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# Optimizing international technology diffusion: A middle-income country's perspective

Hwan C. Lin

*Department of Economics, University of North Carolina at Charlotte, 9201, University City Blvd., Charlotte, NC 28223, United States*

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ABSTRACT

The paper develops a North–Middle–South model to formulate a middle economy that plays catch-up via imitative R&D to acquire newer technologies from a higher-wage innovative forerunner, while playing "reverse catch-up" via outbound FDI to transfer older technologies to a lower-wage follower. A critical policy dilemma facing the middle economy is how to balance its R&D-driven technology inflows against its FDI-driven technology outflows. Numerical simulations are used for dynamic welfare analysis. This paper finds that tightening FDI permits the middle economy to keep a lower saving rate without weakening its ability to acquire newer technologies in the long run.



## 1. Introduction

As Keller (2004) points out, only a few rich countries account for most of the world's creation of new technology.[1] Today most economies are neither leaders nor followers outright in global technological races. As the world's middle economies, they often find themselves playing catch-up via imitative R&D (Research and Development) to acquire newer technologies from their higher-wage innovative forerunners while playing reverse catch-up via outbound FDI (Foreign Direct Investment) to transfer older technologies to their lower-wage followers that also play catch-up. Both imitation and FDI therefore play a key role in global technology diffusion.[2]

For a middle economy, technology acquisition via imitative R&D enables domestic imitators to under-price foreign innovative producers and extends the middle economy's technology frontier, whereas technology transfer via outbound FDI allows domestic firms to profit by shifting production to a lower-wage developing region. But imitative R&D and outbound FDI must compete for domestic resources. Though an economy's outbound FDI can free up some domestic resources (say, production workers) by displacing domestic production, it often chokes off some other domestic resources (say, managers, engineers, scientists, etc.) that would otherwise be employed internally for imitative R&D.

A critical policy issue facing many middle economies, even in the developed world, is how to balance imitative R&D-driven technology inflows against outbound FDI-driven technology outflows. This policy issue is of great importance but was not duly addressed in the literature. Relevant to the present paper, for instance, are North–South models, which were pioneered by Krugman (1979), Dollar (1986) and Jesen and Thursby (1987). These models had been used to study North–South trade and the welfare effects of interregional technology diffusion, usually with intellectual property rights (IPRs) or R&D subsidies serving as policy variables; see Chin and Grossman (1990), Diwan and Rodrik (1991), Deardorff (1992), Helpman (1993), Grinols and Lin (1997, 2006), Zigic (1998), Lin (2002), Grossman and Lai (2004), and others. Almost all North–South models in the literature share the same structural feature that North is a technological forerunner and South is the only follower that plays catch-up. Such models cannot represent a global environment where a middle economy plays catch-up via imitative R&D, on the one hand, and plays reverse catch-up via outbound FDI, on the other hand.

The case of Taiwan as a newly industrialized economy, for example, especially needs a model that can better address a policy dilemma the Taiwanese government faces in managing its economic relationship with China:[3] namely, should the Taiwanese government further lift its policy restrictions on its domestic firms' China-bound

*E-mail address:* hwlin@uncc.edu.

[1] The world's research and development (R&D) spending is extremely concentrated in a few advanced countries. For instance, the largest seven industrialized countries (so-called G-7) made up about 84% of the world's R&D spending in 1995; see Footnote 3 of Keller (2004).

[2] In general, international technology diffusion can stem from FDI, international trade in intermediate goods, and imitative activities; see Rivera-Batiz and Romer (1991), Grossman and Helpman (1991), and Eaton and Kortum (2002), and Keller (2004).

[3] In view of technological capacity and income levels, Taiwan is more like a middle economy and China remains a Southern economy. The United States Patent and Trade Mark Office (USPTO) issued 196,436 patents in total in 2006. Of the total patents, the U.S. received 52%, followed (in descending order) by Japan's 20%, Germany's 5.5%, Taiwan's 4%, South Korea's 3.3%, U.K.'s 2.2%, Canada's 2.1%, and France's 2.0%. The world's two most populated countries, China and India, merely received 0.49% and 0.26%, respectively.

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FDI across the Taiwan Strait? Many argue that as a much-populated developing economy, China is not only a low-cost “world plant” but also a big emerging market; so Taiwan may risk being regionally marginalized if the island economy is refrained from a deeper integration with China. But some others are of the opposing view that Taiwan has over-invested in China since the early 1990s; so Taiwan may risk being internally hollowed if the Taiwanese government does not take policy action to prevent Taiwan's China-bound investment from crowding out resources that would otherwise be used to play catch-up to the world's technological forerunners.[4] Fig. 1 portrays Taiwan's lackluster economic performance since the early 1990s:[5] The annual growth rate of real GDP had largely trended down with a sharp fall of the annual growth rate of real monthly wages in manufacturing industry, while as a fraction of its GDP, Taiwan's China-bound FDI had trended up and recently surpassed its overall R&D.[6,7]

For a middle-income country like Taiwan, South Korea, or other newly industrialized economies in the world, does there exist any room for government intervention in balancing its FDI-driven technology outflows against its R&D-driven technology inflows? Evidently, to address this policy issue, the international economics literature calls for an appropriate model that allows an economy to play both catch-up and reverse-catch-up in the global technological race. This is where the present paper seeks to make a contribution.

For the aforementioned purpose, we develop a three-country, North–Middle–South model to incorporate three technologically differentiated economies. We formulate a middle economy (country II) that plays catch-up via imitative R&D to acquire newer technologies from a higher-wage innovative forerunner (country I), while playing reverse catch-up via outbound FDI to transfer older technologies to a lower-wage follower (country III) that also plays catch-up. We assume that country I innovates new goods at an exogenous rate and specializes in production of innovative goods under monopolistic competition. This assumption can be justified by viewing the middle economy as a small one so that its policy intervention exerts no effects on the innovation rate in the developed world. By contrast, the middle economy needs to devote resources to production of imitative goods, imitative R&D, and outbound FDI. Imitative R&D is intended to acquire newer technologies from country I, thereby increasing the number of imitative goods produced in country II, whereas outbound FDI is intended to transfer older technologies, thereby shifting production of imitative goods to country III. Such outbound FDI creates an externality by unintentionally making a pool of older technologies accessible to the local firms of the FDI-host economy (country III). Hence, any incumbent firm in the world faces the risks of being displaced by lower-cost imitators over time. This gives rise to a dynamic “commoditization” process in which product prices continue to fall with technology diffusion till those products have become ordinary commodities produced by perfectly competitive firms in country III.

As will be shown, the three-country model reduces to a nonlinear autonomous system of four ordinary differential equations. This often presents a challenge of analytical tractability and calls for numerical

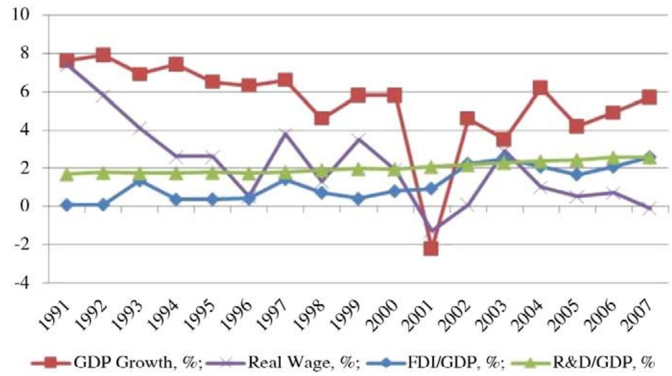


**Fig. 1.** Taiwan's annual changes in real GDP and real wage and its annual ratios of China-bound FDI/GDP and R&D/GDP.

simulations. Assuming the system begins with a steady state, we conduct small-dose policy experiments with country II tightening its FDI-driven technology outflows, perhaps for fear of being internally hollowed, as in the case of Taiwan. With computational analysis, we cope with the system's dynamics in transition to steady state, particularly with respect to the motions of international technology diffusion, resource reallocations, terms of trade, FDI profits, and welfare.[8] While policy intervention causes complicated transitional and steady state impacts via multiple avenues in the model, we can measure different sources of policy-induced impacts on welfare. Results of our numerical simulations are summarized as follows:

1. A tightening of outbound FDI by country II decreases the average rate of return on overall investment activities (imitative R&D and outbound FDI) and forces these activities to free up resources for domestic production of more imitative goods in the FDI-source economy in the short run, which we termed the *resource-diverting* effect. But in the long run, a *policy-discriminating* effect will gradually set in and eventually become dominant so as to redirect resources back into imitative R&D, in fact, as an intended policy goal. Therefore in the long run, the R&D-driven imitation rate is seen to bounce back after its earlier fall and eventually to stay above its initial steady state level, in contrast to the FDI-driven technology transfer rate. Surprisingly but logically, tightening FDI permits country II to keep a lower saving rate permanently without weakening its ability to acquire newer technologies in the long run, since the policy-discriminating effect is seen to dominate the resource-diverting effect eventually.
2. With the two resource reallocating effects mentioned above, tightening FDI can slow down global technology diffusion in the short run but hastens it in the long run; deteriorates country II's external terms of trade in the short run but improves it in the long run; and enlarges both the losses of country II's FDI profits (as a proportion of its domestic production value) and monopoly distortions in transition to steady state. Surprisingly, the extent of long-run technology diffusion to country III turns out to be greater (not smaller) than in the initial steady state.
3. Tightening FDI generates different sources of gains and losses that largely offset one another in transition. The largest source of welfare gains to country II is the permanent decrease in the saving rate, whereas the largest source of losses is the permanent decrease in FDI profits. Country II may or may not have a net welfare gain in transition to steady state, mainly subject to the consumer's time tolerance about delayed consumption. However, the transitional

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[4] Such a concern was incessantly raised, notably, by Mr. Tien-lin Huang, Taiwan's former national policy adviser to the president; see, for instance, “Heeding an ‘economic one China’,” The Taipei Times, July 6, 2007: http://www.taipeitimes.com/News/editorials/archives/2007/07/06/2003368330.

[5] The data are official figures from *Taiwan Statistical Databook* (2008), published by Council of Economic Planning and Development, Executive Yuan, R.O.C. (Taiwan).

[6] We should notice that more than 70% of Taiwan's overall outbound FDI now is concentrated in China, and that its officially reported China-bound FDI was notoriously underestimated because many Taiwanese businessmen indirectly remitted investment funds to China through British Virgin Islands and Cayman Islands (see Morrison 2005).

[7] Whether or not Taiwan's China-bound FDI had crowded out or had allayed the pressure to push its R&D indeed remains an empirically open question. But it is true that Taiwan's overall R&D had failed to reach 3% of its GDP, a high mark that the former DPP government previously aspired to attain and that some other countries such as Finland, Japan, and South Korea had already surpassed.

[8] In the North–South IPR literature, most studies are confined to steady state analysis. Grinols and Lin (1997, 2006) are the few exceptions that deal with both transitional dynamics and steady state.