psi_1\beta\pi_1\varphi_1 L_1}{\omega_1}\right)$

$a_t \in [0,1] \cap$	$\mu_{2t}^{\text{F}}(a_t)$
$[a_2^{\text{Spec}}, \infty]$	$f\left(\psi(a_t)\beta\pi_2\left(\varphi_1 a_t^{-1} L_1 + \varphi_2 L_2\right)\right)$
$[0, a_2^{\text{Spec}}]$	$f_0\left(\frac{\psi(a_t)\beta\pi_2\varphi_2 L_2}{\omega_2}\right)$

Table 2. Probability of innovation in the open economy.

By construction, functions $\mu_{1t}^{\mathrm{F}}(a_t)$, $\mu_{2t}^{\mathrm{F}}(a_t)$ are continuous. When they are non-zero, either $\mu_{1t}^{\mathrm{F}}(a_t)$ is strictly increasing or $\mu_{2t}^{\mathrm{F}}(a_t)$ is strictly decreasing, or both. If they are both zero then neither country specializes. Hence unless both innovation rates are zero, $H^{\mathrm{F}}(a_t)$ is strictly decreasing and there is a unique solution for $H^{\mathrm{F}}(a^*) = 1$, given by the solution to $\omega_2\mu_{2t}^{\mathrm{F}}(a_t) = \omega_1\mu_{1t}^{\mathrm{F}}(a_t)$. Proposition 1 carries over for the case of free commerce as follows:

Proposition 3. Under free commerce, countries fall into three groups.

(1) $H^{\mathrm{F}}(1) > 1$. Country 2 will overtake country 1.

(2) $H^{\mathrm{F}}(1) \leq 1$ and $H_j^{\mathrm{F}}(0) \geq 1$. Country 2 converges in growth rates to country 1. A steady state $0 \leq a^* \leq 1$ exists satisfying $H^{\mathrm{F}}(a^*) = 1$. The steady state is unique unless both innovation rates are zero, when $H^{\mathrm{F}} = 1$ might hold on an interval. Marginal increments in the productivity parameters of both countries will marginally raise levels according to the functions in Table 2.

(3) $H^{\mathrm{F}}(0) < 1$. In this case the steady state is $a^* = 0$. Country 2 diverges in growth rates from country 1 and specializes in producing innovative products satisfying country 1's comparatively huge demand. The growth rate is:

$$\begin{aligned}\lim_{t\to\infty} G_{jt} &= \lim_{t\to\infty} A_{jt+1}/A_{jt} - 1 = (1+g_1)\lim_{t\to\infty}(a_{t+1}/a_t) - 1 \\ &= (1+g_1)\, f_0\left(\frac{\psi_0\beta\pi_2\varphi_2 L_2}{\omega_2}\right) - 1 = \mu_{2t}(0)\,(\Gamma - 1) < g_1.\end{aligned}$$

Any marginal increase in the parameters determining the innovation rate directly or indirectly leads to a marginal growth effect.

(4) The steady state world growth rate when neither country is specialized is:

$$g_1^{\mathrm{F}} = \omega_1 f\left(\psi_1\beta\pi_1\left(\varphi_1 L_1 + \varphi_2 a^* L_2\right)\right)(\Gamma - 1). \tag{4.6}$$

Proof. Everything is clear except for the possible existence of an interval on which $H^{\mathrm{F}} = 1$ if both countries do not innovate. In this case, neither can be specialized in innovation. Their effective innovation incentives must satisfy:

$$\max\left[\psi_1\beta\pi_1\left(\varphi_1 L_1 + \varphi_2 a_t L_2\right), \psi(a_t)\beta\pi_2\left(\varphi_1 a_t^{-1} L_1 + \varphi_2 L_2\right)\right] \leq 1,$$

which holds on some single closed interval or a point, since each function involved is monotonic.■

Proposition 4. Under free commerce, unless both countries are stagnant,

(1) Identical countries under symmetric innovation competition ($\omega_1 = \omega_2$) have the same steady states.

(2) If a country has a higher steady state, it must have an advantage in innovation competition (higher ω_j), or higher fixed productivity effects $\varphi_j$or χ_j.

(3) When neither country is specialized in innovation, population levels L_j affect the global growth rate but not the steady state level a^*.

Proof. (1) and (2) are clear. (3) a^* satisfies $\psi_1 \pi_1 a^* = \psi(a^*) \pi_2$, which is independent of L_j.■

Suppose the measure of winning sectors $\omega_2(a_t)$ is endogenous. For example, it may be reasonable to suppose that it is an increasing function of a_t with $\omega_2(0) = \omega_{20}$ and $\omega_2(1) = \frac{1}{2}$. Then identical economies might have different steady states.

Proposition 5. Consider identical economies and suppose the process of innovation competition is such that $\omega_2(a) > 0$ is small enough at any given a. Then besides $a^* = 1$ there is a stable steady state $a^* < a$. In the case $a = 0$ this implies that there is a divergent steady state with a lower growth rate.

Proof. Steady states occur when $(1 - \omega_2(a)) \mu_{1t}^{\mathrm{F}}(a) = \omega_2(a) \mu_{2t}^{\mathrm{F}}(a)$. For $\omega_2(a) > 0$ small enough, the LHS of this equation becomes larger than the RHS, implying $H^{\mathrm{F}}(a) < 1$, so a stable steady state a^* exists to the left of a. If $a = 0$, the steady state must be a divergent one.

4.4. Free commerce versus autarchy

When is free commerce better than autarchy? Although the model presented here focuses on the interaction between trade and innovation, trade theory also emphasizes the efficiency gains due to comparative advantage. To include these, suppose that when countries engage in trade the fixed productivity effects increase from φ_j (now φ_j^{A}) to φ_j^{F}.

Suppose country 1 has incentives to innovate independently of whether it trades with country 2. Its effective innovation incentives increase by a factor:

$$\frac{\Omega_{1t}^{\mathrm{F}}}{\Omega_{1t}^{\mathrm{A}}} = \frac{\varphi_1^{\mathrm{F}} + \varphi_2^{\mathrm{F}} a_t \frac{L_2}{L_1}}{\varphi_1^{\mathrm{A}}} > 1.$$

It benefits from trade if the growth rate rises, which occurs if $\mu_1^{\mathrm{A}} < \omega_1 \mu_1^{\mathrm{F}}$:

$$f\left(\Omega_{1t}^{\mathrm{A}}\right) < \omega_1 f\left(\Omega_{1t}^{\mathrm{F}}\right).$$

Country 1 must not loose too many innovation sectors to country 2.[27]

Country 2's effective innovation incentives will also rise, by a factor:

$$\frac{\Omega_{2t}^{\mathrm{F}}}{\Omega_{2t}^{\mathrm{A}}} = \frac{\varphi_2^{\mathrm{F}} + \varphi_1^{\mathrm{F}} a^{*\mathrm{A}-1} \frac{L_1}{L_2}}{\varphi_2^{\mathrm{A}}} > 1.$$

If $\omega_1 = \omega_2$, the steady state will occur at $a^{*\mathrm{F}}$ instead of $a^{*\mathrm{A}}$ where

$$\Omega_{2t}^{\mathrm{F}}\left(a^{*\mathrm{F}}\right) = \Omega_{1t}^{\mathrm{F}}\left(a^{*\mathrm{F}}\right).$$

Country 2's relative level a_t rises after opening at the autarchic steady state if:

$$\frac{\Omega_{2t}^{\mathrm{F}}\left(a^{*\mathrm{A}}\right)}{\Omega_{1t}^{\mathrm{F}}\left(a^{*\mathrm{A}}\right)} = \frac{\varphi_1^{\mathrm{A}}}{\varphi_2^{\mathrm{A}}} \times \frac{\varphi_2^{\mathrm{F}} + \varphi_1^{\mathrm{F}} a^{*\mathrm{A}-1} \frac{L_1}{L_2}}{\varphi_1^{\mathrm{F}} + \varphi_2^{\mathrm{F}} a^{*\mathrm{A}} \frac{L_2}{L_1}} = \frac{\varphi_1^{\mathrm{A}} L_1}{\varphi_2^{\mathrm{A}} a^{*\mathrm{A}} L_2} > 1. \tag{4.7}$$

Since $\Omega_{2t}^{\mathrm{A}}\left(a^{*\mathrm{A}}\right) = \Omega_{1t}^{\mathrm{A}}$ defines $a^{*\mathrm{A}}$, it can be shown that (4.7) is implied by:

$$\frac{\psi_0}{\psi_1}\left(1 - \frac{\varphi_2^{\mathrm{A}} L_2}{\varphi_1^{\mathrm{A}} L_1}\right) > \frac{\chi_2/\chi_1 - 1}{\chi_2 \Gamma - 1}.$$

The benefits of free commerce increase the worse the autarchic relative inefficiency of country 2; the smaller its market size relative to country 1's; the higher the advantage of backwardness; the higher (lower) the efficiency of public goods for innovation in country 1 (respectively 2, since $\frac{d}{d\chi_2}\left(\frac{\chi_2/\chi_1 - 1}{\chi_2\Gamma - 1}\right) = \frac{\Gamma\chi_1 - 1}{(\chi_2\Gamma - 1)^2 \chi_1} > 0$); and the larger the innovation share ω_2/ω_1.

4.5. The colonial diktat

The typical "colonial diktat", implied (a) colonies could import only products from the metropolis and tariff rates had to be low, normally 0%; (b) colonial exports could be made only to the metropolis, from where they could be re-exported; (c) production of manufactured goods that could compete with metropolitan products was banned; and (d) transport between colony and metropolis was conducted only on metropolis ships.[28]

Assuming the existence of the colonial diktat, I prove first that for innovative countries as Britain during the Industrial Revolution, colonial possessions lead to

[27] Instead, country 1 may only have incentives to innovate under free commerce. The British cotton industry during the industrial revolution may furnish an example.

[28] See Beaudreau (2004), who cites Bairoch (1997).

economic growth. Condition (a) in effect set up each empire (the leading country and its colonies) in competition with the other empires, and enlarged their market for innovated goods. The incentives for innovation depended positively on the aggregate colonial population and wealth, implying a higher growth rate for larger and wealthier empires. Next, Bairoch's (1997) assertion that the "colonial diktat" was the main cause for the non-transmission of the Industrial Revolution outside Europe can be proved. Condition (b) in effect limited the incentives for innovation for lagging countries to their own and their colonial master's, rather than world markets. If (c) is interpreted as meaning $\omega_1 = 1$, $\omega_2 = 0$, then by Proposition 5 the lagging economy will diverge. Finally, condition (d) on transport implied innovators would have to negotiate part of their profits to pay for transportation. Conditions (b) and (d) both shift the curve $H^{\mathrm{F}}(a_t)$ downwards, implying that the steady states of otherwise identical economies to the leader would be less than 1, that is, persistent inequality and divergence: *underdevelopment.*

4.6. NIC-style policies

If commerce provides such strong incentives for catch-up, why is underdevelopment so persistent? An important part of the answer will be given in the next sections on FDI. However, it is worth mentioning here that innovators from low-income countries attempting to obtain world profits may face a series of difficulties requiring public coordination or support to surmount. This may be especially true in the context of today's technological advances. Japan, Korea, Taiwan and Israel successfully applied such policies to join the ranks of high technology. Formally, not applying such policies may in effect situate country 2 with a low χ_2, pushing its steady state below country 1's and preventing convergence or catch-up.

5. Labor-seeking FDI

Suppose that innovators can choose to produce where labor is cheaper.[29] The consequence will be asymmetric innovation incentives.

[29] 1) It can be assumed that from the moment research takes place, production is planned for the country with lower wages. The results of R&D will then be adapted for production in that country. 2) Succesful innovators run large firms for which additional adaptation costs are proportionally small, compared to those faced by small firms in the competitive sector. 3) For these reasons, innovative, but not competitive firms in the leading country can produce in the lagging country. 4) Access to cheap labor tends to provide access to cheap raw materials.

Suppose, as before, that each country j has innovated on a measure $\omega_j \mu_j$ of sectors, is the unique producer of a measure $\xi_j \geq 0$ of competitive sectors, and that equation (4.1) holds. Suppose innovators from country 1 produce in country 2.[30] Assume that the production function (2.2) for this good in country 2 has Γ replaced by Γa^{-1},[31] the technological jump relative to A_{2t}, and that country 2 provides public goods in the optimal amount $P_t(i) = \left(\chi_2 a_t^{-1}\Gamma - 1\right) L_t(i)$. The privately perceived production function for FDI is:[32]

$$Y_t(i) = \varphi_2 \chi_2 \Gamma A_{1t}(i) L_t(i) = \varphi_2 \chi_2 \Gamma a_t^{-1} A_{2t}(i) L_t(i) \tag{5.1}$$

Profits are given by: $\pi_t(i) = \left(1 - (\chi_2 \Gamma)^{-1} a_t\right) B_t$, so the profit multiplier is now:

$$\pi_1^{\text{FDI}}(a_t) = 1 - (\chi_2 \Gamma)^{-1} a_t.$$

Innovators from country 1 will innovate for production in country 2 only if their profits increase, that is, if $a_t < \chi_2/\chi_1$. Equality is excluded supposing FDI has some small negligeable cost. A similar analysis shows country 2 produces in country 1 if $a_t > \chi_2/\chi_1$, that is, to obtain public good efficiency in the case when $\chi_2 < \chi_1$. For simplicity I assume $\chi_1 = \chi_2 = \chi$ so country 2 never invests in country 1. Country 2 receives FDI if $a_t < 1$.

5.1. Sufficient labor supply in country 2

Suppose country 2 can meet country 1's innovative sector labor demand. Each sector of production, be it competitive or innovative from either country, will demand a total amount of labor $L_{jt}^{C} = B_t / \left(\varphi_j A_{jt} p_t\right)$, where B_t/p_t is aggregate world expenditure. Equating labor demand and supply in each country,

$$\begin{aligned} L_1 &= \xi_{1t} L_{1t}^{C} = \xi_{1t} \frac{B_t}{\varphi_1 A_{1t} p_t}, \\ L_2 &= \left[\xi_{2t} + \omega_2 \mu_{2t} + \omega_1 \mu_{1t}\right] \frac{B_t}{\varphi_2 A_{2t} p_t}. \end{aligned}$$

Applying (4.1), aggregate real world expenditure is again (4.2). Sectoral innovation profits are given by $\pi_{1t} = \pi_1^{\text{FDI}}(a_t) B_t$, $\pi_{2t} = \pi_2 B_t$. Country 2 will not

[30] This represents FDI, although there is no investment other than R&D in the model.

[31] This formulation makes FDI difficult in lower income countries, due to the amount of public goods required.

[32] FDI workers earn less than their marginal product, which may lead to labor conflict.

become specialized in innovative and FDI sectors so long as:

$$\xi_{2t}^{\mathrm{FDI}}(a_t) = \frac{1}{1+\phi^{-1}a_t^{-1}\frac{L_1}{L_2}} - \omega_1\mu_{1t} - \omega_2\mu_{2t} \geq 0. \tag{5.2}$$

The effective innovation incentives in (3.3) for country 1 are now:

$$\Omega_{1t}(a_t) = \psi_1\beta\pi_1^{\mathrm{FDI}}(a_t)(\varphi_1 L_1 + \varphi_2 a_t L_2),$$

while those for country 2 remain unchanged.

5.2. Specialization in FDI and innovation crowding out

Suppose country 1 demands more labor than country 2 has. FDI firms make a higher profit than innovative firms because $\pi_1^{\mathrm{FDI}}(a_t) = 1 - [\chi\Gamma]^{-1} a_t \geq \pi_2$. Hence, as labor becomes rationed between FDI and local innovating firms, local innovation is crowded out. This may occur through the following mechanism. FDI firms will contract all the labor they need, since their profit margin is larger. They could raise wages to bankrupt local innovator's firms, and then return wages to their original levels. The availability of this threat implies leading country innovators can enter the innovation race with a certainty of winning. Hence the measure of innovative sectors ω_2 decreases. The process will reach $\omega_2 = 0$ and $\omega_1 = 1$ or unless labor rationing stops. According to (5.2) this may occur at an endogenously determined level of ω_2, as reflected in the following definition:

$$\omega_2(a_t) = \begin{cases} \omega_2 & \xi_{2t}^{\mathrm{FDI}}(a_t) \geq 0, \\ \frac{\left(1+\phi^{-1}a_t^{-1}\frac{L_1}{L_2}\right)^{-1} - \mu_{1t}}{\mu_{2t}-\mu_{1t}} & \xi_{2t}^{\mathrm{FDI}}(a_t) < 0, \mu_{1t} \leq \min\left[\mu_{2t}, \frac{1}{1+\phi^{-1}a_t^{-1}\frac{L_1}{L_2}}\right], \\ 0 & \xi_{2t}^{\mathrm{FDI}}(a_t) < 0, \mu_{1t} \geq \min\left[\mu_{2t}, \frac{1}{1+\phi^{-1}a_t^{-1}\frac{L_1}{L_2}}\right]. \end{cases}$$

Under partial crowding out ($\omega_2(a_t) > 0$) there is no labor rationing by construction so the incentives defining the innovation rates μ_{jt} remain unaltered. Under full crowding out ($\omega_2(a_t) = 0$) country 2 becomes completely specialized in FDI and ceases to innovate. This describes the 'banana republic'.[33] Country 1 must produce any shortfall in the supply of country 2's innovated goods by producing these domestically. Suppose FDI labor is equally distributed amongst the

[33] I assume workers continue to be paid the wage corresponding to their general knowledge level since their bargaining power against a large firm is small.

μ_{1t} innovative sectors. Taking account of the need for public labor, the aggregate product of country 2 is $Y_{2t} = \varphi_2 A_{2t} L_2$, and aggregate world expenditure is given by (4.2). The sectoral profits obtained by innovators in country 1 are:

$$\pi_1^{\mathrm{FDI}}(a_t)\frac{Y_{2t}}{\mu_{1t}} + \pi_1\left(\frac{B_t}{p_t} - \frac{Y_{2t}}{\mu_{1t}}\right) = (\chi\Gamma)^{-1}(1-a_t)\frac{Y_{2t}}{\mu_{1t}} + \pi_1\frac{B_t}{p_t}.$$

Thus the interior first order condition for μ_{1t} is now given by:

$$1 = (1-\mu_{1t})^2\psi_1\beta\left[\pi_1(\varphi_1 L_1 + \varphi_2 a_t L_2) + \frac{(1-a_t)\varphi_2 a_t L_2}{\chi\Gamma\mu_{1t}}\right].$$

With or without FDI specialization, country 1 has higher incentives for innovation, yielding a larger innovation rate μ_{1t} and therefore a higher world growth rate then the corresponding one for free commerce (in the cases with or without specialization of country 2 but with country 1 not specialized)[34].

5.3. Two-country dynamics with FDI and knowledge diffusion

Though production of innovated goods has shifted to country 2, when country 1 innovates the brains of production are still situated there, so knowledge diffusion due to innovation $A_{1t+1} = [1 + \omega_1\mu_{1t}(\Gamma - 1)]A_{1t}$ still occurs. In country 2, some knowledge diffusion due to FDI also takes place, according to:

$$A_{2t+1} = \left[1 + \omega_2\mu_{2t}(\Gamma - 1) + \Theta(a_t)\omega_1\mu_{1t}\left(\Gamma a_t^{-1} - 1\right)\right]A_{2t}, \qquad (5.3)$$

where $0 < \Theta(a_t) < 1$ is the diffusion coefficient: the spillover is smaller than if the innovation were originally country 2's. I assume that $\Theta(a_t) = \theta a_t$ with $0 < \theta < 1$. This implies a finite rate of diffusion as $a_t \to 0$.[35] Diffusion is proportional to $\Gamma - a_t$ and therefore still higher for smaller a_t. The two-country dynamics are:

$$\frac{a_{t+1}}{a_t} = H^{\mathrm{LFDI}}(a_t) \equiv \frac{1 + \omega_2(a_t)\mu_{2t}(a_t)(\Gamma - 1) + \theta\omega_1(a_t)\mu_{1t}(a_t)(\Gamma - a_t)}{1 + \omega_1(a_t)\mu_{1t}(a_t)(\Gamma - 1)}.$$

The function $H^{\mathrm{LFDI}}(a_t)$ is not monotonic, as was the case for autarchy and free trade. Diverse configurations of multiple steady states generating persistent

[34]The higher growth rate disappears as $a_t \to 0$ in the present model's specific construction because the ratio of public capital to FDI becomes unbounded.

[35]See footnote 8.

inequality and divergence are possible. For 'identical countries', set $L_j = \chi_j = \varphi_j = 1$ for $j = 1, 2$, $\omega_1 = \omega_2 = 1/2$. Then $\pi_j = 1 - \Gamma^{-1}$ and $\pi_1^{\text{FDI}}(a_t) = 1 - a_t\Gamma^{-1}$.

Proposition 6. Suppose country 1 has a positive growth rate in autarchy.

(1) For small enough a_t there is full crowding out. If the FDI spillover coefficient satisfies $\theta \leq (\Gamma - 1)/\Gamma$, a steady state $a^* = 0$ exists at which country 2's growth rate is $\theta\mu_{1t}\Gamma$, less than country 1's rate $\mu_{1t}(\Gamma - 1)$. If $\theta > (\Gamma - 1)/\Gamma$ is not too big, a positive steady state $a^* > 0$ exists with full crowding out.

(2) For identical countries, if the FDI spillover coefficient θ is small enough and $\Gamma < \frac{2+(\psi_0-\psi_1)/\psi_1}{1+(\psi_0-\psi_1)/\psi_1}$, an unstable steady state $0 < a^* < 1$ exists near $a_t = 1$ with no crowding out. If country 2's initial relative technological level $a_t < a^*$, it will diverge away from country 1, first in levels and then possibly in growth rates.■

The proof is in Appendix A.

6. Market-seeking FDI

Assume that innovators can only sell their products where they are produced. This will motivate market-seeking FDI. Competitively produced goods will in effect be used to transfer profits between countries. All goods will be consumed at the same price p_t worldwide, but in equal quantities Y_{jt} only within each country. Profits for innovated good i sold in country j by innovators in country l will be:

$$\pi_{jt}^{l}(i) = \left(1 - \left[\chi_j \Gamma A_{lt}/A_{jt}\right]^{-1}\right) B_{jt}.$$

Goods innovated in country 1 will be produced for sale in country 2 so long as $a_t < \chi_2\Gamma$, which is always the case, since $\chi_2\Gamma > 1$, while goods innovated in country 2 will be produced for sale in country 1 only if:

$$a_t \geq a^{\text{MFDI}} \equiv (\chi_1\Gamma)^{-1}.$$

Thus profits for goods innovated by country 1 are:

$$\pi_{1t}(i) = \pi_1 B_{1t} + \pi_1^{\text{FDI}}(a_t) B_{2t}$$

while profits for goods innovated by country 2 are:

$$\pi_{2t}(i) = \begin{cases} \pi_2^{\text{FDI}}(a_t) B_{1t} + \pi_2 B_{2t} & a_t \geq a^{\text{MFDI}}, \\ \pi_2 B_{2t} & a_t < a^{\text{MFDI}}. \end{cases}$$

In Appendix B, aggregate expenditure B_{jt}/p_t for each country, profits and innovation rates, are derived. The two-country dynamics with FDI spillovers are:

$$\frac{a_{t+1}}{a_t} = H^{\mathrm{MFDI}}(a_t) = \begin{cases} \dfrac{1+\omega_2\mu_{2t}(\Gamma-1)+\theta\omega_1\mu_{1t}(\Gamma-a_t)}{1+\omega_1\mu_{1t}(\Gamma-1)} & a_t \leq a^{\mathrm{MFDI}}, \\ \dfrac{1+\omega_2\mu_{2t}(\Gamma-1)+\theta\omega_1\mu_{1t}(\Gamma-a_t)}{1+\omega_1\mu_{1t}(\Gamma-1)+\theta\omega_2\mu_{2t}(\Gamma-a_t)} & a_t > a^{\mathrm{MFDI}}. \end{cases}$$

In the case of identical countries, if only country 1 invests in country 2, the interior first order condition for μ_{jt} are given by (9.1), (9.2), while if both countries invest in each other the conditions are (9.3), (9.4).

Proposition 7. Consider identical countries 1 and 2, and suppose that if country 2 has enough incentives to innovate, $\omega_1 = \omega_2 = 1/2$, while otherwise $\omega_1 = 1$, $\omega_2 = 0$. Several types of steady states can occur in the two-country dynamics. Interior steady states exist in which country 2 may or may not innovate, and also the zero steady state is possible. (Figures 1.1, 1.2).

Proof (by numerical example). Figure 1.1 shows a steady state $a^* = 0$ with $\beta\psi_0 = 0.25$, $\beta\psi_1 = 15$, $\theta = 0.3$, $\Gamma = 2.857$. Figure 1.2 shows a steady state a^* approximately equal to 0.17 with $\beta\psi_1 = 40$ instead. The Figures are calculated in Excel using a numerical method to solve the simultaneous cubic equations for μ_{1t} and μ_{2t} as indicated in Appendix B, with initial values $\mu_{1t}^0 = \mu_{2t}^0 = 1/2$.■

Proposition 8. For an economy situated at a low steady state, divergent or not, a rise in FDI spillovers may induce a transition to a higher steady state, at which the innovation rate may or may not be positive. (Figures 2.1, 2.2).

Proof (by numerical example). Figures 2.1 and 2.2 model these possibilities. Figures 2.1 first sets $\theta = 0.30$ for $0 \leq a \leq 0.2$ and $\theta = 0.70$ for $0.2 \leq a \leq 1$. Choosing $\beta\psi_0 = 0.5$, $\beta\psi_1 = 3$, $\Gamma = 1.6$ for the other parameters, a^* is 0.05 approximately. At this level, the FDI spillover θ has the low value. Figure 2.1 shows that if θ is raised to 0.70 country 2 will experience an episode of miracle growth taking it to a steady state a^* of about 0.72 *with* innovation. With slightly different parameters ($\beta\psi_1 = 2.5$, low and high θ values 0.3, and 0.6), Figure 2.2 shows a similar trajectory, but from a divergent steady state $a^* = 0$ to a steady state a^* approximately 0.57 but *without* innovation. Of course, the lower and higher steady states need not be linked as in the figures.■

Proposition 8 serves to explain China's current episode of miracle growth. Which of the higher steady state alternatives describes her future?

7. Conclusions

This paper presents a model of development and underdevelopment in an *open* global economy. The model does *not* require the assumption of increasing returns. It shows unequal or divergent steady states may persist between economies differing *only* in their relative status. Thus, geographic, institutional and other differences between countries are *not necessary conditions* for an explanation of backwardness. The model incorporates trade and foreign investment in a Schumpeterian multi-country model of economic growth with technology transfer. It shows that both labor- and market-seeking FDI result in unequal incentives for innovation that favors leading countries. In addition, FDI may crowd out innovation. Its technological spillovers need not be enough compensation to the lagging countries for the asymmetric incentives to innovation that it generates. The model applies in the context of trade that has characterized economic growth since its origins; to the typical colonial diktat imposed by Great Britain; to globalized trade and investment from the repeal of the Corn Laws to World War I (1846-1914); and in the present; and explains in principle how Gerschenkron's advantage of backwardness may be effective only in the presence of effective public policies.

Prolonged episodes of high economic growth have been a repeated feature in economic history, characterizing many countries' transition to development. The model explains this stylized fact, understanding development and underdevelopment as steady states, and miracle growth episodes as transitions between them.

Trade provided a powerful force for economic growth through the economic ascension of Western Europe and the Industrial Revolution. More recently, it has provided a force for economic convergence. Through trade, underdeveloped economies can specialize, access larger markets, and benefit from their cheaper labor and from foreign know-how, which provide high incentives for innovation. However, these benefits may require effective public policies to surmount barriers to technological adoption involving scale, capital accumulation, infant industry and coordination, as were applied in Japan, Korea, Taiwan and Israel.

Even though FDI provides asymmetric incentives for innovation, its technological spillovers and employment possibilities may be enough to cause economic growth or even a transition to a higher steady state, as in Singapore and China.

The experiences of development show that in practice the difficulties of technological adoption are of such magnitude that high rates of economic growth and convergence can only be sustained through integration with the world economy. Economic policies must apply very judicious criteria selecting from the available possibilities to promote as much technological transfer and innovation as possible.

Theories finding that free trade and investment across countries lead to equalization in growth rates and productivity levels, are usually based on competitive markets and on production functions facing diminishing returns. In these situations, the tendency to equilibrium usually generates convergence. Innovation, however, is driven by incentives derived from market power. Public global policy must curb abuses or distortions which can derive from such power. This is the principle behind anti-trust law. In the case of international trade and investment, the same principle holds. Competition between equals — even between huge consortiums — may be beneficial. But when important asymmetries arise, the long-term independence and development of the weak must be safeguarded. Access to markets and cheap labor must be compensated with the transfer of knowledge. Policies guaranteeing technological development must be implemented for globalization to successfully raise incomes and eliminate poverty, and with it, some of the antagonisms that generate terrorism and war. Development is not a zero-sum game. Present-day underdeveloped countries will surely contribute more to global economic growth when they develop than they do now through their cheap labor and smaller markets. They must be ensured the possibility of attaining leadership in some sectors of the economy — the essence of development.

If underdevelopment consists of a technological trap, as is proposed here, it is vital to recognize this. For unlocking the trap will lead to miracle growth and enormous welfare gains, while ignoring it will doom misjudged economic policies.

8. Appendix A. Proof of Proposition 6

(1) Since country 1 has a positive growth rate in autarchy, $\mu_{1t}(a_t)$ is bounded below. Hence for $a_t \leq \frac{\mu_{1t}L_1}{(1-\mu_{1t})\phi L_2}$, $\omega_2(a_t) = 0$ and there is full crowding out. Under these conditions the dynamics are given by $\frac{a_{t+1}}{a_t} = H^{\text{LFDI}}(a_t) = \frac{1+\theta\mu_{1t}(\Gamma-a_t)}{1+\mu_{1t}(\Gamma-1)}$. If $\theta \leq (\Gamma-1)/\Gamma$, $H^{\text{LFDI}}(0) < 0$ and there is a steady state at 0. If $\theta > (\Gamma-1)/\Gamma$ there is a positive steady state $a^* = \Gamma - \frac{\Gamma-1}{\theta}$ with full crowding out so long as θ is small enough for full crowding out at $a_t = a^*$.

(2) Effective innovation incentives for identical countries are:

$$\begin{aligned}\Omega_{1t}(a_t) &= \psi_1\beta\left(1-a_t\Gamma^{-1}\right)(1+a_t),\\ \Omega_{2t}(a_t) &= \psi(a_t)\beta\left(1-\Gamma^{-1}\right)\left(a_t^{-1}+1\right).\end{aligned}$$

First, $\Omega_{1t}(1) = \Omega_{2t}(1)$ so $\mu_{1t}(1) = \mu_{2t}(1) \equiv \mu$. Suppose $\psi_1\beta$ is small enough that $\mu < \frac{1}{2}$. Then $\xi_{2t}^{\text{FDI}}(1) = \frac{1}{2}(1-2\mu) > 0$, so near $a_t = 1$ there is no crowding out. Note that $\Omega'_{1t}(1) - \Omega'_{2t}(1) = 2\psi_1\beta\left[1-2\Gamma^{-1}-\frac{\psi'(1)}{\psi_1}\left(1-\Gamma^{-1}\right)\right]$. This is negative under the stated condition for Γ, implying that country 1 has more incentives for innovation than country 2 in a neighborhood of $a_t = 1$. Since $\mu'_{jt} = \left(1-\mu_{jt}\right)\Omega'_{jt}/2$, $\mu'_{1t}(1) - \mu'_{2t}(1) = (1-\mu)\left(\Omega'_{1t}(1) - \Omega'_{2t}(1)\right)/2 < 0$ implying $H^{\text{LFDI}\prime}(1) = \frac{\left(\mu'_{2t}(1)-\mu'_{1t}(1)\right)(\Gamma-1)/2}{1+\mu(\Gamma-1)/2} > 0$. Hence for $\theta = 0$ there is some $a_0 < 1$ such that H^{LFDI} strictly increases to 1 on $(a_0, 1)$. Therefore for small enough θ, $H^{\text{LFDI}}(a_0) < 1$, $H^{\text{LFDI}}(1) > 1$ and H^{LFDI} remains monotonic. By the intermediate value theorem there is some unstable steady state between a_0 and 1.■

9. Appendix B. Dynamic System under Market Seeking FDI

Consider first the case when $a_t < a^{\text{MFDI}}$ so only country 1 invests in country 2. In sectors in which country 2 has innovated, country 1 uses its own competitive production. Suppose that country 1 underproduces in the remaining sectors, while country 2 overproduces by the same amount, which is traded from country 2 to country 1 balancing the profits from country 1's investment in country 2. Using labor intensities (3.1) as before, labor demand and supply in each country are:

$$L_1 = [(1-\omega_1\mu_{1t}-\omega_2\mu_{2t})(1-\tau_{1t})+\omega_1\mu_{1t}+\omega_2\mu_{2t}]\frac{B_{1t}}{\varphi_1 A_{1t}p_t},$$
$$L_2 = [(1-\omega_1\mu_{1t}-\omega_2\mu_{2t})(1+\tau_{2t})+\omega_2\mu_{2t}+\omega_1\mu_{1t}]\frac{B_{2t}}{\varphi_2 A_{2t}p_t}.$$

where B_{jt}/p_t is aggregate expenditure in each country. Also

$$\tau_{1t}\frac{B_{1t}}{p_t} = \tau_{2t}\frac{B_{2t}}{p_t},$$
$$(1-\omega_1\mu_{1t}-\omega_2\mu_{2t})\tau_{2t}\frac{B_{2t}}{p_t} = \omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}(a_t)\frac{B_{2t}}{p_t}.$$

Substituting in the equation for L_2 (omitting the a_t in π_j^{FDI})

$$\frac{L_2\varphi_2 A_{2t}p_t}{B_{2t}} = 1+\tau_{2t}-\tau_{2t}\omega_1\mu_{1t}-\tau_{2t}\omega_2\mu_{2t} = 1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}},$$

so

$$\frac{B_{2t}}{p_t} = \frac{L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}}.$$

Substituting in the equation for L_1,

$$L_1\varphi_1 A_{1t} = \frac{B_{1t}}{p_t} - \omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}\frac{B_{2t}}{p_t} = \frac{B_{1t}}{p_t} - \frac{\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}},$$

so

$$\frac{B_{1t}}{p_t} = L_1\varphi_1 A_{1t} + \frac{\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}}.$$

Now profits for goods innovated by country 1 are:

$$\begin{aligned}\frac{\pi_{1t}(i)}{p_t} &= \pi_1\left(L_1\varphi_1 A_{1t} + \frac{\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}}\right) + \frac{\pi_1^{\mathrm{FDI}}L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}} \\ &= \frac{\pi_1 L_1\varphi_1 A_{1t} + \pi_1^{\mathrm{FDI}}L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}} + \frac{\pi_1\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}(L_1\varphi_1 A_{1t}+L_2\varphi_2 A_{2t})}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}},\end{aligned}$$

while profits for goods innovated by country 2 are:

$$\frac{\pi_{2t}}{p_t} = \frac{\pi_2 L_2\varphi_2 A_{2t}}{1+\omega_1\mu_{1t}\pi_1^{\mathrm{FDI}}}.$$

Observe that $\pi_1^{\mathrm{FDI}} - \pi_2 = [\chi_2 \Gamma]^{-1} (1 - a_t) > 0$ so the i^{th} innovator from country 1 always makes a higher profit. Under alternative conditions on innovation races this could lead to innovation crowding out.

Consider now the case when $a_t \geq a^{\mathrm{MFDI}}$ so both countries invest in each other. In those sectors in which neither country has innovated, country 1 underproduces by some amount (which could be negative), while country 2 overproduces by the same amount, which is transferred from country 2 to country 1 as payment for net profits. Using labor intensities (3.1) as before, the labor market in each country now clears when:

$$L_1 = \left[(1 - \omega_1 \mu_{1t} - \omega_2 \mu_{2t})(1 - \tau_{1t}) + \omega_1 \mu_{1t} + \omega_2 \mu_{2t}\right] \frac{B_{1t}}{\varphi_1 A_{1t} p_t}$$
$$L_2 = \left[(1 - \omega_1 \mu_{1t} - \omega_2 \mu_{2t})(1 + \tau_{2t}) + \omega_2 \mu_{2t} + \omega_1 \mu_{1t}\right] \frac{B_{2t}}{\varphi_2 A_{2t} p_t}$$

where $\frac{B_{jt}}{p_t}$ is aggregate expenditure in each country. Also

$$\begin{aligned} \tau_{1t} \frac{B_{1t}}{p_t} &= \tau_{2t} \frac{B_{2t}}{p_t} \\ (1 - \omega_1 \mu_{1t} - \omega_2 \mu_{2t}) \tau_{2t} \frac{B_{2t}}{p_t} &= \omega_1 \mu_{1t} \pi_1^{\mathrm{FDI}} \frac{B_{2t}}{p_t} - \omega_2 \mu_{2t} \pi_2^{\mathrm{FDI}} \frac{B_{1t}}{p_t} \end{aligned}$$

Substituting in the equation for L_1, L_2,

$$\begin{aligned} L_1 \varphi_1 A_{1t} &= \frac{B_{1t}}{p_t} \left(1 + \omega_2 \mu_{2t} \pi_2^{\mathrm{FDI}}\right) - \omega_1 \mu_{1t} \pi_1^{\mathrm{FDI}} \frac{B_{2t}}{p_t}, \\ L_2 \varphi_2 A_{2t} &= -\omega_2 \mu_{2t} \pi_2^{\mathrm{FDI}} \frac{B_{1t}}{p_t} + \left(1 + \omega_1 \mu_{1t} \pi_1^{\mathrm{FDI}}\right) \frac{B_{2t}}{p_t}. \end{aligned}$$

Let $\Lambda_j = \omega_j \mu_{jt} \pi_j^{\mathrm{FDI}}$. The determinant of the system is $1 + \Lambda_1 + \Lambda_2$. Hence:

$$\begin{aligned} \frac{B_{1t}}{p_t} &= \frac{(1 + \Lambda_1) L_1 \varphi_1 A_{1t} + \Lambda_1 L_2 \varphi_2 A_{2t}}{1 + \Lambda_1 + \Lambda_2} \\ \frac{B_{2t}}{p_t} &= \frac{\Lambda_2 L_1 \varphi_1 A_{1t} + (1 + \Lambda_2) L_2 \varphi_2 A_{2t}}{1 + \Lambda_1 + \Lambda_2} \end{aligned}$$

Profits in each country are:

$$\begin{aligned} \frac{\pi_{1t}}{p_t} &= \frac{\pi_1 \left((1 + \Lambda_1) L_1 \varphi_1 A_{1t} + \Lambda_1 L_2 \varphi_2 A_{2t}\right)}{1 + \Lambda_1 + \Lambda_2} \\ &\quad + \frac{\pi_1^{\mathrm{FDI}} \left(\Lambda_2 L_1 \varphi_1 A_{1t} + (1 + \Lambda_2) L_2 \varphi_2 A_{2t}\right)}{1 + \Lambda_1 + \Lambda_2} \\ &= \frac{\left[\pi_1 (1 + \Lambda_1) + \pi_1^{\mathrm{FDI}} \Lambda_2\right] L_1 \varphi_1 A_{1t} + \left[\pi_1 \Lambda_1 + \pi_1^{\mathrm{FDI}} (1 + \Lambda_2)\right] L_2 \varphi_2 A_{2t}}{1 + \Lambda_1 + \Lambda_2} \end{aligned}$$

$$\begin{aligned}
\frac{\pi_{2t}(i)}{p_t} &= \frac{\pi_2^{\mathrm{FDI}}(a_t)\left((1+\Lambda_1)L_1\varphi_1A_{1t}+\Lambda_1L_2\varphi_2A_{2t}\right)}{1+\Lambda_1+\Lambda_2} \\
&\quad+\frac{\pi_2\left(\Lambda_2L_1\varphi_1A_{1t}+(1+\Lambda_2)L_2\varphi_2A_{2t}\right)}{1+\Lambda_1+\Lambda_2} \\
&= \frac{\left[\pi_2^{\mathrm{FDI}}(1+\Lambda_1)+\pi_2\Lambda_2\right]L_1\varphi_1A_{1t}+\left[\pi_2^{\mathrm{FDI}}\Lambda_1+\pi_2(1+\Lambda_2)\right]L_2\varphi_2A_{2t}}{1+\Lambda_1+\Lambda_2}
\end{aligned}$$

The two country dynamics are:

$$\frac{a_{t+1}}{a_t}=H^{\mathrm{MFDI}}(a_t)=\begin{cases}\frac{1+\omega_2\mu_{2t}(\Gamma-1)+\theta\omega_1\mu_{1t}(\Gamma-a_t)}{1+\omega_1\mu_{1t}(\Gamma-1)} & a_t\le a^{\mathrm{MFDI}},\\ \frac{1+\omega_2\mu_{2t}(\Gamma-1)+\theta\omega_1\mu_{1t}(\Gamma-a_t)}{1+\omega_1\mu_{1t}(\Gamma-1)+\theta\omega_2\mu_{2t}(\Gamma-a_t)} & a_t>a^{\mathrm{MFDI}}.\end{cases}$$

Consider identical countries. If only country 1 invests in country 2 ($a_t\le a^{\mathrm{MFDI}}$)

$$\begin{aligned}
\frac{\pi_{1t}(i)}{A_{1t}p_t} &= \frac{\pi_1+\pi_1^{\mathrm{FDI}}a_t+\pi_1\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}(1+a_t)}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}} \\
&= \pi_1(1+a_t)+\frac{\left(\pi_1^{\mathrm{FDI}}-\pi_1\right)a_t}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}} \\
&= \pi_1(1+a_t)+\frac{\Gamma^{-1}(1-a_t)a_t}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}}.
\end{aligned}$$

The unrestricted first order condition for μ_{1t} is:

$$(1-\mu_{1t})^2\psi_1\left(\left(1-\Gamma^{-1}\right)(1+a_t)+\frac{\Gamma^{-1}(1-a_t)a_t}{1+\frac{1}{2}\mu_{1t}\left(1-a_t\Gamma^{-1}\right)}\right)=1 \tag{9.1}$$

In the case of μ_{2t} it is:

$$\frac{(1-\mu_{2t})^2\psi(a_t)\pi_2}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}(a_t)}=1. \tag{9.2}$$

When both countries invest in each other ($a_t\ge a^{\mathrm{MFDI}}$)

$$\begin{aligned}
\frac{\pi_{1t}(i)}{A_{1t}p_t} &= \frac{\pi_1+\pi_1^{\mathrm{FDI}}a_t+\frac{1}{2}\pi_1^{\mathrm{FDI}}(1+a_t)\left(\pi_1\mu_{1t}+\mu_{2t}\pi_2^{\mathrm{FDI}}\right)}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}+\frac{1}{2}\mu_{2t}\pi_2^{\mathrm{FDI}}}, \\
\frac{\pi_{2t}(i)}{A_{2t}p_t} &= \frac{\pi_2+\pi_2^{\mathrm{FDI}}a_t^{-1}+\frac{1}{2}\pi_2^{\mathrm{FDI}}\left(1+a_t^{-1}\right)\left(\mu_{1t}\pi_1^{\mathrm{FDI}}+\pi_2\mu_{2t}\right)}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}}+\frac{1}{2}\mu_{2t}\pi_2^{\mathrm{FDI}}}.
\end{aligned}$$

Hence the first order conditions are:

$$\frac{\left(1-\mu_{1t}\right)^2 \psi_1 \left[\pi_1 + \pi_1^{\mathrm{FDI}} a_t + \frac{1}{2}\pi_1^{\mathrm{FDI}}\left(1+a_t\right)\left(\pi_1\mu_{1t} + \mu_{2t}\pi_2^{\mathrm{FDI}}\right)\right]}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}} + \frac{1}{2}\mu_{2t}\pi_2^{\mathrm{FDI}}} = 1, \quad (9.3)$$

$$\frac{\left(1-\mu_{2t}\right)^2 \psi\left(a_t\right) \left[\pi_2 + \frac{\pi_2^{\mathrm{FDI}}}{a_t} + \frac{1}{2}\pi_2^{\mathrm{FDI}}\left(1+a_t^{-1}\right)\left(\mu_{1t}\pi_1^{\mathrm{FDI}} + \pi_2\mu_{2t}\right)\right]}{1+\frac{1}{2}\mu_{1t}\pi_1^{\mathrm{FDI}} + \frac{1}{2}\mu_{2t}\pi_2^{\mathrm{FDI}}} = 1. \quad (9.4)$$

To solve these simultaneous cubic equations for Proposition 7, I solve for the squares and write this system recursively as:

$$\left(1-\mu_{1t}^{n+1}\right)^2 = R_1(\mu_{1t}^n, \mu_{2t}^n),$$
$$\left(1-\mu_{2t}^{n+1}\right)^2 = R_2(\mu_{1t}^n, \mu_{2t}^n).$$

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'able 1. Consolidated World Motor Vehicle Production by Nationality of Origin and Consumption, 1998 (thousand units)

		Consumers							
		Developed				LDC's			
	Origin	NAFTA	European Union	Japan	S Korea	Other Asia, Pacific	Other Europe and Turkey	South America	Total
Developed	American	9508	3846	0	0	350	52	611	14367
	European	3636	11881	0	0	520	1077	1240	18354
	Japanese	2851	811	10049	0	1251	88	39	15089
	S Korea	0	0	0	1954	28	150	0	2132
DC's	Pacific	0	0	0	0	756	0	0	756
	Other Europe	0	0	0	0	0	792	0	792
	South America	-	-	-	-	-	-	-	-
	Total	15995	16538	10049	1954	2905	2159	1890	

Data Source: ILO (2000).

Figure 1. Multiple Equilibria due to Market-Seeking FDI for Economies with Identical Parameters

Figure 1.1 Country 2 Diverges from Country 1

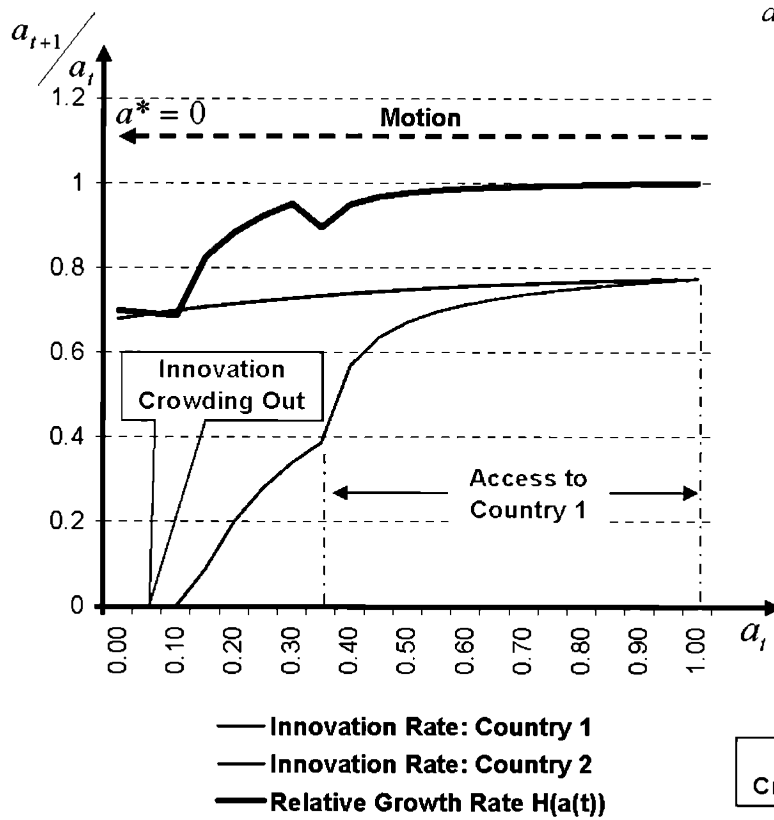

Figure 1.2 Country 2 has Two Equilibria: 1) Divergent; 2) Parallely Lagging

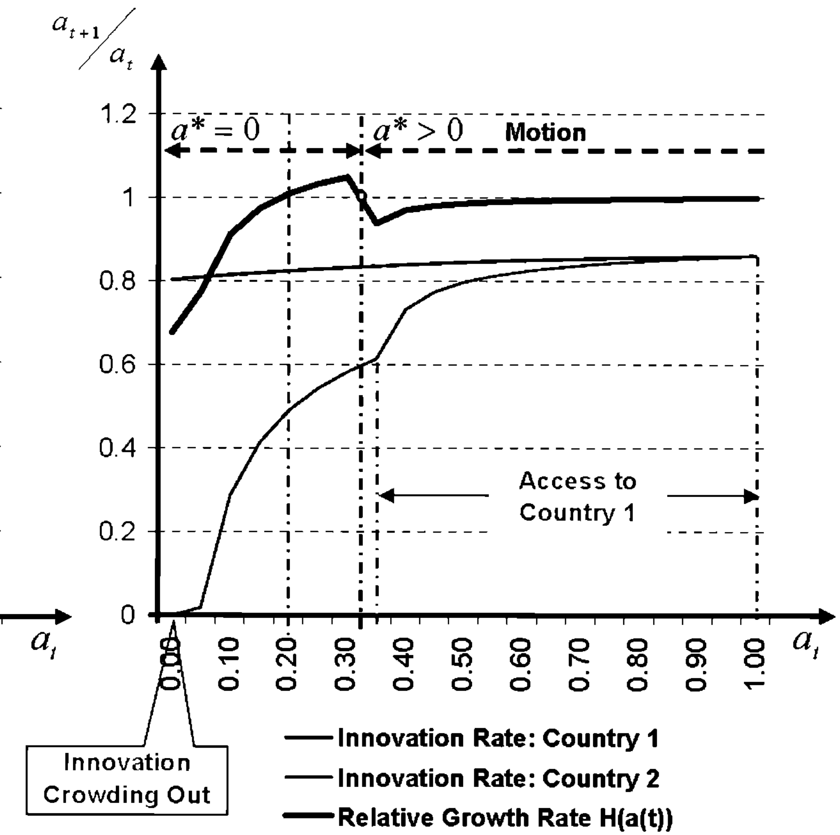

Figure 2. Multiple Equilibria due to Market-Seeking FDI for Identical Economies

Figure 2.1 Country 2, at a Low Parallel Steady State, Raises FDI Technological Transfer and Grows to an Innovative Steady State

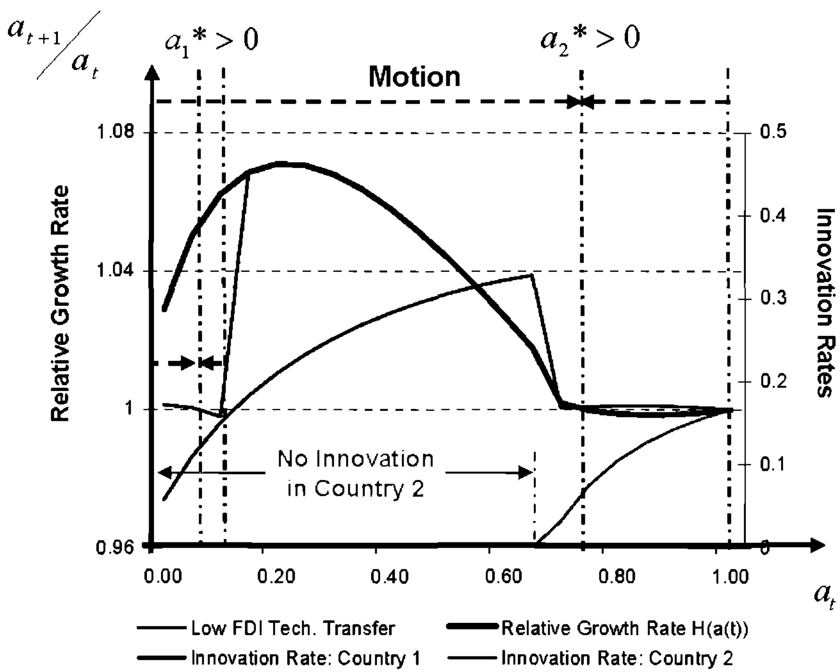

Figure 2.2 Country 2, at a Divergent Steady State, Raises FDI Technological Transfer and Grows to a Non-Innovative Steady State