

Infrastructure, Investment, and the Recent Depression in Taiwan

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Abstract

Taiwan has experienced a depression since late 2000. We have witnessed a large decline in both the level and growth rates of real GDP, and also a huge drop in the real interest rates in almost all maturities of financial assets. In this paper a simple model of infrastructure is proposed to explain these observations. We found that the economic infrastructure in a country is important for the firm's decisions to invest, and therefore it will affect the output and interest rates of this country. We show that neither increasing returns to scale nor endogenous determination of growth rates is necessary to explain our empirical observations. It is *infrastructure* that matters, through its effects on the fixed cost firms must incur to start the business and on the aggregate production frontier. We conclude that the recent depression in Taiwan is *probably* the result of a worsening economic infrastructure.

1. Introduction

Taiwan has experienced a depression since late 2000. We have witnessed a large decline in both the level and growth rates of real GDP, a slight decrease in the price level, and a huge drop in the real interest rates in almost all maturities of financial assets. From the standard aggregate demand-aggregate supply (AD-AS) analysis, output, price, and real interest rate will all decrease if the AD curve shifts to the left, or if the magnitude of left-shift in AD curve is larger than that in AS curve. The left-shift in AD curve may be a result of the decline in all kinds of expenditures, such as consumption and investment (for both private and public) and net export, and also could be the result of a decrease in money supply. Because the net export has not decreased and there has not been any monetary contraction since late 2000, we do not think that net export and

money supply should be responsible for the recent depression in Taiwan. What is important, therefore, is the decline in consumption and investment.

In this paper we suggest that the main driving force behind the recent depression in Taiwan is the significant decrease in investment, especially in both the domestic and foreign *private* investment. The decrease in these two kinds of investment contributes to most of the recent decrease in the investment rate (that is, investment/output ratio) observed in Taiwan. Consumption might be an important factor to explain the output decrease, but it could not adequately count for the huge decrease in real interest rates because usually the interest elasticity of consumption is much smaller than that of investment. This means that if consumption is the main factor behind our story we need an extraordinarily large interest elasticity of consumption to reconcile the theory with the observation. Obviously the candidate of driving force in recent depression in Taiwan is therefore the decrease in investment. So the next question is naturally the following: why has private investment been decreasing dramatically in Taiwan since late 2000?

There is no simple answer to this question. Even if we can identify investment as the driving force, there are still so many factors which might affect the firm's incentives to invest. For example, there are three main theories of investment: Dale Jorgenson's neoclassical theory of the user cost of capital, *Tobin's q*, and the *real options approach* summarized in Dixit and Pindyck (1994). Both Jorgenson and Tobin emphasize the role of marginal product of capital or the original Keynesian concept of marginal efficiency of capital, and the real options approach focuses on the uncertainty firms have to resolve when the investment is *irreversible*.

We make a *detour* in this paper. Inspired by the seminal work of Murphy, Shleifer, and Vishny (1989) and the more recent work of Hall and Jones (1999), and also by the casual and daily observations in Taiwan, we suggest that the driving force behind the significant decrease of investment in Taiwan has been the worsening economic *infrastructure*. By infrastructure we mean things much richer than its usual contents. Here the infrastructure is referred not only to railroads, highways, nuclear power stations, etc., but also to the laws and institutions that favor production, openness to the international markets, and the stability of government policies, as described by Jones (2002, Chapter 7).

Some big events that happened in Taiwan might be helpful for making clear the importance of our emphasis on this broad definition of economic infrastructure. Prior to the year of 2000, the investment project of *Bayer*, one of the largest pharmacies and chemical producers in Germany, was turned down by the local Tai-Chung County government for environmental concerns. This rejection was a *barrier* to follow-up foreign firms to invest in Taiwan, especially to those firms that might give rise to environmental pollutions.

The second event is much more important than the Bayer case. It was the case of the *fourth nuclear power station*. Again this is concerned with pollutions, but some political or even ideological concerns are also involved. The ongoing fourth nuclear power station was turned down in late 2000 after the Democratic Progress Party (DPP) won the presidential election in March 2000. We do not know the true motivation behind this decision but the delay of construction of this power station *did* cause many economic and political conflicts and, consequently, huge social costs.¹ The conflict is still ongoing and this case is one of the best examples of the *instability* of government policies.

The third event is about the openness to the markets in mainland China. Since 1978 the markets in China has been opened to the rest of the world except Taiwan because of the political conflict across the Taiwan Strait. This barrier has been released *partially* since the early 1990s. By partially we mean that the trade between the two sides of the Strait is not official: it must be through a third party (usually, Hong Kong) and many goods and funds are not allowed for landing the mainland China for economic, political and military reasons. There is no *free* trade between China and Taiwan. So policies that do not favor free trade across the Strait would in general reduce the efficiency of resources allocation. This means that governments in both sides of the Strait should try their best removing the barrier to the free mobility of goods, funds, and persons to create a better economic infrastructure across the Strait.

The organization of this paper is as follows. We describe our model in Section 2, and discuss its implications in Section 3. We follow the spirits of Murphy, Shleifer, and Vishny (1989) and Hansen and Prescott (2002) to construct a very simple model of infrastructure. We show that neither increasing returns to scale nor endogenous determination of growth rates is necessary to explain our empirical observations. It is infrastructure that matters, through its effects on the fixed cost firms must incur to start the business and on the aggregate production frontier. Section 4 is an empirical one, in which some growth accounting (as well as level accounting) results are reported. We conclude in Section 5.

2. A Simple Model of Infrastructure

Most people would agree that infrastructure might be important for the economic performance of a country, but the question is *how* to model this idea? We should give it an *operational definition*. This is extremely important for economists who would like to understand the effects of this useful idea. Both

¹There is always a debate or probably a tradeoff between protecting environment from pollutions and promoting investment by constructing factories that might produce goods with harmful effects. The net effects will certainly be an empirical matter, and we do not wish to discuss them here.

Murphy, Shleifer, and Vishny (1989) and Hall and Jones (1999) proposed such a modeling strategy, but both papers seem not useful if we want to explain the simultaneous decrease in output and interest rates.

In their model of investment in infrastructure Murphy, Shleifer, and Vishny (1989, Section VI) made the assumption that “the equilibrium interest rate is always zero” (p. 1020). Though certainly the assumption can be relaxed, as done in the present paper, there are no connections and discussions between interest rates and the infrastructure. In addition, they relied heavily on the assumption that there are two sectors, in which both sectors produce goods using an increasing returns to scale (IRS) technology. This strategy might be necessary for a “Big Push” story in development economics, as required by these authors, but is *not* so for a theory of infrastructure.

Following Hansen and Prescott (2002) we construct a *one sector/two technologies growth model* without the requisition of wage premium to attract factors to migrate from low-tech sector to the high-tech one. Firms will use different technology to produce goods when there are enough (over some *threshold*) advances in the level of high technology, or when some other factors push firms to abandon using the relatively low technology.

Assume that there are two technologies, one of which producing *manufacturing* or low-tech good, and the other producing *information technology* (IT) or high-tech good. The relative price of these two goods are assumed to be unity to keep in a one-sector model. Relaxation of this assumption would not change our main results. The manufacturing and IT technologies are respectively assumed to be

$$(1) Y_M = I^\alpha (A_M K_M)^{1-\alpha},$$

$$(2) Y_T = I A_T [K_T - F(I)],$$

where I stands for the index of infrastructure, A_M and A_T are technology levels in these two production functions, K_M and K_T are aggregate capital stocks used in producing these two goods, labor is normalized to unity such that capital k (K) can stand for either aggregate or individual capital stock, and F is the fixed cost in producing the high-tech good (such as R&D costs, costs to remove barriers to producing this good, etc.), which is assumed to be once-differentiable and nonincreasing in infrastructure ($F'(I) \leq 0$), $0 < \alpha < 1$. Following Jones (2002, p. 147) we also consider infrastructure as an element to augment aggregate output. In this way infrastructure acts a very similar role as that played by total factor productivity (TFP). Then we have a trouble: how can we distinguish the roles between infrastructure and TFP?

We depart from Jones’ model by making two assumptions on modeling infrastructure. First, the fixed cost to produce IT goods is still independent of

output, so this cost is “fixed” in the usual sense. But we want to relate fixed cost with infrastructure with the motivation that economic infrastructure, such as the stability of government policies, or the openness to international markets, is often important for investment. When a country has a better infrastructure it will create an environment that favors firms to invest because it would have more stable policy and more opportunities for international or interregional trade. This is equivalent to a reduction of the fixed cost, or $F'(I) < 0$. When the setup cost is independent of infrastructure, it reduces to the ordinary case in which $F'(I) = 0$. We consider the $F'(I) > 0$ case to be either impossible or economically uninteresting, and do not include this case in our discussion.

Second, TFP growth is possibly unbounded. But infrastructure is usually *not* so. In the work of Hall and Jones (1999) they use two indices as instruments to measure infrastructure. Both measures are in terms of fractions so they could not grow in the long run. This distinction between TFP and infrastructure makes sense of the separation among the variables I , A_M , and A_K in equations (1) and (2). They are different variables because they have different long run properties and different implications for the fixed cost of investment in high-tech goods. Because most elements of infrastructure are created and protected by the government, consumers and firms would take them as exogenously given. The fixed cost of producing high-tech goods is therefore exogenous as well even though we assume that it is a function of infrastructure.

Like Arthur Lewis’ surplus labor model or Michael Todaro’s migration model, as emphasized by Lucas (2003) and similarly in Hansen and Prescott (2002), the problem of economic development is almost all about the *transition* between different sectors or technologies. In this paper we allow agents for *migrating* between different *technologies*. But the transition here is *asymmetric*: to use the high technology needs incurring a fixed cost, but it is costless to draw back to using the low technology. Because $F'(I) \leq 0$, this asymmetry has another interpretation: if the infrastructure is worsening, it gets harder and harder to produce high-tech goods because the fixed cost is getting larger; and it is easier for income to drop from a high level to a lower one than from a low level to a higher one, because the level and growth rates of aggregate income when using high technology are usually larger than those when using low technology. We lose 5 dollars if the income decreases by 50% from 10 to 5 dollars, but we earn only 2.5 dollars if the income increases by the same 50% from 5 to 7.5 dollars. And if we put different growth rates to different income levels in this example, say 50% drop from high income to a low one but only 30% increase from low income to a high one, just like the possibility in our model where high-tech good grows faster than the low one does, the asymmetry becomes more obvious. This means that creating a better infrastructure to foster investment is more difficult than destroying the infrastructure to detract investment.

Aggregate output Y is the sum of low- and high-tech outputs, or $Y = Y_M + Y_T$. The maximum of this equation defines the aggregate production frontier of

the economy, as assumed in Hansen and Prescott (2002). The technology levels A_M and A_T are assumed to grow at exogenously given constant but different rates. It is not necessary that A_T should grow faster than A_M . Firms can always choose between these two technologies. IT goods might grow faster, given a constant technology level, because they have a larger marginal product of capital and manufacturing goods have diminishing marginal product of capital ($0 < \alpha < 1$). But this does not imply that firms would always produce IT goods because they have to incur a fixed cost to start the IT business.

The distinction between different marginal product of capital in different goods production arises for two reasons. First, we want IT goods still competitive to manufacturing ones when their technology growth is low (like what happened in last few years around the world) or when the fixed cost to start producing is high. Otherwise all firms will turn to the production of low-tech goods. Second, motivated by the recent literature on *vintage capital*,² because the information technology grows rapidly in the second half of the 1990s, manufacturing sector and IT sector itself have benefited from these developments, and the embodied Solow-neutral or capital augmented technological change formulation as shown in equations (1) and (2) might be the simplest setup to capture the effects of these developments on aggregate production. This indicates that both the quantity and the *quality* of capital are productive, and the latter will be more important. We use A_T and A_M to represent the quality of capital, so capital at different point of time, or coming in different *vintages*, will have different productivity, and usually the productivity is increasing in time or in vintages, as required here in this paper.

Aggregate output is the sum of aggregate consumption C and aggregate investment $\dot{K}$, or $Y = C + \dot{K}$, where the depreciation rate of capital is assumed to be zero. Aggregate capital K is the sum of K_M and K_T , or $K = K_M + K_T$. For simplicity and without loss of generality, assume the economy lasts for two periods. In the first period, firms produce the manufacturing good using the technology described in equation (1) up to a threshold level where they earn enough income to incur the fixed cost to start the IT industry, where the profits will realize in the second and last period. Investment needs *one* period of time to build. In the second period, both technologies in equations (1) and (2) are available for all firms who have paid the fixed cost in period one. Because firms can switch between these two sectors by investing different levels of capital in different sectors, the *firm's transition problem* is to

$$(3) \max Y = \max \{I^\alpha (A_M s K)^{1-\alpha} + I A_T [(1-s)K - F(I)]\},$$

with respect to s , the share of capital in manufacturing sector, where $s = K_M/K$, and $1-s = K_T/K$. This is a standard concave programming problem because it is concave in s , and therefore has a unique solution s^* , where

²Cooley, Greenwood, and Yorukoglu (1997) and Greenwood, Hercowitz, and Krusell (1997) are two prominent examples.

$$(4) \ s^* = \left(\frac{1-\alpha}{A_T}\right)^{\frac{1}{\alpha}} \left(\frac{A_M}{I}\right)^{\frac{1-\alpha}{\alpha}} \frac{1}{K}.$$

There are several interesting implications from this equation. First, a better infrastructure (an increase in I) will lower s^* , that is, firms will devote less fraction of capital to producing manufacturing goods, or there will be less firms staying in the low-tech sector, and the *transition* is from low-tech to high-tech sectors. This is because the high-tech sector is assumed to have a larger marginal product of capital and hence a larger profit *if* firms have paid the sunk cost to enter into the high-tech business in the first period.

Second, a higher A_M will induce a higher s^* , but a higher A_T results in a lower s^* . These results are obvious. The technology change is assumed to be embodied in capital, so a technology improvement will increase the quality or productivity of capital, and so the share of this capital. Third, a larger total capital stock K will cause s^* to fall. Since the manufacturing sector has diminishing marginal product of capital, but this is not the case for the IT sector (it has a constant marginal return), an increase in K will have a *markup* on the IT sector: the gap between the marginal product of capital in the high-tech sector (say, MPK_T) and in the low-tech one (say, MPK_M) will be widened. This provides firms strong incentives to migrate to the high technology sector.

Finally, $F(I)$ does not enter equation (4) *directly*. It is usually assumed that $F'(I) = 0$, or fixed cost has nothing to do with the infrastructure. In this case the fixed cost would have no effects on s^* . But if we allow for the case that $F'(I) < 0$, then an increase in the fixed cost will be related to a decrease in I , or a worsening infrastructure, and this in turn will cause s^* to rise or, equivalently, cause $1 - s^*$ to fall. That is, a larger setup cost will induce firms more likely to shift from using a high technology to using a low one *if* this larger cost has been induced by a worsening infrastructure.

Now we would like to state clearly what is the threshold firms must face in the first period if they want to use IT technology. Let Y_1 , Y_2 , C_1 and C_2 be aggregate output and aggregate consumption in periods 1 and 2 respectively. Then the aggregate resource constraints in these two periods are

$$(5) \ Y_1 (= Y_M) = C_1 + F(I),$$

$$(6) \ Y_2 (= \max Y) = C_2.$$

In period 1 firms have to incur a fixed cost and collect the profits a period later. Firms can only use manufacturing technology to produce output in the first period. In the second period, both technologies can be used to maximize the aggregate output. This would make sense provided that the following threshold condition is satisfied:

$$(7) \quad \frac{Y_2}{1+r} \left(\frac{MPK_T - MPK_M}{MPK_T} \right) - F(I) > 0.$$

Equation (7) states that the present value of the profit to use IT technology should be greater than the fixed cost to start the IT business, where r is the real interest rate, and the term $(MPK_T - MPK_M)/MPK_T$ is the marginal profit rate per unit of output, or the *markup* induced by the difference between the marginal product of capital in these two technologies. We can summarize the above results in the following proposition:

Proposition 1 (Firm's transition problem): Firms will migrate between different technologies to maximize their profits. In the process of transition, firms will solve the problem stated in equation (3) subject to equations (1), (2), and (7). The optimal share of capital in using manufacturing (or low) technology s^* will decrease with increases in infrastructure I , in IT technology index A_T , and in aggregate capital K ; and s^* will decrease with a decrease in manufacturing technology index A_M . Fixed cost to start the IT (or high-tech) business will have positive effects on s^* if and only if $F'(I) < 0$.

To close the model we need to describe the problem of consumers. The representative consumer wishes to maximize

$$(8) \quad \frac{C_1^{1-\sigma}}{1-\sigma} + \beta \frac{C_2^{1-\sigma}}{1-\sigma},$$

subject to the aggregate resource constraints (5) and (6), where $0 < \beta = 1/(1 + \rho) < 1$ is the subjective discount factor, $\rho > 0$ is the time preference rate, $1/\sigma$ is the intertemporal elasticity of substitution between consumptions in periods 1 and 2. Since population is normalized to one there is no difference between per capita consumption and aggregate consumption. We, therefore, use capital c (C) to stand for consumptions of this representative individual. When consumer's utility is maximized we have the usual equilibrium conditions (or *Euler equation*):

$$(9) \quad \frac{\dot{C}}{C} = \frac{r-\rho}{\sigma},$$

where $\dot{C}/C = \lim_{\Delta t \rightarrow 0} (C_2 - C_1)/C_1$. Remember that one of the main concerns in the present study is to figure out what have been the key factors behind the dramatic drop in real interest rates since the second half of the year 2000. There are many other reasons behind the story, such as the decline in interest rates induced by the US reductions of her interest rates through the interest rate parity argument. But according to the most updated data, the overnight loan rate in Taiwan (similar to the federal funds rate in the US) has been lower than federal funds rate. So there must be other reasons that could not be captured by the equation of interest rate parity. As a simple illustration of our argument in this paper, we take a look at the "balanced path" in our growth model. Because there are only two periods, the "long run" would be referred

to the second period. The balanced path can be derived through some simple calculations.

Since $Y = Y_M + Y_T$, the growth rate of Y can be decomposed into two parts: $\dot{Y}/Y = s_Y \dot{Y}_M/Y_M + (1 - s_Y) \dot{Y}_T/Y_T$, where $s_Y = Y_M/Y$ is the output share in using the manufacturing technology, and $1 - s_Y$ is the output share in using the IT technology. By equation (1) we have $\dot{Y}_M/Y_M = (1 - \alpha)(\dot{A}_M/A_M + \dot{K}_M/K_M)$, and by equation (2) we have $\dot{Y}_T/Y_T = \dot{A}_T/A_T + [K_T/(K_T - F(I))]\dot{K}_T/K_T$, where we have assumed that $\dot{I}/I = \dot{F}/F = 0$. In other words, infrastructure and the fixed cost cannot grow in the long run. Since the gap of marginal product of capital stemming from the markup in investing in IT rather than in manufacturing technology will be widened over time, this makes that the growth rates of A_M will be smaller and those of A_T be larger over time in the balanced path of long run growth. The growth rates of Y_M , K_M , and K_T will all approach to zero in the long run because fewer and fewer firms would like to invest in the manufacturing technology, and all the long run growth effects of the IT technology stem from the long run growth of its technology level A_T . To summarize, we have

Proposition 2 (balanced path): In the balanced path of this one sector/two technologies growth model, $\dot{C}/C = \dot{Y}/Y = \dot{Y}_T/Y_T = \dot{A}_T/A_T > 0$, $\dot{K}/K = \dot{K}_M/K_M = \dot{K}_T/K_T = \dot{A}_M/A_M = \dot{Y}_M/Y_M = 0$, $s \rightarrow 0$, and $s_Y \rightarrow 0$.

From Proposition 1 we know that both I and A_T are inversely related to s^* , so infrastructure I and A_T are positively related in equilibrium. This means that infrastructure has *growth effects* because the long run balanced path growth in our model is basically generated by the long run growth of A_T . When infrastructure is worsening, the growth rate of A_T would be smaller, and by Proposition 2 the growth rates of aggregate consumption decline, and this will imply a drop in real interest rates by equation (9). Besides, all the long run growth in capital stems from the growth in *quality*, not in its quantity.

Since the model here is similar to the usual Romer-Rebelo “AK” model, the balanced path growth rate $\dot{A}_T/A_T$ would be function of K . The closed-form solution of this growth rate is complicated, given the nonlinear structure in the balanced path equilibrium. But it can be derived when we add equation (9) into the equilibrium conditions defined by equations (1)-(3) and (5)-(7). Notice that whether $\dot{A}_T/A_T$ is determined endogenously is not important for the effects of infrastructure on the long run growth rates of output and consumption, as well as on the equilibrium level of real interest rates. To sum up, we have

Proposition 3 (infrastructure matters): By Propositions 1 and 2, and equations (4) and (9), infrastructure will have growth effects in the long run. A worsening infrastructure would in general cause a fall in real interest rates, and a decrease in both the level and growth rates of output and consumption. Since

$\dot{Y}_T/Y_T = \dot{A}_T/A_T + [K_T/(K_T - F(I))]\dot{K}_T/K_T$, then by Proposition 2 fixed cost would have only level effects, and it has growth effects if and only if $F'(I) < 0$.

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