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# The Role of the Government in Facilitating TFP Growth during Japan's Rapid Growth Era

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## Abstract

Japan experienced high growth of TFP following World War II. This paper studies the sources of this technological growth and documents the role played by different government policies in achieving such growth. We find that in non-agricultural sectors, TFP growth occurred at first through the import of foreign technologies via licensing, and subsequently through the innovation of its own technologies. In agriculture, TFP grew mostly through the development of its own technologies. The Japanese government played a part in the growth of TFP by directing the adoption of foreign technologies, promoting coordination of R&D activities, and setting up channels for the domestic diffusion of available technologies.

Keywords: TFP, Japan, Government Policies

JEL Classification: O33, N15, Q16

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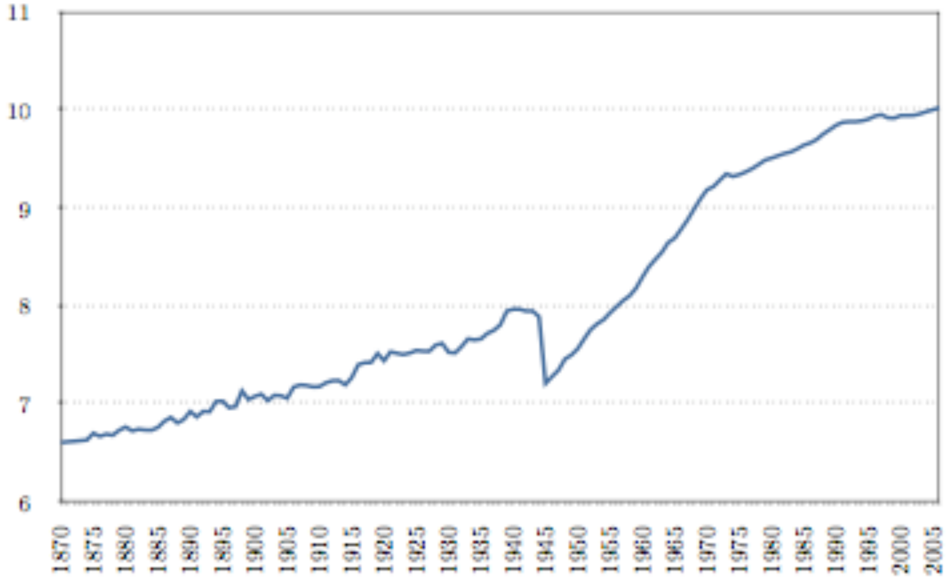
## 1. Introduction

It is widely known that Japan experienced rapid economic growth in the late 1950s and 1960s, when per capita gross domestic product grew at a remarkable rate of over 10 percent (Figure 1). There are numerous books and academic papers written on the reasons behind this success of the postwar Japanese economy. Some studies rely on descriptive macro-level statistics (Inada et al., 1993; Kosai and Kaminski, 1986; Minami, 1994; Nakamura, 1995; Ohkawa and Rosovsky, 1973) and others employ the growth accounting framework to decompose the high growth rate into different factors (Denison and Chung, 1976; Young, 1995; Hayami and Ogasawara, 1999, 2002; Yasuba, 2002). More recent works on the Japanese economy rely on modern calibration techniques to replicate the postwar rapid growth (Parente and Prescott, 2004; Chen, Imrohologlu, Imrohologlu, 2006; Braun, Ikeda and Joines, 2009; Braun, Esteban-Pretel, Okada and Sudou, 2006; Otsu, 2007).

**Figure 1: Japan's Gross Domestic Product per capita**



Source: Professor Angus Maddison's Database <http://www.ggdc.net/maddison/>.

There is an emerging consensus both in the growth-accounting studies, such as Young (1995) and Hayami and Ogasawara (1999), and in the calibration works, such as Otsu (2007) and Esteban-Pretel and Sawada (2009), that Japan's postwar rapid growth was driven by a high growth rate of total factor productivity (TFP). These studies, while careful in their analysis and accurate in their results, assume that the evolution of TFP is exogenous to their models, and, thus, do not address questions related to the sources of the high rates of TFP growth. However, uncovering the determinants of TFP growth is important, especially when studying government policies, since some of these policies could have affected the economy by influencing TFP.

This paper studies the main forces behind the high growth of Japanese TFP in the postwar period, and the role that the government played in the evolution of Japanese technology. To do so, we first review the growth literature and expose the main determinants of long-run growth and development, and the diffusion of new technologies. We show that the determinants of TFP are multi-faceted. Theoretically, the level of TFP and its growth may be determined by endogenous human capital investment decisions, international technological transfers, firms' research and development decisions, or government support to research and development (R&D) activities, as well as to agricultural research and extension (R&E) activities.

For the case of postwar Japan, we argue that it is necessary to analyze the evolution of TFP for the agricultural and non-agricultural sector separately. This is due to the changing level of economic development of the Japanese economy in the postwar period, and the initial importance of the agricultural sector, both in the share of employment and total output, right after the war.

We show that, for the non-agricultural sector, technology improvement in the early years following WWII started with the import and licensing of specific foreign technologies. With time, the adoption of foreign technologies was gradually replaced by the development of Japan's own domestic technologies. We argue that the government played a role in both stages, although it is not always clear whether the influence was positive or negative. In terms of the adoption phase, the main impact of the government was through heavily regulating the number and types of technologies which companies were allowed to license and import from foreign firms. As for the phase of the development of new technologies, the stage in which the Japanese economy is still immersed, the government has not contributed as much as governments in other developed countries in terms of expenditures. However, it is argued that its main influence has been through the establishment of R&D consortia, and by not affecting the R&D industry with distortionary subsidy systems, and finally by not strengthening patent laws.

The agricultural sector followed a different process than the non-agricultural sector. Due to the difficulties associated with adopting agricultural technologies by countries with very different climates and landscapes, TFP in this sector has been mostly increasing due to the development of own technologies. The role of the Japanese government in the growth of TFP in the agricultural sector was primarily through the promotion of R&E activities, which helped the implementation and diffusion of many locally developed technologies. It also played a role in the development of high-yield varieties of farm products, which have been argued to be crucial to the growth of agricultural TFP.

In terms of the domestic diffusion of technologies within Japan, both for the case of imported and locally developed ones, the main factors that explain this are the high level of human capital of the population, the quality and quantity of infrastructures, and a patent system that facilitated imitation. The Japanese government played an important part in all of these, both by providing financial support and the necessary organizational infrastructure.

The remainder of this paper is organized as follows. Section 2 reviews the main theories and empirical studies on the development and diffusion of new technologies. In Section 3 we decompose aggregate Japanese TFP into agricultural and non-agricultural sectors, and explain their main characteristics. In Section 4, we present evidence of technology adoption and innovation in postwar Japan in the non-agricultural sector. Section 5 discusses the determinants of agricultural TFP. In Section 6 we focus on the domestic diffusion of technology. Finally, Section 7 summarizes and concludes.

## 2. Development and diffusion of new technologies: A review of theories

In this section we provide an overview of different theories and empirical studies that have been put forward in the literature to explain the growth and development of technology, as well as its diffusion across countries.[1]

### 2.1. Technological Growth

One of the workhorses of many macroeconomic models with growth is the neoclassical growth model developed by Solow (1956) and Swan (1956). The model assumes a production function with constant returns to scale and diminishing productivity of each input, and a constant savings rate. Cass (1965) and Koopmans (1965) introduced consumption optimization into the Solow-Swan model, which provided an endogenously determined savings rate. The neoclassical growth model, while standard and used in many types of analysis, assumes that long-run economic growth is exogenous to the decisions of the agents and driven by exogenous technological progress.

During the second half of the 1980s several models were developed to endogenize the

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[1] For a more comprehensive review of the economic growth and technological diffusion literatures, see Aghion and Howitt (1988), Barro and Sala-i-Martin (2004) and Keller (2004).

growth rate of the economy. Papers such as Romer (1986), Lucas (1988) and Rebelo (1991) build models where different Marshallian externalities deliver endogenous long-run growth. In Romer (1986) firms use an increasing returns to scale production function, where knowledge is accumulated through the investment in private capital, which in turn increases the aggregate level of knowledge in the economy and fosters economic growth. Lucas (1988) and Rebelo (1991) build models where the production of final output involves the use of both physical and human capital. Human capital is accumulated over time with the use of previously available human capital,[2] and is readily available in the economy. This externality is what delivers endogenous growth in these two models. The implication of the existence of knowledge spillovers in these endogenous growth models is that the decentralized equilibrium is not efficient, since it fails to internalize the benefits of private investment in physical or human capital in the aggregate knowledge in the economy. These models, while producing endogenous long-run economic growth, still do not address the core question of what lies beneath the development of new technologies and its diffusion across countries. However, it was not long before models addressing these issues were built.

Models of technological development can be broadly split into two categories: (i) new variety models; and (ii) quality ladder models. Both types of models deliver endogenous technological progress through the investment of firms in research and development (R&D), which is translated into new technologies that are used by final output producing firms. Since the creation of new technologies involves an ex-ante sunken cost in R&D, it is crucial to assume that research firms are granted some kind of monopoly over such technologies, so that firms have incentive to undertake the research investment.

A pioneer in the models of expanding varieties is Romer (1990). In his model, research firms incur the cost of developing new varieties of intermediate goods, which are sold in monopolistically competitive markets at a premium over the marginal cost to the firms that produce the final output. The creation of new varieties, which is interpreted as new technologies, delivers or affects growth in two ways. First, it directly increases the level of technology used in current production, and second, it eases the creation of future new technologies, which build on existing knowledge.

Two main references of quality ladder models are Aghion and Howitt (1992), Grossman and Helpman (1991). These models consider that the number of varieties is fixed, and attribute the

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[2] In the case of Rebelo (1991), physical capital is used to produce human capital.

growth of technology of the economy to increases in the quality of the existing number of goods. As in the case of expanding varieties models, research firms incur the cost of developing the new technologies, which they sell over the marginal cost to recover the sunken investment. However, these models have the property that every time an improvement in the quality of a good occurs, a Schumpeterian creative destruction effect takes place. The development of higher quality products makes the previous goods with lower quality obsolete, and therefore destroys the value of existing firms.

There is another less-known strand of literature that hypothesizes that technological innovations are driven by the scarcity of production factors. This hypothesis, which has come to be known as the induced technological innovation hypothesis, was first formulated by Hicks (1932) and further developed by Hayami and Ruttan (1971 and 1985) in the context of agricultural technological innovations. These models show that innovations are directed toward technologies that use smaller amounts of relatively scarce resources. The reason is that the scarcity of factors of production impacts the relative price of inputs and has a clear effect on the incentives for innovation on certain technologies that save such scarce inputs. In this context, Binswanger (1974) formalized the induced technological innovation theory using the duality framework.

Due to the fact that the development of new technologies affects the pace of future technology growth, as in the new variety models, or destroys the profits of existing firms, as in the quality ladder models, the decentralized equilibrium is in general not efficient. This leaves room for government interventions to bring the economy to the social optimum. One clear policy is the promotion of research activities, which can be implemented by subsidizing the cost of R&D for firms, or directly performing the research through government institutions, such as research centers and universities. Other policies that the government can introduce include the sponsorship of the new technologies by firms through subsidies to their adoption costs, or the subsidization of the cost of final goods, since their production requires intermediate goods that use the new technologies. Since the excludability of ideas provides the right incentives for innovations in the Romer (1990) model, the enforcement of the property rights of new patents is essential in the previous theoretical frameworks. Hence, this is clearly an area where the government plays an important role.

## 2.2. Technological Diffusion

While technological improvement is crucial for the growth of an economy, many countries do not develop new technologies themselves. Instead, they import and adopt technologies created abroad, and it is this absorption of foreign technologies that allows them to grow. This is particularly true for developing countries where a major source of technological progress is import of advanced technologies from developed economies (Hayami and Godo, 2005, p. 188).

The economic literature has pointed out several channels of international diffusion of technologies. Some of the most important ones are international trade, foreign direct investment, licensing and imitation. Each of these channels affects the manner and speed in which technology spreads and is adopted in the different countries.

International trade diffuses the available technologies through the goods that a country imports. New technologies can be imported and used as intermediate inputs in the production process, which generates the improvement of the overall technological level of the economy. The introduction of new technologies by importing technologically advanced goods may be much less costly than the local development, or even production of such products, thereby providing countries that are not on the technology frontier with access to such advanced products, and the growth associated with them. Eaton and Kortum (2001 and 2002) are prime examples of papers with models in which trade provides access to foreign technologies through imported goods. In their model, trade expands the production possibility frontier of the country and delivers economic growth. The empirical literature (e.g. Coe and Helpman, 1995; Coe et al., 1997; Xu and Wang, 1999) shows that while imports of intermediate goods (especially capital) seem to be important for the diffusion of technology, exports do not seem to play an important role.

Foreign direct investment (FDI) has long been considered as a major determinant of the international diffusion of technology. In this literature, some studies (e.g. Markusen, 2002) show how technology may flow from one country to another when multinational corporations use firm-specific technologies in local subsidiaries. Other studies, such as Fosfuri et al. (2001), stress the role of training at big international firms as an important way to spread knowledge to the countries where the FDI takes place.

Another way in which countries can have access to foreign technologies is through the direct licensing of such technologies. Companies can pay for the right to use specific techniques, processes or machinery in their own production lines. The capability of using the most advanced technologies gives these firms the ability to produce at the maximum capacity, and grants them an edge over the competition, allowing the economy to grow beyond the domestic possibilities.

One final and important way in which technology moves around and gets adopted, is through imitation. While the imitation of products requires some degree of research and development, the cost of imitation is normally lower than the cost of innovation, and therefore, many companies and countries that are not on the technological frontier use this. Barro and Sala-i-Martin (1997) build a model of imitation, where property rights are not internationally enforced, and firms in the country which is the follower are able to extract the benefits from the leader's firms by imitating their technologies and selling them in the local market.

Many factors have been argued to affect the level, speed and channel through which technology is diffused across countries. Some of the most important factors are the economic differences between the country of origin and the receiving one, the level of R&D and the cost of imitation in the receiving economy, and the level of human capital, both in absolute terms and relative to the country where the technology is developed.

Differences in the levels of economic development, quality of institutions, culture, geographical distance, climate or educational level of the population, are crucial determinants of the costs for companies, both foreign and local, to set up FDI, license technologies, or imitate existing technologies. Several empirical studies (e.g. Jaffe et al., 1993; Branstetter, 2001; Eaton and Kortum, 1999) find that technological diffusion occurs faster and more frequently within a given country, where the previous differences are small, than across countries, where they are likely to be big, especially with distantly located, less developed countries.

The level of human capital and of R&D expenditures has also been emphasized as a necessary condition for the diffusion of technology. The idea is that for a country to be able to import, adapt and absorb new technologies, it must have a certain stock of knowledge and technology. The work of Eaton and Kortum (1996), Xu (2000), and Benhabib and Spiegel (2005) shows that without basic know-how and the ability to learn and adapt more advanced technologies, technological diffusion is much more difficult and less likely to take place.

The previous factors are not only important for the dissemination of technology across countries, but they also play a crucial role in diffusing technologies within a country. The theoretical models reviewed above, as well as most of the other existing models in the literature, assume that once a new technology is developed or imported, it is instantaneously available for use at other firms in the same country. However, in reality the domestic diffusion of technology is also affected by the factors stated above, as well as by other factors such as the level of infrastructure of the economy.

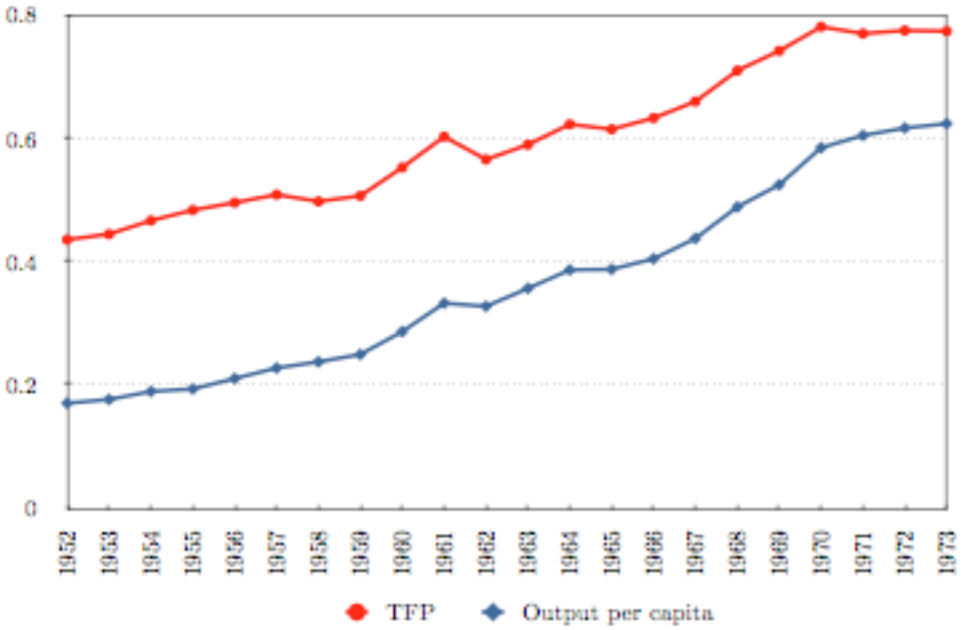
Given the previous channels and factors that determine international and domestic technology transfers, there are several policies that governments could institute to increase the rate of such diffusion. Some of these policies include the promotion of education to facilitate the absorption of knowledge, the subsidization of research and development to incentive firms to imitate and adapt existing technologies, the enforcement of patent laws if the objective is to attract FDI, and the negotiation and help for the licensing of key technologies.

## 3. Evidence on overall Japanese TFP and its sectoral decomposition

As the models discussed in the previous section emphasize, the innovation and adoption of new technologies are the two key driving forces of the TFP growth. The following sections review how new technologies were created and diffused, and how the government facilitated these processes in the Japanese postwar economy.

When the Second World War (WWII) ended in 1945, the Japanese economy found itself far behind the technology frontier of the world. In 1964, the Agency of Industrial Science and Technology, which was in charge of industrial research and development under the Ministry of International Trade and Industry (MITI), looked back at the 1940s and 1950s and wrote: “The technology gap between Japan and the advanced countries in the prewar period was preserved, and it further expanded due to the vacuum of technology adoption during the war” (Agency of Industrial Science and Technology, 1964). Indeed, in 1952 the productivity gap between Japan and U.S. was substantial in the early postwar period. According to the estimate by Christensen et al. (1995), Japanese TFP was as low as 43% of that of the U.S. However, the productivity of the Japanese economy increased rapidly after that, and it became 80% of that of the U.S. in the early 1970s, when the high growth came to an end (Figure 2).

**Figure 2: Productivity of Japan relative to the U.S.**

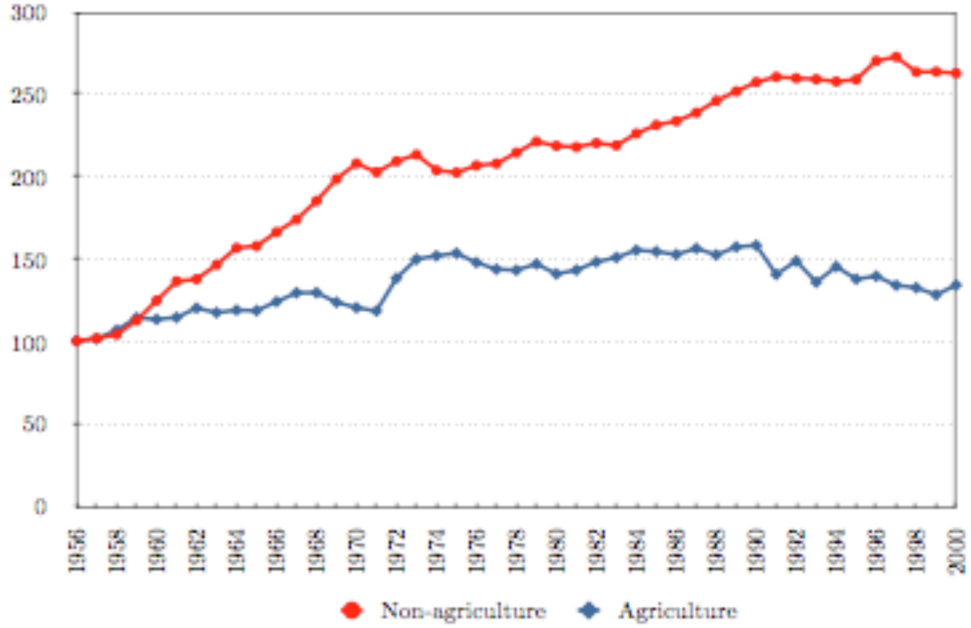


Source: Christensen, Cummings and Jorgenson (1995), pp.316-320.

In the following sections, we divide the economy into the agricultural and non-agricultural sectors. The reason behind this division is two-fold. First, right after WWII, the share of output and employment in the agricultural sector was more than 50%. As is shown in Esteban-Pretel and Sawada (2009) accounting for the structural change that took place in Japan in the postwar period is essential to understand the rapid growth era. During a structural change process, TFP growth, or more precisely, labor productivity growth in the agricultural sector is an important determinant of economic growth. In models with non-homothetic preferences (e.g. Eswaran and Kotwal, 1993; Gollin, Parente, and Rogerson, 2007; Esteban-Pretel and Sawada, 2009), households first consume the subsistence level of food that is essential for their survival, and then consume other goods such as manufacturing goods or services. In such models, if agricultural TFP level is low, even if the TFP level in the non-agricultural sector is high, the economy needs to allocate a large fraction of resources to unproductive food production, which reduces economic growth.

Second, while the adoption of foreign technologies in the manufacturing sector is widespread and has been documented for many developing economies, the international diffusion of agricultural technologies is often very difficult due to differences in climate and other farming conditions. As we discuss later, given these difficulties, the Japanese agricultural sector was forced to innovate independently, while in the other economic sectors the adoption of foreign technologies was more common, at least right after WWII.

**Figure 3: Sectoral Total Factor Productivity**



Source: Esteban-Pretel and Sawada (2009) dataset. Note: Labor input is total hours.

Figure 3 shows the evolution of TFP in the agricultural and non-agricultural sectors in postwar Japan. We can observe that both TFP series increase significantly until the first oil crisis, although the growth rate of non-agricultural TFP was significantly higher than that of agriculture.

In order to further understand the relative contribution of the sector-specific TFP to the overall TFP level, we decompose aggregate TFP, $A$, into four components: Agricultural TFP, $A_a$, non-agricultural TFP, $A_m$, and the contribution of the reallocation of capital and labor. We follow Syrquin (1984) and Basu and Fernald (2002) and decompose aggregate TFP as follows:

$$\frac{\dot{A}}{A} = s_{Va}\frac{\dot{A}_a}{A_a} + s_{Vm}\frac{\dot{A}_m}{A_m} + \sum_{i\in\{a,m\}} s_{Vi}s_{Ki}\left[\frac{r_i - r}{r_i}\right]\frac{\dot{K}_i}{K_i} + \sum_{i\in\{a,m\}} s_{Vi}s_{Li}\left[\frac{w_i - w}{w_i}\right]\frac{\dot{L}_i}{L_i}$$

where $K$ is capital; $L$ is labor; $r$ and $w$ are capital and labor returns, respectively; $s_{Vi}$, $s_{Ki}$, and $s_{Li}$ are the nominal value added share, capital share, and labor share of sector $i$, respectively. Note that variables without subscripts denote aggregate levels, and those with subscripts are those in the agriculture ($a$) or non-agriculture ($m$) sectors. The final two terms on the right-hand side of the previous equation are the ‘growth bonus’ effect arising from reallocating capital and labor from a low to a high marginal productivity sector. When capital or labor are reallocated to a sector with higher marginal product, the third and fourth terms are positive. We refer to these last two terms as the capital and labor reallocation effects.

Table 1 shows the decomposition of aggregate TFP for various subperiods starting in 1956. We can see that the main contributors to aggregate TFP growth are non-agricultural TFP and the reallocation of labor. Both terms are high during the rapid growth era, from 1956 to 1973. The importance of the labor reallocation effect is consistent with the findings of Hayashi and Prescott (2008) and Esteban-Pretel and Sawada (2009), which show that the elimination of migration barriers from rural to urban areas can be seen as one of the important determinants for Japan's postwar economic miracle.[3] The contribution of agricultural TFP is low, which is partly due to the declining share of agricultural production in total output over the period of study.

**Table 1. TFP Decomposition**

| | Aggregate TFP | Agr. TFP | Non-agr. TFP | Capital reallocation | Labor reallocation |
|---|---|---|---|---|---|
| 1956-73 | 4.78% | 0.11% | 3.96% | 0.05% | 0.66% |
| 1973-83 | 0.50% | 0.00% | 0.25% | 0.04% | 0.21% |
| 1983-91 | 2.26% | -0.01% | 2.13% | 0.01% | 0.13% |
| 1991-2000 | 0.17% | -0.01% | 0.09% | 0.01% | 0.08% |

Source: Esteban-Pretel and Sawada (2009) dataset. Note: Labor input is total hours.

## 4. Technology adoption and innovation in the non-agricultural sector

The previous section showed the importance of non-agricultural TFP in the overall growth of aggregate TFP. We now move to study the way this high increase of non-agricultural technology occurred in Japan.

As explained in Section 2, for countries that are on the technology frontier the development and innovation of new products and techniques precedes the process of international diffusion. However, for a country like Japan in the early postwar period, the order of these processes was reversed. Initially Japan relied on imported foreign technologies, and later started the development of its own technologies. This sequence, which is also observed in other countries

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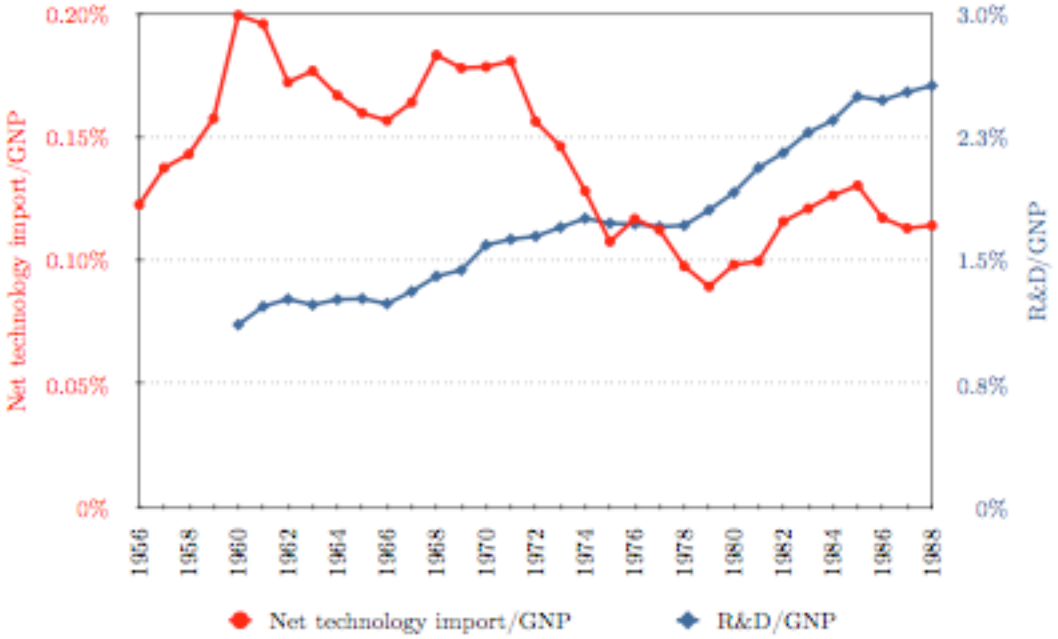
[3] Mundlak and Strauss (1978) show that income differentials between the agriculture and non-agricultural sectors were important in determining the rate of migration out of the agricultural sector in Japan.

that are not the technology leaders, can be clearly seen in Figure 4. The ratio of net technology imports to GNP, which was initially high, has declined gradually over time. Simultaneous into this decline, Japan experienced a rise in the ratio of R&D expenditures to GNP. This indicates that over time Japan substituted the import and adoption of foreign technologies for the development of their own. We now study these two processes in more detail.

**Figure 4: Adoption and Innovation of Technology**



Source: Science and Technology Agency (1972, 1974, and 1991) and SNA. Note: The left axis is for "net technology import/GNP," while the right is for "R&D/GNP."

### 4.1. Technology adoption

As can be seen in Figure 2, the technology gap between Japan and the U.S. was greatly reduced during the 1950s and 1960s. Furthermore the high growth of Japanese TFP was mostly due to the growth of non-agricultural TFP. A major driving force of this rapid technological progress in the decades following WWII was the adoption of foreign technologies. Figure 5 shows the trend of technology adoptions quantified by the number of "Type A" technological assistance contracts, i.e., contracts whose terms were longer than one year, from 1950 to 1979. While the number of technology adoptions per year was around 100 until 1959, it increased to around 2,000 by the late 1960s. Breaking down these numbers by industry, we find that they concentrated in a few industries, i.e. chemical products, general machinery and electric machinery, from the 1950s to the 1970s (Table 2). The proportion of these three industries was

62% in the 1950s and 1960s.

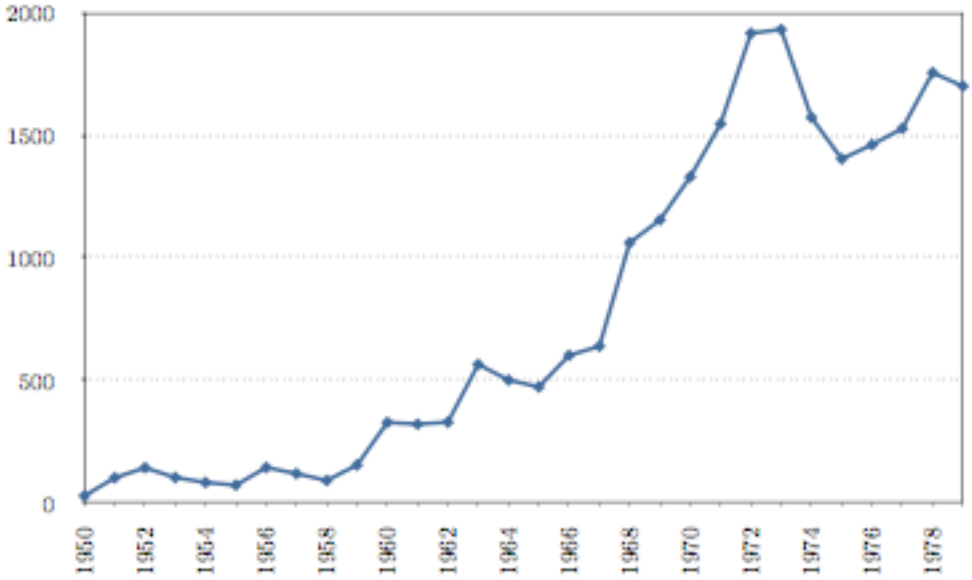
**Table 2: Number of Licenses**

| | 1950-1954 | 1955-1959 | 1960-1964 | 1965-1969 | 1970-1974 | 1974-1979 |
|---|---|---|---|---|---|---|
| **Number** | | | | | | |
| Total | 454 | 575 | 2,039 | 3,926 | 8,295 | 7,846 |
| Chemical products | 82 | 116 | 280 | 678 | 1,048 | 808 |
| Petrochemical plant engineering | 0 | 19 | 38 | 73 | 82 | 92 |
| Petroleum and coal products | 15 | 17 | 24 | 73 | 217 | 84 |
| Iron, steel and non-ferrous metals | 38 | 56 | 96 | 181 | 201 | 147 |
| Fabricated metal products | 6 | 20 | 74 | 124 | 225 | 217 |
| General machinery | 98 | 120 | 589 | 1,021 | 1,973 | 1,759 |
| Transportation equipment | 42 | 34 | 94 | 209 | 438 | 391 |
| Precision instruments and machinery | 0 | 8 | 48 | 125 | 261 | 304 |
| Electric machinery | 108 | 109 | 469 | 664 | 1,251 | 1,451 |
| Food and tobacco | 0 | 1 | 8 | 58 | 260 | 151 |
| Textile products | 24 | 33 | 83 | 172 | 794 | 1,060 |
| Ceramic, stone and clay products | 10 | 8 | 45 | 81 | 206 | 134 |
| Plastic products | 1 | 5 | 94 | 209 | 403 | 187 |
| Others | 30 | 29 | 97 | 258 | 936 | 1,061 |
| **Percentage** | | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Chemical products | 18.1 | 20.2 | 13.7 | 17.3 | 12.6 | 10.3 |
| Petrochemical plant engineering | 0.0 | 3.3 | 1.9 | 1.9 | 1.0 | 1.2 |
| Petroleum and coal products | 3.3 | 3.0 | 1.2 | 1.9 | 2.6 | 1.1 |
| Iron, steel and non-ferrous metals | 8.4 | 9.7 | 4.7 | 4.6 | 2.4 | 1.9 |
| Fabricated metal products | 1.3 | 3.5 | 3.6 | 3.2 | 2.7 | 2.8 |
| General machinery | 21.6 | 20.9 | 28.9 | 26.0 | 23.8 | 22.4 |
| Transportation equipment | 9.3 | 5.9 | 4.6 | 5.3 | 5.3 | 5.0 |
| Precision instruments and machinery | 0.0 | 1.4 | 2.4 | 3.2 | 3.1 | 3.9 |
| Electric machinery | 23.8 | 19.0 | 23.0 | 16.9 | 15.1 | 18.5 |
| Food and tobacco | 0.0 | 0.2 | 0.4 | 1.5 | 3.1 | 1.9 |
| Textile products | 5.3 | 5.7 | 4.1 | 4.4 | 9.6 | 13.5 |
| Ceramic, stone and clay products | 2.2 | 1.4 | 2.2 | 2.1 | 2.5 | 1.7 |
| Plastic products | 0.2 | 0.9 | 4.6 | 5.3 | 4.9 | 2.4 |
| Others | 6.6 | 5.0 | 4.8 | 6.6 | 11.3 | 13.5 |

Source: Science and Technology Agency ed. (1980).

**Figure 5: Technology imports**

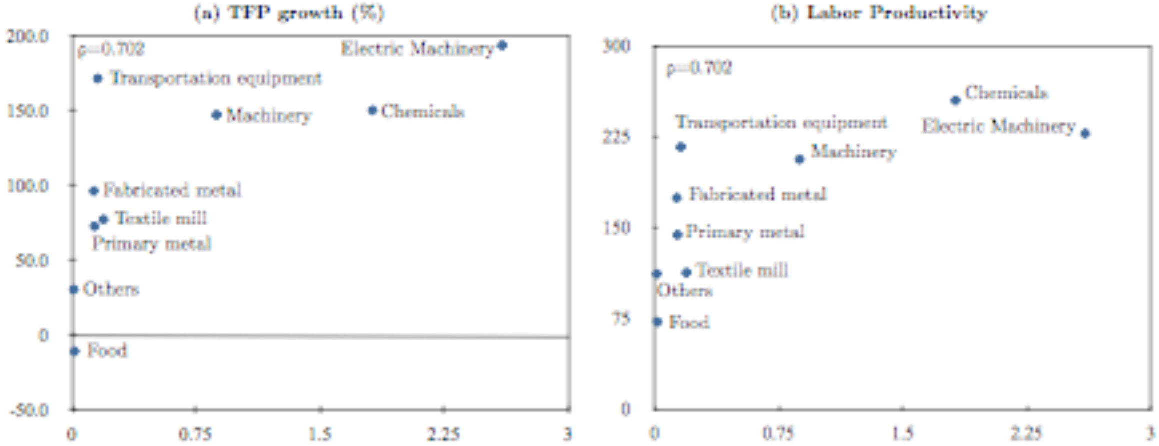
**(Number of Type A technological assistance contracts)**



This large contribution of imported technologies to the postwar Japanese economic development is widely accepted in the preceding studies. For example, Peck and Tamura (1976) characterize the postwar Japanese technological development as one with "high returns from importing technology in terms of exports and productivity." Goto and Odagiri (1996) point out that Japan efficiently utilized the channels of technology transfer such as import of machinery and equipment, purchase of technology and technological services. Figure 6 is a scatter diagram between technology adoptions and productivity growth by industry. The horizontal axis denotes the number of technological adoptions from 1955 to 1969, normalized by average real value added in 1955 and 1970, while the vertical axis denotes the productivity growth from 1955 to 1970 (TFP in Panel (a) and labor productivity in Panel (b)). We can clearly observe a positive correlation between technology adoption and growth, both for TFP and labor productivity.

The impact of the technology adoptions on the different industries, suggested in Figure 6, has been well documented in the literature. Previous work on the industrial development of postwar Japan is full of anecdotes about the positive effects of technology imports (e.g. Committee for Foreign Technology Survey, 1961; Agency of Industrial Science and Technology, 1964; Society for Industrial Studies, 1995; Yonekawa et al. eds, 1990-1991; Kohama, 2001). In particular, the Committee for Foreign Technology Survey (1961) comprehensively describes the technology imports by individual industries and their impacts in the early stage of postwar growth. Let us briefly look at the cases of electric machinery, automobiles, and the iron and steel, which, relying on the Committee for Foreign Technology Survey (1961), became the major export industries of Japan.

**Figure 6: Technology adoption and productivity growth by industry**



Source: Economic and Social Research Institute of Cabinet Office (2001) and Economic Research Institute of Economic Planning Agency(1998).

Electric machinery is usually sub-divided into “heavy electric machinery” and “light electric machinery.” The former is composed of investment goods for electricity companies, while the latter encompasses consumption goods for households. With respect to the heavy electric machinery, three of the major companies, Toshiba, Mitsubishi Electric and Fuji Electric, entered into comprehensive technology adoption contracts with GE, Westinghouse and Siemens, respectively in the early 1950s. Other major companies also adopted individual technologies. One of the most remarkable results of these contracts was that the Japanese electric machinery companies became able to produce thermal generators of large capacity. In the early 1950s, the Japanese electric companies started to shift from hydroelectric generation to thermal generation. It was for that purpose that they imported advanced thermal generators larger that 200 thousand KW each, which the Japanese electric machinery companies could not produce. Owing to the technology adoptions in the early 1950s, the Japanese electric machinery companies acquired the ability to produce these advanced thermal generators.

Concerning the light electric machinery, technology adoptions created a new industry, i.e. the television set industry. TV broadcasting started in Japan in 1953. Since research and development for producing TV sets was suspended during the war, and the start of TV broadcasting occurred at a later time than in the advanced countries, the Japanese technology for TV production was substantially behind in the early 1950s. Many basic patents for TV sets were owned by foreign companies, in particular RCA, Westinghouse and EMI. Hence, more than thirty Japanese electric machinery companies entered into technology assistance contracts with these foreign companies in the early 1950s. While the cumulative number of TV sets produced in Japan until 1954 was 75 thousand, in 1959 alone, 2.9 million TV sets were produced, and out of those, 27 thousand sets were exported.

The occupation authority (SCAP) allowed the production of automobiles in 1949, although at this time automobiles were just remodeled small trucks, whose performance was 10 to 20 years behind the world standard. In the early 1950s, three major automobile companies, Nissan, Hino and Isuzu, entered into technology adoption contracts with Austin Motors, Renault Corporation and Roots Motors, respectively. According to the contracts, information on design, specifications, materials, processing, and others, was provided to the Japanese companies, which enabled them to produce world-class automobiles. Furthermore, the technology adoption of these technologies introduced the mass production system based on transfer machines to the Japanese automobile industry.

The iron and steel industry developed fairly well in Japan, but the technology for producing strip, whose demand was increasing as the durable consumption goods industry developed, lagged behind. In order to catch up with the advanced countries, MITI and iron and steel companies drew the “First Iron and Steel Rationalization Plan” in 1951, the focus of which was the construction of strip mills. Based on the plan, Fuji Iron Works and Yawata Iron Works, the two largest iron and steel companies in Japan, entered into technological assistance contracts with Armco Steel to obtain know-how on the design, construction and operation of strip mill factories. A similar contract was entered into between Kawasaki Iron Works and Republic Steel in 1958. The “First Iron and Steel Rationalization Plan” was followed by the “Second Iron and Steel Rationalization Plan” in 1956. The focus of the second plan was the introduction of the basic oxygen furnace (BOF), which was a substitute for the open hearth. In 1956, Nippon Kokan Corporation (NKK) acquired a general license in Japan with Alpine Co., and six other major Japanese steel companies acquired the sublicense of BOF from NKK in the late 1950s.

There are few studies that quantitatively identify the effect of technology adoption in 1950s and 1960s Japan. Kiyota and Okazaki (2005) examine the effect of technology adoption on the firm’s performance using firm-level data from 1957 to 1970. They matched the complete list of individual technology adoptions by the firms listed on the Tokyo Stock Exchange in that period with the financial data from the JDB database. They analyze the impact of technology adoption on variables such as TFP, labor productivity, value added, capital-labor ratio, and R&D-sales ratio, one and three years after the technology is adopted. They find that in the 1950s, technology adoption had a positive impact on labor productivity, value-added, the capital-labor ratio and the R&D-sales ratio, although not on TFP. Furthermore, the impact faded in the 1960s. In a different study, Nakamura and Ohashi (2008) estimate the effect of the adoption of BOF technology on TFP, using plant-level data of the Japanese steel industry from 1957 to 1968. Based on the estimation of the production function with vintage capital, they revealed that the adoption of BOF raised the annual TFP growth rate of the steel industry from 7% (counter-factual) to 17% (actual). At the same time, they find that the learning effect was significant. That is, just after a plant introduced BOF, its TFP dropped 9% and it took two years until TFP reached the level achieved by the old open hearth technology. This learning effect also seems to be an explanation for the result of Kiyota and Okazaki (2005) that technology adoption did not have a positive impact on TFP.

### 4.2. Policy framework for technology adoption

The Japanese government played an important role in the import of the technologies described above by imposing a strict framework for such adoptions.[4] This policy framework, which started in 1950 with the enactment of the Foreign Investment Law and had mostly disappeared by 1968, was intended for the selective adoption of what were thought as key technologies. Let us describe this framework in more detail.

The 1950 Foreign Investment Law required advanced government approval of all “Type A” technological assistance contracts. By this approval system, the government aimed at selectively importing technologies that would contribute to Japan’s balance of payments and the development of “important” and public industries. Meanwhile, the government guaranteed and protected the investments and contracts that were approved, and thereby intended to promote the adoption of desirable technology.

In the late 1950s, requests for relaxing regulations on technology adoption were made by the domestic industries as well as these from foreign countries. The domestic industries were keen to adopt more technology to cope with the trade liberalization expected in the near future.

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[4] See Ozaki (1972), Ozawa (1974), and Peck and Tamura (1976) for details.

Responding to these requests, the government simplified the examination procedure of technology adoption in 1959, which was called the “new method for capital import.” This measure was meant to be tentative until the more substantial deregulation, which was conducted in 1961.

After the deregulation in 1961, technology adoptions were approved automatically, except for cases which were thought to be detrimental for the Japanese economy, while the government continued to examine each application of technology adoption. In 1968, the government finally ceased the individual examination process, except for certain cases, such as aircrafts, weapons, gun powder, and nuclear power. In other words, in 1968 the government intervention in technology adoption was basically abolished.

We can observe in Figure 5 several qualitative jumps in the amount of imported technologies. These jumps divide the sample period into the four phases generated by the deregulations of 1959, 1961 and 1968. The numbers in Figure 5 suggest that the government regulation indeed affected technology adoptions in Japan. Studying the influence of such regulation of the number of imported technologies, Kiyota and Okazaki (2005) use firm-level data and find a negative impact of the regulation on the amount of technology adoptions. They also find that the government regulation affected the composition of the adopted technologies. Peck and Tamura (1976) points out that MITI gave priority to adopting technologies on intermediate and capital goods for heavy industries in the 1950s. The relatively high percentage of the chemical products and “iron, steel and non-ferrous metals” in the 1950s, which was the period under the rigid control, seems to reflect the priorities of MITI.

The advantages and disadvantages of the government intervention in technology adoptions in Japan have been controversial. On one hand, Johnson (1982) and Lynn (1982 and 1998) highly evaluate the contribution of MITI’s control over technology adoptions. According to them, thanks to MITI’s intervention, the Japanese industries were able to obtain cutting-edge technologies at lower prices. Their rational is that MITI’s intervention and controlled competition among Japanese firms helped reduce the concerns of foreign technology suppliers, who otherwise may not have dealt with Japanese firms that did not have international reputations. Nakamura and Ohashi (2008) argue that, given the high estimated learning costs of new technologies in the steel industry, MITI’s intervention encouraged Japanese steel companies to adopt the more productive BOF technology through the lowering of royalties.

On the other hand, it has been stressed that MITI’s intervention hindered or delayed competent Japanese firms from accessing foreign technologies. A case cited often is that of Sony in the early 1950s (Peck and Tamura 1976; Okimoto 1989; Goto and Odagiri 1996). It is said that Sony had to wait for two years until the adoption of the transistor technology from Western Electric was approved by MITI. This delay was due to MITI's skepticism about the abilities of Sony, a small start-up firm at that time. This anecdote is consistent with MITI's general policy in screening applications for technology adoption, which Kiyota and Okazaki (2005) revealed. They regressed the number of technology adoptions by a firm to its attributes including the cumulative number of technologies it had adopted, and found that the coefficient of the cumulative number of adopted technologies is significantly positive in the 1950s, whereas it is around zero after the deregulation in the 1960s. This implies that MITI preferred approving technology adoption by experienced firms, and this had an unfavorable effect on competent start-up firms like Sony in the 1950s.

### 4.3. Innovation of new technologies

As the Japanese economy caught up with the other developed countries, it gradually shifted from the adoption process, where firms were eager to absorb foreign technologies, to the innovation process, where they engaged in R&D investments more intensively to further increase the technology level.

The R&D expenditure to GNP ratio in Japan increased from about 50% of the U.S. level in 1961 to about the same level in 1989.[5] As in the case of the U.S., around 40% of the R&D expenditure in Japan is used for basic and applied research, and the remaining is used for the development of new products.[6] Firms' activities in R&D also contributed to the development of science. Two Japanese Nobel laureates in the natural sciences were corporate researchers when they achieved their scientific breakthroughs.

One of the characteristics of R&D in Japan is that the government's share of R&D expenditure is the lowest among the developed countries, whereas the industry's share is the highest. Table 3 shows that while the U.S government provided around 50% of R&D expenditures in 1988, the Japanese government only provided around 20%. Japanese firms accounted for almost all the remaining expenditures, 74%. At the user level, however, Japan's R&D expenditures are similar to those of other developed countries.

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[5] Science and Technology Agency (1974 and 1991).

[6] Science and Technology Agency (1990).

### 4.4. Policies on technology innovation

One of the implications of the endogenous growth theory reviewed in Section 2 is that R&D investment is lower in laissez-faire economies than the social optimum. This is due to the existence of externalities and imperfect competition arising naturally from increasing-returns-to-scale technologies. Such externalities justify the intervention of the government through policies such as the provision of financial incentives via subsidies and tax benefits to the R&D investment, or the strengthening of patent rights.

**Table 3: Decomposition of R&D expenditure**

**(Share in total R&D expenditure in each country)**

| | Government | | Industry | | University | | Private laboratory | |
|---|---|---|---|---|---|---|---|---|
| | Provider | User | Provider | User | Provider | User | Provider | User |
| Japan (1988) | 18.4% | 9.3% | 76.3% | 73.9% | 4.5% | 12.6% | 0.7% | 4.3% |
| U.S. (1988) | 48.0% | 11.5% | 47.9% | 71.8% | 2.8% | 13.8% | 1.4% | 2.9% |
| West Germany (1987) | 36.6% | 3.4% | 62.3% | 73.1% | - | 12.9% | - | 10.6% |
| France (1983) | 53.8% | 26.4% | 42.0% | 56.8% | 0.2% | 15.9% | 0.4% | 0.9% |
| U.K. (1987) | 38.7% | 15.1% | 49.7% | 67.0% | 0.6% | 14.2% | 1.9% | 3.7% |

Source: Westney (1994) (originally taken from Science and Technology Agency, 1990).

As we see in Table 3, the Japanese government's subsidies for R&D investments are much smaller than those in other developed countries. Moreover, according to Okimoto (1989), specific tax incentives, such as the one for R&D investment are also small compared with the U.S.[7]

The previous evidence seems to suggest that the Japanese government did not pursue the

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[7] He writes, "Japan grants tax credits of 20 percent for all R&D expenditures that exceed the highest annual rate in a corporation's past, up to a ceiling of 10 percent of the corporation's taxes. The United States, by contrast, allows tax credits of 25 percent for all R&D expenditures exceeding the *average* over the preceding over the preceding three years; there is no ceiling on the amount that is deducible and the tax credit can be carried over a fifteen-year period" (p.89).

pro-incentive policies to correct market failures as is suggested by the endogenous growth theory. The fact that such policies can easily generate an excuse for pork-barrel spending, might be one of the reasons why R&D policies in Japan were relatively free from distortions arising from government failures. According to Okimoto (1989), MITI has traditionally refused to protect depressed industries. While in the U.S. the declining sectors tend to be the biggest beneficiaries of tax exceptions, this tendency is weaker in Japan. These relatively non-distortionary tax policies of the Japanese government towards the R&D sector may have been beneficial for competition and ultimately innovation, making the R&D sector one of the highest growth industries in Japan. On the other hand, Beason and Weinstein (1996) argue that the Japanese government, including MITI, allocated a disproportionate amount of resources to low growth industries[8] They also find that the financial support by the government did not positively affect TFP. Thus, in either case, subsidization was not effective.

MITI also avoided other types of policy distortions. Okimoto (1989) argues that after WWII, Japan discarded superpower aspirations. As a result, the Japanese government did not need to protect and promote defense-related industries, which meant that, contrary to other countries, the government did not spend substantial quantities on R&D investment in the defense industry. He also argues that the Japanese government de-emphasized the importance of national prestige. This implied that, unlike France and other European countries, MITI has not followed a strategy of cultivating one or two “national champions.” For example, Japan has had no Strategic Defense Initiative, supersonic jet, or airbus project.

In terms of intellectual property protection, the Japanese patent system had been traditionally beneficial to the user side. While a user-favorable patent system helps and promotes the imports of technologies in the adoption process, it is has been argued to be harmful to the innovation process. This is one of the reasons why patent rights in Japan were strengthened in 1988 through a substantial patent reform. However, the benefits of such a reform are debatable, since Sakakibara and Branstetter (2001) show that the 1988 Japanese patent reform does not seem to have increased either R&D expenditures or product innovation.

The endogenous growth theory emphasizes the importance of knowledge spillover in the process of the creation of new technologies. Since this kind of spillover is a type of externality, it is thought to be justified for governments to implement policies aimed at internalizing the benefits of such knowledge spillover. One such policies is the establishment of R&D consortia.

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[8] The size of the distortion effect, compared with other countries such as the U.S., is an open question.

In theory, the internalization of the spillover externality, through R&D consortia, provides incentives for firms to innovate and create new technologies. MITI assisted in the formation of R&D consortia, or research projects, where potential competitive firms cooperated on the R&D of targeted technologies and shared their knowledge.[9] The R&D consortia utilize "the community enforcement mechanism in modern business societies in Japan" (Hayami, 2006). Probably, the most famous R&D consortium is the project on very large-scale integrated circuits. In addition, Okimoto (1989) argues that R&D consortia, which facilitate the exchange of research ideas, would have been more effective in Japan than in other countries, because in Japan, lifetime employment prevents the exchange of research ideas. However, R&D consortia may not always be effective means of promoting innovation. For instance, if participant firms compete in the product market, R&D consortia do not work well. Then, what was the performance of R&D consortia in Japan?

Branstetter and Sakakibara study empirically in a series of papers the effectiveness of Japanese R&D consortia. They find that even after controlling for fixed effects, government subsidies and the endogeneity problem of nominating participants, involvement in R&D consortia increases member firms' R&D expenditures and patent production (Branstetter and Sakakibara, 1998 and 2002). They also find that similar technological knowledge among participant firms tends to increase patent production (Branstetter and Sakakibara, 2002), but to decrease R&D expenditures (Sakakibara, 2001).

It has been argued that financial support to R&D consortia is not entirely relevant to the success of an R&D consortium. Branstetter and Sakakibara (2002) note that, for instance, the design of an R&D consortium is more important to its success than the level of resources expended on it. These results might indicate, that although government financial support for R&D consortia was modest in Japan (Sakakibara, 1997), their role may not have been negligible, since the government was involved in their conception.

Contrary to the previous studies, Krugman and Obstfeld (2006) argue the negative impact of MITI's policy on R&D consortia. When forming R&D consortia, MITI selects the projects with the most promising future. However, they argue that MITI failed to select the right industries to be promoted. They say, "The semiconductor industry appeared, on its face, to have all the attributes of a sector suitable for activist trade policy. But in the end it yielded neither strong

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[9] According to Sakakibara (1997), participant firms perceived that the single most important objective of the R&D consortia is knowledge sharing.

externalities nor excess returns" (p.266).

Another policy that promotes the development and sharing of knowledge is the promotion of institutions such as research institutes and universities. According to Okimoto (1989), the laboratories of Nippon Telegraph and Telephone Public Corporation, and its successor Nippon Telegraph and Telephone Corporation (NTT), have played an important role on R&D activities in Japan, as the American Telephone & Telegraph Company (AT&T) has done in the U.S. However, unlike AT&T, which used affiliated firms as its supplier, NTT itself procured all the materials from the market, which promoted technology diffusion between NTT and the suppliers. The university share of R&D expenditure, as a user, is similar to that of other developed countries (see Table 3). Despite the obvious potential for interaction, Okimoto and Nishi (1994) report that the relations between firms and universities have been traditionally small, which have limited the knowledge sharing between these two important types of developers of ideas. Furthermore, Aldrich and Sasaki (1995) report that university-based R&D is not allowed in Japanese R&D consortia. All this suggests that university R&D in Japan has been conducted independently from that of the industry. .

## 5. Technology adoption and innovation in the agricultural sector

Unlike in the non-agricultural sector, technology adoption is not easy to implement in agriculture. This is primarily due to the fact that agriculture is strongly constrained by environmental conditions, which makes it difficult to transfer advanced technologies developed in the temperate zone to the tropical zone (Hayami and Godo, 2005).

The induced innovation theory by Hicks (1932) and Hayami and Ruttan (1971 and 1985) formalizes an idea that technological innovations are directed toward technologies that use smaller amounts of relatively scarce production factors through price adjustment mechanisms. However, such innovations are not always possible with the effort of private farm producers alone, especially in the early stage of economics development, where market mechanisms do not necessarily function well (Hayami and Godo, 2005). Hence, to facilitate TFP growth in agriculture it is essential to develop the appropriate adoptive research, along with the mechanisms to later diffuse the new technologies. For this reason, the government can potentially play a very important role in the agricultural sector. Indeed, many governments have set up both research stations to develop new knowledge, as well as extension stations to encourage the use of this research (Rustichini and Schmitz, 1991). Indeed, Japan was the first economy in the world to develop high-yielding varieties of crops complementary to the heavy use of fertilizer, and also the first to develop chemical fertilizers (Flath, 2005; Hayami and Ruttan, 1970).

In Japan, modern technological progress in the agricultural sector has taken place in two phases, the prewar and postwar eras. During the prewar era, Japan achieved rapid TFP growth of agricultural production. As Hayami (1975) notes, this rapid growth in the initial growth phase was supported by a backlog of technological potential accumulated before the Meiji era, when superior methods and advanced knowledge were embodied in practices of the wealthy veteran farmers (Rounou) in the leading position in their villages. After the Meiji Restoration, these veteran farm leaders started identifying and disseminating their knowledge across regions. The government helped the exploitation and diffusion of the backlog of indigenous technologies by sponsoring ”seed-exchange meetings” and ”agricultural discussion meetings” and promoting scientific agricultural-research and extension activities (Minami, 1994). These activities were also complemented through irrigation investments by the government and their maintenance performed by the neighboring communities. The introduction of modern communication and transportation systems, including the postal service and railway, was also important (Hayami, 1975).

Agricultural TFP improvement in the early postwar rapid growth period, shown in Table 1, was the consequence of the implementation of many of the technological advancements that had been accumulated during the prewar period, and in many instances during the war (Hayami and Ruttan, 1985). TFP growth in the postwar years played an essential role in the increase of agricultural output growth (Hayami, 1975; Kuroda, 1995, 1997).

Traditionally, it has been argued that the postwar TFP growth in the agricultural sector has come from two main sources: the mechanization of agriculture, and the introduction of high-yield varieties of farm products. During the rapid growth era, mini-tractorization based on innovations and the adoption of small-scale machinery became an important factor of agricultural growth. In this process, the research conducted during the war for non-agricultural purposes formed a backlog used in the advancements of agricultural techniques (Hayami, 1975). Related to the advantages of using these newer technologies, Lau and Yotopoulos (1989) show that there is a positive association between scale economies and tractorization, and Hayami and Kawagoe (1989) find that increasing returns of agricultural production emerged in Japan as agriculture developed, and they were accompanied by sharp wage increases during the mid-1960s. These increasing returns and rises in wages occurred because of the substitution of large-scale machineries, such as riding tractors, for small hand-pushed ones.

In order to assess the validity of the traditional view, Kuroda (1995) decomposes TFP changes into the scale economy factor and the technological improvement factor. He finds that, on average, 90% of the TFP growth rate for the period 1960-90 is explained by technological improvements, and 10% by scale economies. This implies that the introduction of high-yield variety of farm products, such as the biological and chemical aspects of rice technologies, is more important than mechanization in explaining the agriculture TFP growth in the initial postwar Japan.

It has been argued that the Japanese government played an important role in this process of agricultural technological improvement. In particular, the R&E efforts of the Ministry of Agriculture, Forestry and Fishery (MAFF) resulted in the development of new rice varieties, both from the pureline and crossbred “Norin” selections. [10] These R&E activities were crucial in the early postwar period because they allowed for the reduction of costs in agricultural production. However, the effect of R&E on TFP growth dramatically decreased after the late 1960s, despite the fact that the level of R&E investment did not decrease. The diminished impact of R&E on TFP growth is what Kuroda (1997) identifies as the main source of the agricultural TFP growth slowdown after 1969.

## 6. Domestic diffusion of technology

The previous sections have focused on the role of the Japanese government on the adoption of foreign technologies, as well as the development of new ones. As most of the models reviewed in Section 2 show, the engine behind long-run economic growth is the adoption and creation of new technologies. However, all these models assume that once a new technology is developed, or imported from overseas, it is readily available to use by any firm willing to pay its price. While this perfect and instantaneous diffusion of technology may be a reasonable simplification for these models, in reality technologies and know-how do not immediately diffuse within a country. Indeed, using a numerical dynamic general equilibrium model with endogenous TFP, Oshima (2009) shows that a major part of TFP growth in Japan’s postwar rapid growth era can be explained by domestic knowledge diffusion. In this section we study the factors that affect the domestic diffusion of existing technologies and the role of the Japanese government in this

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[10] Norin is the Japanese acronym of MAFF.

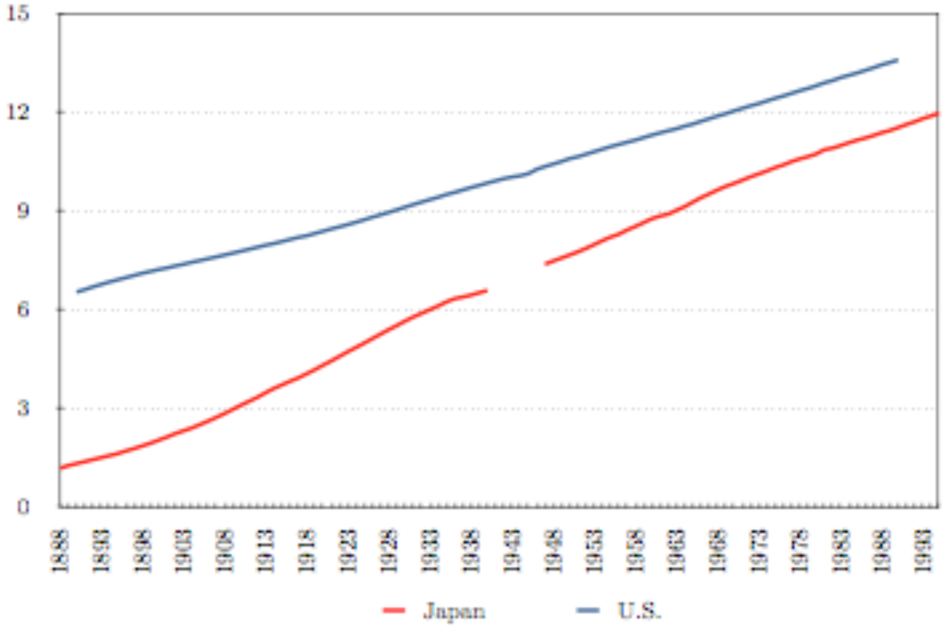
process.

Several factors have been pointed out in the literature as being important to understand the local diffusion of technology. Some of them are similar to those noted as determining its international diffusion, and include such factors as the level and distribution of human capital, quality of infrastructures and enforcement of patent laws.

The level of human capital is an important lubricant for the diffusion of technologies. Once a new technology is imported or invented, for it to be widely used, workers in firms need to be able to learn how to use it. The ability of the labor force to learn and implement new techniques is strongly linked to the educational level of a country. Godo and Hayami (2002) compared the progress of education between Japan and the U.S. in the period from 1890–1990, finding that while Japan greatly caught up with the U.S. in terms of education in the prewar period, there was a missing link between improvements in education and the macro performance of Japan. This missing link can be clearly observed in the postwar period, when Japan rapidly caught up with the U.S. in terms of per capita GDP, although the catching up process in terms of schooling was much less dramatic. They argue that the weak contemporaneous correlation between education and TFP growth in the postwar period is due to the fact that what was important in the diffusion of technologies after the war was the available educational level, rather than its current improvements. In particular, they state that it was the sharp increase in Japanese vocational training prior to 1940 that was critical to the diffusion of technologies in the 1950s and 1960s, therefore making education affect TFP only with a lag.

The government has implemented several policies that have been important to increase the human capital level of Japan. It introduced mandatory elementary education in the late 19th century, made tuition free in 1900, and started to implement vocational training programs as early as 1893. It also provided certificates for technicians through exams, such as “Ginou Kentei Seido” of the Ministry of Health, Welfare, and Labor, introduced in 1959, which helped workers move across jobs and diffuse the existing technologies.

**Figure 7: Average Years of Schooling in Japan and the US**



Source: Godo and Hayami (2002)

It is widely accepted that physical infrastructure plays an important role in the process of economic development. One way it has been argued to help is by facilitating the diffusion and adoption of technological advancements. Since the classical works of development theory such as Hirschman (1958) and Rosenstein-Rodan (1943), development economists have considered infrastructure as an indispensable precondition of industrialization. A government's industrialization program would be successful when physical infrastructure is shared among the firms and investors, since the coordination of various investments generates strong pecuniary externalities, which is identified as the key to successful industrialization (Murphy, Shleifer and Vishny, 1989, and Ciccone and Matsuyama, 1996). In facilitating the domestic diffusion of technologies, the Japanese government played an important role by providing physical infrastructures such as the postal system, telecommunications, railways, and paved roads and highways (Kohsaka, Yoshino, and Nakahigashi, 2007). For instance, the government built the transportation infrastructure crucial for the delivery of materials that were needed to implement the BOF technology explained in Section 4.2 (Okazaki, 2001).

In diffusing borrowed technologies imported from foreign advanced countries, or those domestically developed, imitation through industrial clusters may have also been important. As an example of technology spillovers in clusters, Yamamura, Sonobe, and Otsuka (2005) examine the evolution of the motorcycle industry in Japan from 1948 to 1964. Using individual firm data, they show that the industry's rapid growth of the early phase is explained by the massive entry and imitation of simple technologies. On the other hand, the sustained growth of the later phases is explained by the domestic innovations and subsequent imitations by other local firms, as well as the exit of inefficient firms. Sonobe and Otsuka (2006) found similar patterns in different industries in Japan and other East Asian countries.

The motorcycle industry example of Yamamura et al. (2005) also highlights the role of the government as the enactor and enforcer of patent laws, since most of the industry's growth is explained by the imitation of the competitor's technology. Japan's patent system somehow allows these types of imitation patterns. It is a system that promotes easy opposition to patents before they are even issued. As pointed out by Flath (2005), this provides incentives to firms to license their new inventions on terms favorable to users, and encourages the early revelation of new technologies.

## 7. Concluding remarks

In this paper we have shown that the growth of aggregate TFP in postwar Japan was mainly driven by that of non-agricultural TFP, although agricultural TFP also played an important role in the structural transformation of employment, which precipitated industrialization. The Japanese government played a role in the technological growth of both sectors, and its contributions comprise both financial support and the necessary organizational infrastructure.

The high growth of non-agricultural TFP in the postwar period was driven initially by the adoption of foreign technologies and later by the innovation of domestically developed ones. Most of the initial adoption of technologies was done through licensing by Japanese firms under the strict supervision of the government. The government influenced the types and quantities of technologies imported by setting a very restrictive process for the approval of the foreign technologies that were allowed to be imported. The government's share of R&D in Japan is smaller than in other developed countries. However the government has been highly involved in the establishment of R&D consortia. This suggests that the role of the Japanese government in the innovation phase has been primarily to not distort the incentives of innovating firms through subsidies, and to enhance coordination through R&D consortia.

In the agricultural sector, TFP growth was driven mostly by innovations of new technologies. The mechanization of agriculture through locally invented mini-tractors, as well as the development of high-yield varieties of farm products have been argued to be behind the growth in agricultural TFP. The government's participation in this process was crucial since many of these high-yield varieties were developed directly by the Ministry of Agriculture, Forestry and

Fishery.

In terms of diffusing both imported and locally developed technologies, the Japanese government helped by increasing the human capital level of the economy, building many of the necessary physical infrastructures, and by setting up a patent system that is fairly favorable to imitators.

In summary, the Japanese government played a part in the growth of TFP in the rapid growth era by directing the adoption of foreign technologies, promoting coordination of R&D activities, and setting up ways in which available technology could be diffused across the country. Yet, we should also note that Japanese government was not immune to its failure. Indeed, the government failed to foresee the importance of higher education in the post catch-up growth era. Japan was not successful to accumulate high level of knowledge due to insufficient investments in tertiary or post-graduate education, therefore intangible capital intensive technological progress was not fully induced (Hayami and Godo, 2009). This unsuccessful induced innovation is consistent with the low TFP growth of the 1990s.

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