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**The Relationship between Opaque Markets  
and High Speed Growth: How Good  
Information Interferes with Investment in a  
Rapidly Changing Environment**

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**Comments Welcome**

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Work in progress: please do not cite without permission of author

First Draft: May 5, 1996

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## Non-technical summary:

This paper shows that, in contrast to the many calls for 'increased transparency' in developing countries, market opacity can facilitate high-speed economic growth. It examines growth by asking if and when various types of investment will occur. The investment that is necessary for high-speed growth likely will not occur unless markets are opaque.

In addition, an economy is better off if an investment that is more beneficial is more likely to be undertaken than an investment that is less beneficial. However, firms are *not* more likely to make an investment the more beneficial it is. In an environment of rapid change, firms will only be induced to make particularly beneficial investments if markets are opaque. The paper also points out that market opacity can act as a substitute for a weak patent system even when all competitors know the details of the investment opportunity. However, market opacity leads to different timing of investment than a patent system does in many situations.

The model presents its analysis in a game theory framework, presenting a 'technology adoption' game with an infinite time horizon. The greatest difference between this and previous technology adoption models is the large number of equilibria in which investment does not occur. Competition makes many types of socially beneficial investment unprofitable, and this is more likely to be the case in rapidly changing markets. In a situation in which investment is clearly going to be unprofitable, there is no reason to assume that investment will occur.

The paper also applies the basic model to the effect of tariffs on import substitution and the effect of government-run cartels on declining industries. Tariffs generally *decrease* the likelihood of import substitution occurring in a country with decelerating development—even without any negative income effects from the tariff. Government-run cartels can prolong the existence of an industry within a country even if the cartels have no direct effect on profitability.

Much of the discussion addresses concerns about the recent Asian 'financial crisis,' and both the present Japanese economy and its high-speed growth phase.

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Calls for increasing transparency in the developing countries involved in the Asian crisis are ubiquitous:

From the Bureaucracy: "The causes of the Asian financial crisis include...opacity."<sup>1</sup>

From the Popular press: 'One of the many problems with Asia is that markets are so opaque that it's not possible to tell what businesses are investing in.'<sup>2</sup>

From Academia: "Accounting and disclosure requirements in financial markets, which are often particularly lacking in emerging markets... need to be beefed up considerably."<sup>3</sup>

Yet, no author has analyzed the effect of increasing transparency on growth. Emerging financial markets do *not* need increased transparency. Emerging markets do need appropriate, effective financial regulation that investors find credible, but enforcing transparency may *not* be appropriate financial regulation in the case of developing nations. Increasing transparency may be inappropriate because developing nations can obtain high-speed economic growth as they catch up with the developed world if effective policies are implemented.<sup>4</sup> A primary goal of this paper is to emphasize that *market opacity can facilitate high-speed economic growth*.

Those calling for increased transparency generally begin with the observation that financial market regulation was improperly conducted in many Asian countries, and that these faults may have helped cause the Asian crisis.<sup>5</sup> However, close analysis of the effects of opacity is always missing from these arguments. This paper presents the analysis of market opacity, showing what the Asian markets have gained from their opacity: the option of high-speed economic growth.

On the other hand, there are also many calls for increased transparency in Japan. Japan is clearly not a developing country, and thus the arguments regarding the link between market opacity and high-speed economic growth do not apply. However, many authors suggest that the Japanese patent system does not, by itself induce as much innovation and investment as the American patent system.<sup>6</sup> This paper describes several aspects in which market opacity is similar to and can be a substitute for patents. Therefore, the effects of market opacity on invention and innovation need to be considered before changes to market opacity are made.

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<sup>1</sup> Chan (1998).

<sup>2</sup> Unknown 'market commentator,' on "Marketplace," National Public Radio WUOM, October 1998.

<sup>3</sup> Robertson (1998).

<sup>4</sup> See, for example, Radelet, Sachs and Lee (1997) for a sample argument.

<sup>5</sup> See Krugman (1998) and Radelet and Sachs (1998) for sample arguments regarding causes of the Asian crisis.

<sup>6</sup> E.g., Aoki and Prusa (1995) suggest that the earlier timing of patent disclosure in the Japanese system is likely to decrease innovation by Japanese firms. Whitener (1990) suggests that the narrowness of the Japanese patent system can inhibit small firms from using the patent system, which can decrease innovation in the face of other market failures.

The idea that corporate secrets can act as a substitute for patents is not new to the economics literature. However, patents and market opacity do not work in exactly the same manner. Existing literature differentiates corporate secrecy from patents in that secrecy does not give information regarding investment opportunities to competitors while patents do.<sup>7</sup> This paper, on the other hand, deals with the situation in which all competitors already have complete information regarding the existence and nature of such opportunities; the difference between patents and market opacity lies in the way in which the two induce investment. Specifically, the timing of investments that are induced is likely to be different when patents are used than when they are not.

The term 'opaque market' is defined here as follows: a market is opaque if a company whose goal is to maintain secrecy from its competitors regarding an investment plan has a high likelihood of success. The term 'transparent market' is used to contrast with 'opaque market.'

Market opacity relates to actual investment as follows: with no information flows outside of price-setting behavior, a perfectly opaque market could exist in which rivals never learn of competitors' investments. However, the implementation of most investments (and certainly all investments whose goal is to increase product appeal), is clearly visible once a firm begins selling products created using the production process that results from the investment.

Nonetheless, market opacity still plays a role because preparation to implement an investment takes time. Investment begins with planning, continues with implementation, and only finishes with production using the new process—quite a long time after the investment process begins.<sup>8</sup> Competitors in an opaque market are unlikely to learn of investment plans during these preparatory phases. If a firm can move well into implementation before rivals learn this investment has begun, the firm will have a long lead on rivals that invest only upon learning of the firm's implementation. The greater the market opacity, the more likely firms will be able to maintain secrecy regarding implementation from rivals for an extended time.

Post- World War II Japan, perhaps the quintessential high-speed growth economy, illustrates some of the elements that can combine to create an 'opaque market':

- 1) A lack of clear accounting requirements and the allowance of different financial year-ends for related companies, which allows investment to be hidden from publicly available

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<sup>7</sup> See, for example, Friedman et al (1991).

<sup>8</sup> For example, a length of 3 years between decision to change production location and initial production at a new location was mentioned in interviews with representatives of three very different industries: paper, medical piping, and robotic printing.

<sup>9</sup> See, for example, Saxonhouse (1979) for discussion of the historically limited requirements for consolidated and unconsolidated accounting in Japan, particularly pages 3-25 to 3-29. For a more general,

accounting reports.<sup>9</sup>

- 1) A tradition for the members of corporate boards to come from life-long employees<sup>10</sup> which decreases the likelihood that corporate board members will leak proprietary information.
- 2) A higher reliance on bank debt rather than equity financing<sup>11</sup> (the so-called 'Main bank system'). The monitoring provided by the banks reduces the necessity for outside, public monitoring. Meanwhile, because bank financing is with a single private entity, such financing requires less public disclosure of information.
- 3) 'Long-term (lifetime) employment'<sup>12</sup> that, by decreasing turnover, decreases the likelihood that company secrets will escape when employees depart.

As this example illustrates, the financial system itself is only one element that affects market opacity. However, it is an important element: the better methods competitors have for monitoring each other through financial statements or otherwise, the less opaque the market becomes.

Of course, firms often do not avail themselves of the option to maintain secrecy, but rather choose to publicize their investment plans early in the planning process. However, this paper shows that it is the *option* of maintaining secrecy can play the critical role in inducing investment in rapidly changing environments— even when firms do not take advantage of the prospect of secrecy in equilibrium. If markets are opaque, then firms will pre-announce and make their investments that propel economic growth. On the other hand, if markets are transparent, then investment plans are liable to be canceled and growth is stifled.

The model presented here is in the same spirit as the patent literature.<sup>13</sup> Specifically, the possible market failure and the intuition behind the mechanisms that correct for this failure are the same. However, this model applies to a different set of situations and leads to a different set of results.

The source of possible market failure in both the patent literature and the model presented here is that there are externalities to investment. In particular, investment done by one firm decreases the profits of its competitors. The prospect of multiple firms in an industry all investing therefore diminishes the incentives for any individual firm to invest.<sup>14</sup> Both the patent literature and this paper also point out the same general method of getting firms to make the investment. This method is to give firms an extended period in which

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basic discussion of some of the particularly challenging aspects of gathering information from Japanese financial accounts, see, for example, Choi and Mueller (1992), pages 100-107.

<sup>10</sup> See, for example, Fukao (1995), particularly pages 12-20

<sup>11</sup> See, for example, Sheard (1989)

<sup>12</sup> See, for example, Mincer and Higuchi (1988)

<sup>13</sup> For a relatively recent overview of the patent race side of the literature, see Bridges et al. (1991)

<sup>14</sup> Patents may also be called for because other economic actors may free-ride and receive benefits from other's achievements. This free-riding plays no role in this model.

they have the market power of being the sole firm in the industry to have made the investment. Here, firms do not necessarily obtain all of this market power, but are tantalized with the prospect of obtaining it.

In the patent literature, the patent, which comes with a government-mandated monopoly, plays the role of extending the period in which a firm is the sole competitor to have implemented the investment. In the model presented here, two different elements play the role of extending the period of market power. These two elements are 1) a slow pace of market or technological change, and 2) market opacity. Which of these two elements actually induces the investment depends on the situation. A description of these mechanisms and how they work follows shortly.

The class of investments covered by the patent literature and this model are characterized by the following criteria:

- investment increases flow profits of the investing firm and decreases the flow profits of competing firms (i.e. firms are selling substitutes in demand)<sup>15</sup>
- investment is duplicable

In addition, the investment covered by the model presented in this paper is additionally characterized by:

- the investment is most efficiently done by existing competitors,
- the cost advantage or change in preferences that create the incentives for investment is durable rather than transitory, and
- the flow of benefits accruing to the investor are (at least in part) increasing exogenously over time.

Some examples of types of investment which are both necessary in large quantities for economic development and often satisfy these characteristics are:

- Movement of production in order to decrease production costs (e.g. import substitution)
- Replacement of labor for capital in production processes as economic development occurs
- Modification of products in response to the changing tastes of consumers whose income is rising

The results presented in this model differ from the patent literature in three primary ways:

1. By not requiring identification of a particular item for government protection, this model additionally relates to the range of investments that are not easily dealt with using a patent system.<sup>16</sup>
2. Because there is no period of government-protected monopoly power, markets freely

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<sup>15</sup> Once again, patents can also be beneficial simply because they help firms internalize the benefits that accrue to non-innovating free riders. However, such free riding is not necessary to make patents beneficial.

<sup>16</sup> This set of non-patented innovations is likely to be quite large in the real economy. Although measurement is always a challenge, Arundel and Kabla (1998), for example, suggest that only a minority of 'innovations' is patented. The majority are not, and thus models without patents must be used to explain these innovations. This application is in addition to the non-technology related, duplicable investments.

set investment timing. This leads to different timing of investment.

2. Due to market power timing, the more rapidly the investment environment is changing in this model, the more important the role market opacity plays in this model. While the same is true of patents, the literature has only highlighted the idea that rapid change can decrease the effect of patents by decreasing the period in which the technology covered by the patent is 'cutting edge.'

The results presented in this paper do not exist solely in theory but also exist in the real economy. For example, the elements in the model presented in this paper clearly play a critical role in the Chinese and ASEAN carbonless copy paper markets. This model can explain which elements determined the contrasting actions of market participants, and why these elements played a critical role in these particular markets.

A planning division manager at a world leader in the paper industry explained the following situation in a recent interview<sup>17</sup>: until recently, both the Chinese and ASEAN carbonless copy paper markets were supplied by Japanese and American exports. However, because of sizeable tariffs, shipping costs, and increasing development of these economies, a competitor producing in these markets would have a significant cost advantage over their competitors producing overseas. As the economic development continues, the possible local producer cost advantage has been increasing. Beginning recently, a single firm producing in these markets would certainly be able to quickly recoup the costs associated with building a new factory in either market. The natural investor would be a new branch of an existing Japanese or American paper company.

This is exactly what occurred in the ASEAN carbonless copy paper market: it is large enough to support a single local producer but is not large enough to support multiple producers. With no competitors to compete profits away, there was a race between paper companies to be the sole ASEAN local carbonless copy paper producer. As soon as one company announced definite plans with government approval to open a plant in Thailand, the other paper producers backed off, leaving only one carbonless copy paper plant in ASEAN (Oji Seishi's recently opened joint venture factory in Thailand).

On the other hand, China is a larger market for carbonless copy paper than is ASEAN. While this larger size initially seems likely to increase the attractiveness of building a carbonless copy paper plant there, the opposite is true—the large size of the market makes it *less* attractive. If one company successfully moves production to China by building a carbonless copy paper plant there, rivals will be right behind them, also moving production to China. This competition will drive down the Chinese market price, making the investment unprofitable. Therefore, the Chinese market is continuing as an export destination for

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<sup>17</sup> Ishida (1998).



carbonless copy paper rather than realizing import substitution—despite significant growth in China's comparative advantage in this product and the existence of trade barriers.

The model presented in this paper can also explain why the problems of a large market are more likely to deter investment in a rapidly developing economy like China's than in a slowly developing nation.

Consider the case of an investment that has some given effect on production costs or product desirability. The following statement is true under the very general assumptions laid out in the body of this paper: the profit increase a first firm in an industry obtains by making that investment is greater than the profit increase a second firm obtains by making that same investment. The profit increase obtained by a second firm is greater than that obtained by a third firm, and so on. The result is that an investment must have a greater effect on production costs or product desirability to induce two firms in an industry to undertake it than it would to induce only one firm.

When an investment's effect on production costs or product desirability is increasing over time (e.g. due to economic development), then there will be a lag between when the first firm and when the second firm invests—assuming firms ever make the investment. The more slowly the investment's effect on production cost or product desirability is increasing over time, the longer this lag will be. Meanwhile, flow returns from the investment to the first-investing firm are generally highest during this lag because of the market power associated with being the sole competitor to have implemented the investment. The longer this lag is, the longer this period of greatest flow-return is, and thus the higher the total return from the investment.

Slow economic growth makes investment more inviting by lengthening the lag between when a first firm and second firm in the industry will make the investment, and thus increasing the maximum total return to investment for the first firm to invest. Conversely, high-speed economic growth makes investment less inviting by shortening the lag and thus decreasing the total return to investment. In other words, the rapid changes in the Chinese economy make investment less inviting.

However, the Chinese high-speed economic growth would not be possible without investment. Thus, an element must exist that induces investment in such high-speed growth environments. That element is market opacity.

The mechanism by which market opacity induces investment is similar to the way inability to monitor rivals breaks down price and quantity collusion. The collusive price is more profitable than the one-shot, non-collusive equilibrium price. However, if one firm unilaterally deviates from the collusive strategy, their profits are even greater than in collusion. Meanwhile, difficult monitoring means that unilateral deviations from collusion would not be caught until the deviant had obtained huge deviation profits. Thus the

temptation to deviate becomes irresistible when monitoring is difficult. The result is that in the equilibrium in an environment with minimal monitoring, firms realize the irresistibility of temptation and do not even try to collude.<sup>18</sup>

Similarly, in the model presented here, investment in a rapidly changing environment is less profitable in equilibrium than not investing would be; i.e. not investing is the collusive outcome. However, if one firm invests without causing other firms to also invest, then their profits are even higher than if they follow the collusive strategy of not investing. Meanwhile, market opacity leads to a long period between when investment occurs and when competitors respond by also investing, thereby increasing the temptation for firms to individually invest. The result is that in equilibrium in an opaque market, firms realize the temptation and invest early in the game. A significant difference between the model presented here and price collusion models is that collusion in the model presented here is an all or nothing proposition.

In short, market opacity can induce investment in a rapid-growth environment while, conversely, market transparency can decrease it in the same environment. Thus, opaque markets can facilitate the high-speed economic growth. The carbonless copy paper industry may require a higher level of market opacity to induce investment, is less opaque, or is changing 'more rapidly' than most Chinese product markets. Whatever the case, this lack of the necessary opacity combined with the fast pace of change can explain the lack of development in China's carbonless copy-paper industry.

The link between market opacity and economic growth can be more explicitly considered in a general equilibrium context. Although a complete general equilibrium model is not presented in this paper, the intuition is clear: while market opacity is likely to decrease investment needed for high-speed growth, it does not lead to a situation without any equilibrium. Rather, the lack of investment slows growth. The slower growth becomes, the more investment is induced by the slow rate of change; i.e. slower growth allows an economy to be less dependant on market opacity to facilitate investment. Therefore, the degree of market opacity acts as a growth speed limit.

In addition to covering the basic elements of the relationship between the speed of economic change and market opacity, this paper also extends the basic model, applying it to two particular situations related to production location changes. The first application is the role of tariffs in facilitating or inhibiting import substitution as perhaps is the case in the Chinese carbonless copy paper industry. Many of the results of this application are straightforward after the previous discussion. For example, increasing a tariff may decrease the incentive for the creation of a 'home industry' by increasing the number of firms that move production

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<sup>18</sup> See, for example, Green and Porter (1984) and Abreu, Pearce, and Stacchetti (1990) for more discussion of this type of model.

to within the country if any do.

However, a more interesting relationship between import substitution and tariffs arises from a comparison of the following two scenarios: a country in which economic development is accelerating, and a country in which economic development is decelerating. Tariffs increase the cost difference between foreign production and home market production for given production costs in the two locations. Therefore, as production costs within the protected country are falling due to growth, any investment that does occur will be done earlier than if the tariff did not exist.

If development is accelerating, then this earlier investment occurs during slower development. Slower change means a longer lag between when a first firm will invest and when a second will. These longer lags increase the incentive to invest—increasing the likelihood that import substitution will be induced.

The situation is the opposite for decelerating development; the earlier investment occurs during more rapid growth. Faster growth means a shorter lag between when a first firm will invest and when a second will, and thus less incentive to invest—*decreasing* the likelihood that import substitution will be induced.

The second application of the model is an analysis of the effect of government-sponsored cartels for ‘sunset industries’ in high-speed growth environments. Of course, cartels can have direct effects on firm profitability. However, something of a paradox exists related to the effect of government-sponsored ‘recession cartels’ in Japan. Many such cartels seem to have effectively limited production movement from Japan to other locations that became more suitable as Japan’s comparative advantage changed.<sup>19</sup> In a seeming contradiction to such claims, Dick (1992) and Weinstein (1995) find that the government-run cartels had relatively little effect on prices. With no effect on prices, it seems unlikely that the cartels were effective in making production within Japan more profitable.

The model presented in this paper can explain these results: a common element of government-instituted cartels is greater interaction between rivals and thus increased market transparency (decreased opacity.) As already described, this market transparency can deter investments such as the movement of production from the present location to a more appropriate one—even if the cartel does not affect pricing decisions.

In addition, when government actions to decrease market opacity fail, they can also have another effect. Without government action, firms may have moved production abroad over an extended period of time. Government meddling may, to borrow Ross Perot’s famous phrase, lead to the ‘giant sucking sound’ of an

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<sup>19</sup> E.g. see Tilton (1996) and Uriu (1996) for discussion of Japanese cartels. The impact of cartels was also reiterated to the author during several informal discussions with MITI bureaucrats.

entire industry departing en masse.

The model presented here is based on the investment timing literature. In particular, the model is based on the model described by Reinganum (1981), modified in Fudenberg and Tirole (1985), and used in Tombak (1995), among others. However, a completely new dimension is added to the model in this paper by relaxing the assumption made or implied in the previous versions that investment will necessarily occur.

The first section of the paper describes the game theory model. The second section describes the results of the basic model without uncertainty and is divided into three cases. The third section discusses the model in the context of import substitution, while the fourth section adds uncertainty to the model in a discussion of the link between tariffs and import substitution. The paper ends with a conclusion.

## The Model

As mentioned earlier, the model presented here is based on the one described by Reinganum (1981), modified in Fudenberg and Tirole (1985), and used in Tombak (1995). To simplify discussion of the game, the model is applied to the particular type of investment discussed in the carbonless copy paper example—change in production location where the benefits to investment come in the form of decreased marginal production costs.

Bayesian perfection is used as the equilibrium concept. For this concept, each participant in the game is given a strategy and set of beliefs. The beliefs are regarding past competitor moves. A set of beliefs and strategies is an equilibrium if beliefs match opponent strategies and strategies in all subgames are best responses.

The 'industry' consists of two symmetric firms,  $i \in (1,2)$ , in which firm 1 is, WLOG, the first firm to make the investment necessary to change production location; if neither firm changes production location, then firm 1 is randomly noted.<sup>20</sup> The two firms play the game over an infinite time horizon, each firm having the option of changing production location at any moment. The beginning of the game is denoted  $t=0$ .

Prior to  $t=0$ , both firms have set up the factories, distribution lines, and other facilities necessary for

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<sup>20</sup> This does *not* limit the types of equilibria in any way. Another way of approaching the model would be to name one firm A and the other B, and to analyze the equilibria in which firm A and those in which firm B move first separately. However, the assumption of symmetric firms leads to both analyses being identical. Thus, this shortcut of calling the first firm to move firm 1 places no limitations on the model.

production at the 'Present Production Location' (PPL). However, firms also have the option of producing at an 'Alternative Production Location' (APL). Thus, there are three possible combinations of (X,Y) in which firm 1 produces at location X and firm 2 produces at location Y:

Production Location Combination (X,Y)  $\in$  [(PPL,PPL),(APL,PPL),(APL,APL)].

Initially, marginal production costs are lower at the PPL. However, the marginal costs at the APL are falling over time while those at the PPL are unchanging. The opportunity to take advantage of lower or eventually lower APL costs is the benefit firms receive from changing production location. Arbitrarily and with no qualitative effects on results in this model, firms do not change production location if they are exactly indifferent between changing and not changing.

Production location change is not instantaneous. Rather, opening the new production facility at the APL and closing the PPL facility takes preparation time. The length of this preparation is independent of when during the game the investment is made and what has occurred prior.<sup>21</sup> The time at which the preparation must begin for initial production at the APL at time t is denoted Z(t).

Due to market opacity, firms have the option of maintaining secrecy regarding plans to change production location for at least a part of this preparation time. For firms beginning production at the APL at time t and choosing to take advantage of market opacity to hide their preparations, H(t) represents the amount of time they had before their competitors learned of the preparations. Thus, any competitor that did not begin their own investment plans until they learned of the firm's preparations is not able to begin production at the APL until t + H(t).

The more opaque the market is during the preparation period, the longer H(t) is. In the sections of the paper without uncertainty, firms have complete information regarding H(t) at the beginning of the game. In the section including uncertainty, firms learn the length of H(t) just prior to when they must begin preparations that would lead to initial production at the APL at time t.

In addition to the option of maintaining secrecy, firms also have the option of costlessly pre-announcing their production location change in a credible manner at Z(t). Once announced, firms are committed to changing production location at time t. These modeling changes do affect the timing of investment and whether rents are completely competed away in equilibrium.<sup>22</sup> However, these characteristics do not affect whether investment could be profitable for a set of best-response strategies beginning at *some* point in the

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<sup>21</sup> A technology 'spillover' as seen in the patent literature would have implementation cost of a follower lower than a leader's. This effect would only serve to strengthen the more interesting results of the model.

<sup>22</sup> See Mills (1988) regarding this effect.

game. These characteristics, therefore, do not alter whether or not investment occurs at all—the primary focus of this paper.

In addition to requiring preparation, investment to change production location is also costly. This cost is subsumed in a sunk cost  $K > 0$  paid at the moment production begins at the APL; this cost is independent of when during the game the investment is made. A firm that never changes production location does not incur this cost.

The model concentrates on the strategic implications of investment opportunities. Therefore, it is set up in reduced normal form with non-investment decisions for each instant  $t$  assumed to come from equilibria of the one-shot game in which firms produce in locations  $(X, Y)$  under the conditions at that instant. Parameters in these one-shot games are assumed to satisfy the single-crossing condition, and thus flow profits are a function solely of the production location of the two firms. The flow profits for firm  $i$  in instant  $t$  with production location combination  $(X, Y)$  is denoted  $\Pi_{(X, Y)}^i(t)$ .

The profit a firm earns as a result of competition in which both firms produce at the PPL is the baseline, and thus assumed constant:  $\Pi_{(PPL, PPL)}^i(t) \equiv \Pi_{(PPL, PPL)}$ . Meanwhile, the flow profits for the other production

location combinations are assumed to be changing smoothly over time at rate  $\dot{\Pi}_{(X, Y)}^i(t)$ <sup>23</sup>. This set of

flow profits follows the usual set of assumptions for this type of game. ‘Graph 1: Profits Over Time’ presents a representative set of flow profits for all production location combinations that satisfy the following five assumptions:

- **Assumption 1:**

$$\int_{t=0}^{\infty} e^{-rt} \Pi_{(APL, PPL)}^1(t) dt - K < \int_{t=0}^{\tau} e^{-rt} \Pi_{(APL, PPL)}^2(t) dt + \int_{t=\tau}^{\infty} e^{-rt} \Pi_{(APL, APL)}(t) dt - e^{-r\tau} K \quad \forall \tau$$

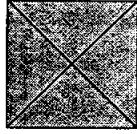
At  $t=0$ , production at the APL is so much more expensive than at the PPL that no firm would possibly change production location at that time.

- **Assumption 2:**  $\Pi_{(APL, APL)} = \Pi_{(PPL, PPL)} \Leftrightarrow \Pi_{(APL, PPL)} = \Pi_{(PPL, PPL)} \Leftrightarrow \Pi_{(APL, PPL)} = \Pi_{(PPL, PPL)}$

This comes from symmetry: flow profits are equal when production costs are equal.

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<sup>23</sup>  $\dot{X}$  refers to the first derivative, while  $\ddot{X}$  is the second derivative.



- **Assumption 3:**  $\Pi^1_{(APL,PPL)}(t) > 0 \forall t$ .

This is a result of the constant PPL and falling APL costs: a firm whose costs are falling while their opponent's remain constant realizes increasing profits.

- **Assumption 4:**  $\Pi^2_{(APL,PPL)} < 0 \forall t$ .

This is also a result of constant PPL and falling APL costs: the rival of a firm whose costs are falling suffers decreasing profits.

Both assumptions 3 and 4 always hold for competition between firms selling goods that are substitutes in demand. This type of competition also sets a range for flow profits in production location combination (APL, APL):

$$\Pi_{(APL,APL)}(t) \in (\Pi^1_{(APL,PPL)}(t), \Pi^2_{(APL,PPL)}(t))$$

Slightly greater limits are added to the results of this situation by assumption five.

- **Assumption 5: Flow profits are smoothly submodular in costs:**

The definition of submodularity,

$$F(X)+F(Y) \geq F(X \wedge Y) + F(X \vee Y),$$

translated into this model gives the following equations:

$$\Pi^1_{(APL,PPL)}(t) - \Pi_{(PPL,PPL)} \geq \Pi_{(APL,APL)}(t) - \Pi^2_{(APL,PPL)}(t) \quad \forall t \text{ S.T. APL has lower costs than PPL}$$

$$\Pi^1_{(APL,PPL)}(t) - \Pi_{(PPL,PPL)} \leq \Pi_{(APL,APL)}(t) - \Pi^2_{(APL,PPL)}(t) \quad \forall t \text{ S.T. PPL has lower costs than APL}$$

Smoothness translates in this model as the situation in which both sides of these inequalities are increasing smoothly at all times.<sup>24</sup>

The goal of each firm is to maximize the net present value of their profits. They do this by deciding when to move production to the APL and whether to move in secrecy. The time firm *i* actually begins production in the APL is denoted  $M_i$ . If firm *i* never changes production location then  $M_i = \infty$ . This leads to payoffs  $V^i(M_1, M_2)$  to firm *i*:

<sup>24</sup> This assumption is generally simply implied. However, it is useful to examine why it is reasonable; this exercise is done in 'Appendix 1: The Meaning of Smooth Submodularity in this Model.'

$$V^i(M_1, M_2) = \int_{t=0}^{M_1} e^{-rt} \Pi_{(PPL, PPL)} dt + \int_{M_1}^{M_2} e^{-rt} \Pi^i_{(APL, PPL)}(t) dt + \int_{M_2}^{\infty} e^{-rt} \Pi^i_{(APL, APL)}(t) dt - e^{-rM_i} K$$

## The Results

The dynamic programming method of solving the game begins by finding the payoffs to all strategies that are promising candidates to be equilibrium paths. This information is then used to solve for the Bayesian perfect equilibria.

The first step is to find the strategies followed by a firm 2 that knows that firm 1 changes production location at  $t=0$ . This is quite simple as firm 2 is facing a one-player decision problem.

By assumption 5, the net present value of firm 2 flow profits is quasiconcave in  $M_2$  for this situation. The constant sunk cost associated with investment thereby guarantees that there is a maximum of one critical point in the game,  $T^*_2$  which is characterized by:

$$T^*_2 = t \text{ S.T. } \Pi_{(APL, APL)}(t) - \Pi^2_{(APL, PPL)} = rK$$

If  $T^*_2$  exists, the best response for firm 2 is to change production location at  $T^*_2$ , and to not change production location if  $T^*_2$  does not exist..

This also gives the optimal response to any firm 2 that finds out that firm 1 is in the process of changing production location. If this knowledge is acquired in time to change production location at  $T^*_2$ , then firm 2 changes production location at exactly  $T^*_2$ . If this knowledge is acquired later on, then firm 2 begins preparation to change production location immediately. If  $T^*_2$  does not exist, then firm 2 never changes production location. These strategies are best responses, and thus must hold in all subgames for Bayesian perfect equilibrium.

The next step is to solve for firm 1's optimal response to a firm 2 that pledges never to change production location first. This is finding firm 1's best response to firm 2 never changing production location.

Assumption 1 results in concave net present value of firm 1's flow profits with respect to  $M_1$ . The constant sunk cost associated with investment thereby guarantees that  $T^*_1$  is characterized by:

$$T^*_1 = t \text{ S.T. } \Pi^1_{(APL, PPL)}(t) - \Pi_{(PPL, PPL)} = rK$$

*This  $T^*_1$  is the most profitable time for firm 1 to change production location assuming firm 2 does not*

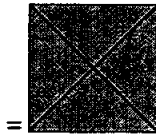


change production location until after  $T^*$ . In other words, if it exists,  $T^*_1$  is the  $M_1$  which is the best response to a perfectly informed firm 2 playing this strategy: change production location at the  $\text{argmax}(T^*_2, M_1)$ —as long as the best response ever includes firm 1 ever changing production location. Assumption 5 guarantees that  $T^*_1 < T^*_2$ .

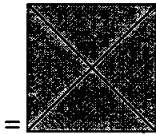
The last step is to consider whether production location change occurs at all, and how the option of preemptively changing production location fits into equilibrium strategies. The information used to characterize  $T^*_1$  and  $T^*_2$  is also used to characterize the payoffs to the types of strategies presented in 'Graph 2: Profits, Moves.' These strategies are:

$$\begin{aligned} N(t) &= \text{payoffs if neither firm moves} \\ &= V^1(\infty, \infty) \end{aligned}$$

$$A(t) = \text{payoff to firm 1 for beginning production in APL in period } t. \text{ Firm 2 does not consider preemptively changing production location, but otherwise responds optimally.}$$



$$F(t) = \text{payoff to firm 2 when firm 1 begins production in APL in period } t. \text{ Firm 2 does not consider preemptively changing production location, but otherwise responds optimally.}$$



$$S(t) = \text{payoff to firm 1 for beginning production in APL in period } t. \text{ Firm 2 is surprised by information regarding firm 1's move.}$$

$$= \begin{cases} V^1(t, T^*_2) & \text{if } Z(t) + H(t) < Z(T^*_2) \\ V^1(t, t + H(t)) & \text{if } Z(t) + H(t) \geq Z(T^*_2) \end{cases}$$

$$\begin{aligned} M(t) &= \text{payoff to both firms moving at time } t \\ &= V(t, t) \end{aligned}$$

$A(t)$  and  $F(t)$  are clearly continuous and continuously differentiable for the entire game. Some other characteristics of these curves will also prove to be useful.

The early portion of the game is characterized by:

- \*  $F(0) > A(0)$  by Assumption 1.

- \*  $A(T^*_1) > F(T^*_1)$  by Assumptions 3 and 4.
- \*  $A(t)$  is maximized at  $T^*_1$  for  $t \in [t, T^*_2]$  by Assumptions 3 and 4 and the definition of  $T^*_1$ .
- \*  $M(t) < F(t) \forall t < T^*_2$  as  $T^*_2$  is the profit-maximizing period for firm 2 to follow firm 1 to the APL; any earlier move clearly decreases profits.
- \*  $A(t) = S(t) \forall t \in T^*_2 - H(T^*_2)$  as firm 2 moves production at  $T^*_2$  whether surprised or not.

Later portions of the game are characterized by:

- \*  $A(t) = F(t) = M(t) \forall t \geq T^*_2$  as they all refer to both firms moving simultaneously at  $t$ .
- \*  $S(t) > A(t) \forall t \geq T^*_2$  because a 'surprise move' allows firm 1 produce alone in the APL for  $H(t)$ .
- \*  $S(t)$  for  $t \geq T^*_2$  is not necessarily continuous because  $H(t)$  may not be continuous.

There are three sets of parameters, Case 1, Case 2, and Case 3, which lead to different types of Bayesian perfect equilibria.

**Case 1: Minimal Eventual Difference:**  $\lim_{t \rightarrow \infty} (\Pi^1_{(APL, PPL)}(t) - \Pi_{(PPL, PPL)}(t)) \leq rK$

The shape of the relevant curves when there will never be a particularly large difference in costs between the APL and PPL is shown in 'Graph 3: Limited Difference'. The following is highlighted in this case:

- \* If the eventual difference in production costs is too small, then neither firm changes production location.

If the difference in production costs between PPL and APL is small enough, then

$$\lim_{t \rightarrow \infty} (\Pi^1_{(APL, PPL)}(t) - \Pi_{(PPL, PPL)}(t)) \leq rK$$

In this situation which is represented by curve  $A'(t)$  in Graph 3, neither  $T^*_1$  nor  $T^*_2$  exist. If  $T^*_2$  does not exist, then firm 2 does not change production location. With firm 2 not moving, the non-existence of  $T^*_1$ ,

$$T^*_1: \Pi^1_{(APL, PPL)}(t) - \Pi_{(PPL, PPL)}(t) = rK,$$

is the necessary and sufficient condition for neither firm to change production location.<sup>25</sup> Therefore, firm 1 will also not change production location. Lastly, both firms switching simultaneously is also not an equilibrium path as  $M(t) < F(t)$ ; firms would do better by individually switching to never changing production location.

Therefore, the only Bayesian perfect equilibrium is for neither firm to ever move, and to believe that the

<sup>25</sup>  $K$  is the moving charge and  would be the benefit to moving at  $T^*_1$ .

other firm has never moved. If they ever learn that the other firm has moved production, they do not follow.

**Case 2: Moderate Eventual Difference:**

$$\lim_{t \rightarrow \infty} (\Pi_{(APL, PPL)}^1(t) - \Pi_{(PPL, PPL)}(t)) > rK, \quad \lim_{t \rightarrow \infty} (\Pi_{(APL, APL)}(t) - \Pi_{(APL, PPL)}^2(t)) \leq rK$$

This situation is also shown in ‘Graph 3: Limited Difference’; it is represented by curve A(t) rather than A'(t). The following is highlighted in this case:

1. With costs at the APL eventually moderately lower, exactly one firm will move production there.  
There is no equilibrium in which no firm changes production location.
2. The firm that changes production location does so earlier than is profit maximizing. In fact, they may move production to the APL when production costs there are still *higher* than at the PPL.
3. Equilibrium profits for the two firms are likely to be lower than N(t). In other words, the option of moving production to lower costs can decrease equilibrium profits for both firms.

This moderate range does exist for some eventual difference in production costs by Assumption 5. In this situation  $T_1^*$  does exist but  $T_2^*$  does not; this will lead to one firm (but not two) changing production location.

If neither firm moves, then payoffs are N(t). A strategy featuring neither firm ever changing production location is dominated by firm one announcing at  $Z(T_1^*)$  their intention to move. Because  $T_2^*$  does not exist, firm 2 would never follow. Firm 1 would therefore receive more than the interest charge on the moving fee each period ad infinitum. Therefore, neither firm moving is not an equilibrium path.

Firm 1 moving at  $T_1^*$  is also not an equilibrium. By moving at  $T_1^*$ , firm 1 would receive  $A(T_1^*)$  and firm 2 would receive the lower  $F(T_1^*)$ . However, firm 2 could receive higher profits by preemptively announcing their movement preparations at  $Z(T_1^* - \epsilon)$ ; by doing so, they would obtain  $A(T_1^* - \epsilon)$  which is only marginally less than  $A(T_1^*)$ . Firm 1 is only successful at preventing preemption by moving production to APL at  $T_1$ , the point at which preemption by firm 2 would no longer occur because both firms receive the same profits.

The move at  $T_1$  must be pre-announced at  $Z(T_1)$ . An equilibrium set of strategies in which firm 1 did not pre-announce the move must have firm 2 correctly believe firm 1 will change production location at  $T_1$ . Firm 2 will not preemptively move immediately after  $T_1$  if firm 1 does not because of their belief that firm 1 will have moved by then. Therefore, firm 1 would have the opportunity to profitably postpone their  $T_1$  move until some time closer to  $T_1^*$ , thereby making firm 2's belief incorrect.

The net result leads to equilibrium profits for both firms equal to  $A(T_1)=F(T_1)$ . This profit level is lower than  $A(T_1^*)$ , and is likely to be even lower than N(t)—both firms are likely to earn lower profits when the

option of lower cost production is available than they would if that option were not. This is certainly the case if production costs at the APL are lower than at the PPL at  $T_1$  as firm 1 has costs equal or lower than at the PPL for the entire game. The resulting disadvantage for firm 2 leads to lower profits.<sup>26</sup>

On the other hand, firm 1 may move from what is initially a low-cost production location to a higher-cost APL. The more quickly production costs are falling at the APL up to  $T^*_1$ , the more likely this type of move is; the key lies in the rent equalization,  $A(T_1)=F(T_1)$ . For given activity after  $T^*_1$ , firm 2 loses the same profits relative to  $N(t)$  due to being at a cost disadvantage after  $T^*_1$ . The more quickly production costs are falling prior to  $T^*_1$  the less firm 1's profits fall relative to  $N(t)$  for any production location change prior to  $T^*_1$ .<sup>27</sup>

**Case 3: Large Eventual Difference:**  $\lim_{t \rightarrow \infty} (\Pi_{(APL,APL)}(t) - \Pi_{(APL,PPL)}^2(t)) > rK$

The shape of the relevant curves when there will eventually be a 'relatively' large difference in costs between the APL and PPL is drawn in 'Graph 4: Greater Difference.' The following is highlighted in this case:

1. Firms may not move even if there are significantly lower production costs at the alternative location.
2. The longer the information lag,  $H(t)$ , the more likely it is that firms will change production location.
3. The more quickly circumstances are changing, the more likely market opacity is necessary to ensure that firms do move production to the APL.
4. As in Case 1, if there is a first firm to move production, it does so earlier than would maximize profits. The resulting profit level may be greater or less than  $N(t)$ . Also, again, firm 1 may move to an initially higher cost production location.

If both  $T^*_1$  and  $T^*_2$  exist, then the eventual difference in production costs at the two locations is larger than in Case 1. Because  $T^*_2$  exists, firm 2 will necessarily follow any move by firm 1. The act of firm 2 following decreases the value of  $A(t)$  and thus can lead to equilibria in which neither firm changes production location.

It is theoretically possible that the cost of changing production location is low and that industry-wide profits

<sup>26</sup> This situation is possible because firm 1's flow profits are lower in any portion of the game in which they are producing in the APL prior to  $T^*_1$  as the interest costs of the moving charge are not covered.

<sup>27</sup> Mathematically, this is decreasing the discount rate for all time prior to  $T^*_1$  without changing the interest rate.

rise a vast amount in response to all firms in the industry cutting costs by changing location. Such a scenario would lead to all firms happily changing production location. However, building new factories and other similar investments are very expensive, and increased competition as other firms also cut costs mitigates any resulting increase in flow profits. Therefore, the following discussion deals with the situation in which any increase in an individual firm's flow profits due to industry-wide location change is insufficient to cover the interest on the moving charge.<sup>28</sup>

Just as in Case 2, firms change production location if a set of best response strategies would lead to higher payoffs for at least one firm than never moving. In other words, firms always change production location if the maximum of  $A(t)$  or  $S(t)$  is greater than  $N(t)$ . However, because firm 2 will necessarily follow a firm 1 move, the existence of  $T^*_1$  is no longer a sufficient condition for  $A(T^*_1)$  to be greater than  $N(t)$ .

The more quickly production costs at the APL are falling, the less likely  $A(t)$  is to be higher than  $N(t)$ . The more quickly costs are falling up to  $T^*_2$ , the more closely  $T^*_2$  follows behind  $T^*_1$ . Because the period between  $T^*_2$  and  $T^*_1$  is the time a first firm moving at  $T^*_1$  would have the advantage of producing alone in the APL, the shorter this period of advantage is, the lower  $A(T^*_1)$  is. Mathematically, rapid change, i.e. allowing for more rapid growth in this high-return period, is, once again, increasing the discount rate between  $T^*_1$  and  $T^*_2$  without altering the interest rate. This change decreases total returns to investment.

If  $A(T^*_1)$  is less than  $N(t)$ , then a move will only necessarily occur if  $S(t)$  is greater than  $N(t)$ . In other words, if  $A(T^*_1) < N(t)$ , production location change is induced only if a firm could, at some point in the game, profitably surprise an unsuspecting opponent by moving production.

If a firm could only obtain a short advantage with a surprise move due to lack of market opacity, then  $S(t)$  will look more like  $S(t)^2$  in Graph 4, which does not incite a location change. In this situation,  $A(T^*_1) < N(t)$ , and  $S(t)$  is below  $N(t)$  for all  $t$ . Thus, there is no reason for firms to ever change production location. This equilibrium path is  $M_1 = M_2 = \infty$ : neither firm changes production location, and each believes its opponent has not begun preparations to change either. Off the equilibrium path, if a firm learns that their opponent is changing production location then they do the same at the  $\text{argmax}(t+H(t), T^*_2)$ .

$S(t)$  would only look like  $S(t)^1$ , which does induce a production location change if the market is opaque. In other words,  $S(t)$  looks like  $S(t)^1$  only if a firm could make a significant portion of their plans to change production location without their rival knowing. If such a surprise is possible, then it is not possible for

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<sup>28</sup> One reason the infinite length game is reasonable is that it is that it correctly models competition whose finish is unknown. This means the true depreciation rate is higher than the interest rate. In that case, the results described in this section can also hold even if increased profits cover interest on the moving charge.

firms to coordinate on non-production location changing equilibria. The best response to an opponent not changing production location and not believing their opponent will would be to 'sneak away' at the point where  $S(t) > N(t)$ .

All equilibria end up with no surprises. Therefore, firm 1's certain move at the maximum of  $I^2(t)$  would be preempted by firm 2. Just as in case 2, the equilibrium path must have firm 1 pre-announcing and changing production location at  $T^*_1$ . Firm 2 will follow behind at  $T^*_2$ .<sup>29</sup> Profits, again, may be lower than  $N(t)$  as in Graph 4, although not necessarily. The same example as in case 2 still holds regarding firm 1 possibly moving to an initially higher cost production location.<sup>30</sup>

It is noted that another Bayesian perfect equilibrium does exist when  $A(T^*_1) < N(t)$  and  $S(t) < N(t)$ . In this equilibrium, both firms believe (correctly) that their opponent will certainly change production location if they are not preempted. Thus, they will attempt to preempt this investment. Firm 1 changes production location at  $T_1$  and firm two at  $T^*_2$  along this equilibrium path.

In a game featuring patents, similar equilibria for this case also exist. However, the timing of investment (production location change) is likely to be different. With a patent, a second firm is legally unable to also invest until the end of the patent's length. The length of time between  $T_1$  and  $T^*_2$  plays no direct role in the equilibrium of the model presented here. With a patent, however, if the period between  $T_1$  and  $T^*_2$  is less than the length of the patent, then invest at  $T_1$  and  $T^*_2$  can not be the equilibrium investment path.

If firm 2 is unable to respond to a firm 1 production location change at  $T_1$  by changing production location at  $T^*_2$ , then  $F(t)$  is even lower. Therefore, firm 2 would preempt a firm 1 production location change at  $T_1$ ; in equilibrium, firm 1 would change production location even earlier. This earlier, more spread out change in production location when patents exist could either increase or decrease social welfare relative to change at  $(T_1, T^*_2)$ .

## Tariffs and Import Substitution

It is generally assumed that tariffs encourage import substitution by increasing the relative costs of exporting to the country relative to producing within it. This can certainly also occur in this model. The

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<sup>29</sup> Prior to  $T^*_2$ , the cause for preemption is caused by the difference between  $F(t)$  and  $A(t)$ . Past  $T^*_2$ , the preemption is caused by the fact that a preempting firm, by preempting, could earn  $\Pi^1_{(APL,PPL)}(t) - \Pi_{(PPL,PPL)}$  which is greater than the cost  $rK$ .

<sup>30</sup> See 'Appendix 2: Bayesian Perfect Equilibrium Details' for details regarding the Bayesian perfect equilibrium strategies for Cases 1, 2, and 3.

tariff could, for example, change the situation from Case 1 to Case 2. In addition, if tariffs are large enough to completely block imports, then Assumption 4 ceases to hold and import substitution occurs.

However, this model shows that *tariffs can also decrease the likelihood that import substitution occurs*.<sup>31</sup>

The simplest example of this is a situation that would be Case 2 without a tariff, but Case 3 with the addition of the tariff. Case 2 necessarily leads to import substitution while Case 3 does not. If markets are relatively transparent and growth is rapid, then a reasonable equilibrium with the tariff would be no change in production location—no import substitution.

More interesting, however, is the situation that would be Case 3 both with and without the tariff. This situation in which there will eventually be significantly lower production costs within a country even without a tariff is the topic of the following discussion. This discussion refers to 'Graph 4: Greater Difference.'

The amount firms can increase their profits in equilibrium by changing production location determines how likely it is that import substitution occurs. In an oligopolistically competitive market, this, in turn, is based on how flow profits change for given absolute changes in marginal costs from different bases in which all competitors have the same relative marginal costs. For many functional forms, the change in flow profits is primarily a function of the *change* in marginal costs of the various competitors; differences in the competitors' initial marginal production cost levels are relatively unimportant. Consideration of change in flow profit as a function solely of differences in marginal costs rather than levels is consistent with the assumptions of the model presented earlier in this paper, although it is not implied by them.

Therefore, this discussion is based on the assumption that changes in flow profits are a function only of the amount production costs change.<sup>32</sup> While this assumption will not generally hold exactly in mathematical models of competition due to various elasticities, it is generally a reasonable approximation; therefore, the qualitative results should still generally hold. Just as in the earlier section of the paper, production costs at the PPL are assumed to be constant. In addition, any tariff is assumed to be a fixed charge per-unit imported, and is implemented before the game begins if at all. The net result is that the marginal cost of production at the PPL is simply increased by the amount of any tariff.

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<sup>31</sup> The negative income effects of tariffs could also lead to this effect. However, this analysis concentrates on other factors.

<sup>32</sup> For example, the analysis assumes *changes* in flow profit between the initial and final situation will be similar for both A and B:

A:	Initial situation:	Firm 1: MC=20	Firm 2: MC=15
	Final situation:	Firm 1: MC=10	Firm 2: MC=5
B:	Initial situation:	Firm 1: MC=30	Firm 2: MC=25
	Final situation:	Firm 1: MC=20	Firm 2: MC=15

Economic development leads to changing comparative advantage. In the partial equilibrium context of this model, this becomes marginal costs falling for production of 'more sophisticated' products as the country develops:

$$MC(\dot{A}PL) < 0$$

With changes in flow profits a function solely of differences in marginal costs,  $T_1$ ,  $T^*_1$  and  $T^*_2$  can be solved for *differences* in marginal cost of production:

$$T^*_1 = t \text{ S.T. } MC(PPL) - MC(APL) = \alpha$$

$$T^*_2 = t \text{ S.T. } MC(PPL) - MC(APL) = \beta$$

$$T_1 = t \text{ S.T. } MC(PPL) - MC(APL) = \xi \quad (\xi < \alpha < \beta)$$

Therefore, as expected, the critical periods in the game all occur earlier when a tariff exists than when one does not; *any import substitution that does occur, does so earlier with a tariff than without*. The element of interest is whether a tariff makes it more or less likely for investment to be induced; i.e. whether the net effect of the tariff is to increase or decrease the likelihood that the only equilibrium include import substitution.

Presumably, implementation of a tariff has no effect on market opacity. Therefore, the determination of whether import substitution is more likely to be induced with or without a tariff can be divided into two factors. These two factors are those that affect the level of profits firm 1 could obtain by moving at  $T^*_1$  relative to never moving ( $A(T^*_1)$  relative to  $N(t)$ ):<sup>33</sup>

- 1) The effect of the tariff on the total increased profits<sup>34</sup> firm 1 could earn by moving production at  $T^*_1$  before firm 2 follows at  $T^*_2$ : profits firm 1 obtains during their greater market power.
- 1) The effect of the tariff on the increased (decreased) profits firm 1 earns after firm 2 follows at  $T^*_2$ : profits firm 1 obtains as a result of industry-wide costs falling.

The increase in profits firm 1 would obtain during their period of greater market power (between  $T^*_1$  and  $T^*_2$ ) is simple to derive. This is because the increase in flow profits is a function solely of changes in relative costs—but the set of production costs at the APL relative to at the PPL between  $T^*_1$  and  $T^*_2$  is the same with and without the tariff. Therefore, the set of firm 1 flow profit increases during this interval is independent of whether or not a tariff has been implemented. It is the *length of time* firm 1 enjoys these benefits (between  $T^*_1$  and  $T^*_2$ ) that determines the net present value of these benefits.

<sup>33</sup> The effect on  $S(t)$  is also derived from the same factors, and is dealt with at the end of the section.

<sup>34</sup> Relative to neither firm changing production location at any point.



As mentioned earlier,  $T^*_1$  and  $T^*_2$  are earlier in the game with tariffs than without. However, which of  $T^*_1$  and  $T^*_2$  is *more* earlier in the game with tariffs is set by the second derivative of marginal costs at the APL (inside the country) set; thus, the length of time between  $T^*_1$  and  $T^*_2$  is set by this second derivative.

In the context of economic growth, the second derivative of costs depends on the speed of economic development. The more rapidly an economy is developing, the more rapidly its comparative advantage is changing. In the partial equilibrium context of this model, this suggests that the more rapidly an economy is developing, the more rapidly production costs in the goods the country is developing a comparative advantage in are falling. If development is accelerating, then marginal costs in the industries of interest are likely falling in a convex pattern. On the other hand, if development is decelerating, then marginal costs are likely falling in a concave pattern.

Thus, if development is decelerating, then marginal costs are falling in a concave pattern,

$$MC(\ddot{APL}) > 0$$

This leads to  $T^*_2$  that is more earlier in the game with tariffs implemented than is  $T^*_1$ —the time between them is shorter.<sup>35</sup> This shorter interval between  $T^*_1$  and  $T^*_2$  when a tariff is implemented in this situation decreases the net returns during this period of increased market power that a first firm to move production could earn. The lower returns during this period are shown by lower  $A(T^*_1)$ , which, as discussed in Case 3, decreases the likelihood that import substitution is induced. This effect of the tariff in an economy with decelerating development is to decrease the likelihood that import substitution is induced relative to a non-tariff baseline.

Conversely, if development is accelerating, then marginal costs are falling in a convex pattern:

$$MC(\ddot{APL}) < 0$$

This leads to a  $T^*_2$  that is less earlier in the game with tariffs implemented than is  $T^*_1$ —the time between them is longer.<sup>36</sup> This longer interval when a tariff is implemented in this situation leads to higher net returns during this period of increased market power that a first firm to move production could earn. The higher returns during this period are shown by lower  $A(T^*_1)$ , which, as discussed in Case 3, increases the likelihood that import substitution is induced. This effect of the tariff in an economy with accelerating development is to decrease the likelihood that import substitution is induced relative to a non-tariff baseline.

<sup>35</sup> In addition, any comparable portion of the period between  $T^*_1$  and  $T^*_2$  will also be shorter.

<sup>36</sup> Again, same for any comparable portion of the period between  $T^*_1$  and  $T^*_2$ .

There is another effect to take into consideration, however: tariffs are also likely to change the relative profits for the entire industry producing in the PPL versus in the APL. Profits do not generally remain constant as industry-wide costs fall, and this effects the likelihood that production location change is induced by changing the returns to moving production that are received after  $T^*_2$ ,  $[\Pi_{(APL,APL)}(t) - \Pi_{(PPL,PPL)}]$ .

It is theoretically possible for falling industry-wide costs to lead to lower industry-wide profits (decrease  $\Pi_{(APL,APL)}(t)$  relative to  $\Pi_{(PPL,PPL)}$ .) In this situation, this tariff effect decreases  $S(t)$  and  $A(T^*_1)$  relative to  $N(t)$ , thereby decreasing the overall probability that import substitution is induced.

However, it seems perhaps more likely that decreasing industry-wide costs leads to higher industry-wide profits. In this situation, this tariff effect increases  $S(t)$  and  $A(T^*_1)$  relative to  $N(t)$ , thereby increasing the overall probability that import substitution is induced.

The net result is that if the rate of economic development is predicted to be relatively constant or accelerating, then both tariff effects are likely to reinforce pressure for import substitution occurring. However, if economic development is decreasing, then the effects of the tariff are less certain. In a relatively opaque market, the increase in  $S(t)$  resulting from the tariff could induce some investments. However, the effect of the tariff on  $[\Pi_{(APL,APL)}(t) - \Pi_{(PPL,PPL)}]$  is likely to be small. Therefore, *if economic development is predicted to decelerate, then tariff implementation is likely to decrease the likelihood that import substitution is induced.*

## **Cartels and Investment: Uncertainty Regarding Market Opacity**

By many accounts, government-sponsored cartels for 'sunset industries' in Japan have been effective in limiting the departure of some industries from Japan. The simplest way cartels could decrease the incentive for production movement is to increase the profitability of producing in Japan. The implicit assumption is that the cartel allows firms to collect rents from collusion as long as they produce in Japan; once the cartel is broken (firms move production abroad), these rents are no longer possible.

However, Japanese government-run cartels seem to have had difficulty producing rents for the firms involved. Specifically, firms often did not abide by the agreed upon sales quantities and prices.<sup>37</sup> Dick (1992) and Weinstein (1995) are both unable to find a statistically significant effect of Japanese government-run cartels on prices. It is thus unlikely that the ability of recession cartels to slow the

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<sup>37</sup> See, for example, Uriu (1996) for more description.

movement of production from Japan can be explained, at least in general, by their effect on price and quantity decisions.

The model presented in this paper describes another avenue by which the cartels may have had their effect; the bureaucracies entrusted to implement the cartels may have been very effective in directly or indirectly ensuring that information was gathered and disseminated throughout the industry. As Case 3 points out, this greater market transparency can decrease the likelihood that production location change is induced.

However, while slowed, production in these cartelized industries often did eventually leave Japan.<sup>38</sup> This aspect can be explained with a simple extension to the basic model: uncertainty regarding future transparency. Firms certainly knew the cartel would end at some point in time. However, they did not know when the end would be; in other words, firms did not know when the market transparency the cartel created would switch back to production location change-inducing market opacity.

The results of this extension also lead to another implication. Without a cartel, the firms may have moved production one by one over an extended period of time. However, the transparency associated with the cartel may have led to a greater number of firms leaving en masse. The rest of this section begins with an intuitive discussion of the results, followed by some simple modeling.

When the difference in production costs at two prospective locations is 'small', or 'moderate', then results are always the same as in 'Case 1: Minimal Eventual Difference' and 'Case 2: Moderate Eventual Difference,' respectively. If the difference in production costs is 'large' but  $A(T^*_1) > N(t)$ , then the equilibrium is the same as in 'Case 3: Greater Eventual Difference.'<sup>39</sup> In these Case 3 instances, production location change occurs at  $(T_1, T^*_2)$ . All of these similarities arise because market opacity plays no role in these equilibria.

However, there is more information to consider when there is a large difference in production cost but  $A(T^*_1)$  and all  $M(t) < N(t)$ . Even in this case it is possible for the equilibria here to mirror those in Case 3:

\* If it is very likely that  $S(t) > N(t)$ , then there is definitely a preemption race with firm 1 changing production location at  $T_1$  and firm 2 at  $T^*_2$ .

\* If it is very unlikely that  $S(t) > N(t)$ , then production location change is never induced, unless the realization of the game in which  $S(t)$  actually is greater than  $N(t)$  occurs. Because  $S(t)$  is a function of market opacity,  $H(t)$ , this similarity to the Case 3 results can be restated in terms of predictions of market opacity. The restatement is as follows: both firms will necessarily change

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<sup>38</sup> For example, see Tilton (1996).

<sup>39</sup> The same caveat also applies here: if firms could profitably invest, i.e.  $M(t) > N(t)$  for some  $t$ , then investment does occur.

production location if they think their market is likely to be opaque, but will not necessarily do so if they think their market is likely to be transparent. Firms will also change production location at  $(T_1, T_2^*)$  in a transparent market if they are fairly certain when the market will become opaque.

However, firms' generally can not accurately predict timing of changes in market opacity with any degree of certainty. If the market is unlikely to become opaque during any particular period of time after  $T_2^*$ , then production location change is not induced early in the game. After this, if firms come to believe at the moment just in time to begin production in the APL at time  $t \in [T_1, T_2^*)$  that the market will become opaque, then firm 1 begins preparations to change production location immediately, and firm 2 changes production location at  $T_2^*$ . Beyond this, if the market actually becomes opaque or firms get better information about when in the game the market will become opaque, then both simultaneously begin preparation to change production location.

With uncertainty, the correct continuation value to not changing production is no longer  $N(t)$ . This is because there is the possibility that the market may become opaque enough at some time in the future to induce production location change. Therefore, an additional curve,  $I(t)$  is drawn in 'Graph 5: Information Flows.'  $I(t)$  is the expected continuation value of industry profits for an industry in which neither firm has moved production location by time  $t$ . This curve only has meaning in the cases in which uncertainty about future market opacity leads to uncertainty about the timing of when or if production location change will ever occur.

Although there may be infinite total points at which there is a positive probability that information updates regarding future market opacity induces location change, there can not be an infinite number of such points within any discrete interval.<sup>40</sup> For the 'sunset industry' cartels, these updates could be daily or weekly government news conferences, for example. These points at which beliefs about the set  $H$  of future values of  $H(t)$  are updated are denoted  $T_i \in [T_1, \dots, T_N]$ . Any  $T_n$  for which there is a  $T_{n+1}$  prior to  $T_1$  has no effect on play of the game.

$I(t)$  can be defined recursively from the profits earned prior to the next update in information set  $H$ ,  $T_{n+1}$ , plus the expected profits from the next update on. For all  $t \in [T_n, T_{n+1})$ :

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<sup>40</sup> The probability of something occurring after an infinite number of repetitions of an event in which it has a positive probability of occurring is one.

$$I(t) = \left\{ \int_t^{T_{n+1}} e^{-rv} \Pi_{(PPL,PPL)} dv \right\} + \left\{ e^{-rT_{n+1}} \mathbf{E} \left[ p(\text{ind}_{T_{n+1}}) \left( \arg \max [M(T_{n+1}), A(T_{n+1})] \right) + (1 - p(\text{ind}_{T_{n+1}})) I(T_{n+1}) \right] \right\}$$

Where  $p(\text{ind}_{T_{n+1}})$  is the probability that production location change is induced at  $T_{n+1}$ .<sup>41</sup>

$$p(\text{ind}_{T_{n+1}}) = p(\exists t \in [T_{n+1}, T_{n+2}) \text{ S.T. } H(t) > I(t))$$

The  $\arg \max (M(t), A(t))$  is  $A(t) \forall t \in [T_1, T_2^*]$ , and  $M(t) = A(t)$  for all later  $t$ .

Although this dynamic problem is not generally explicitly solvable, two stylized versions lead to the implications discussed. Both of these stylized games take advantage of the simplifications allowed by symmetry. In both stylized games, it is assumed that no new information is available until  $T_2^*$ , but that from that point on there are regular updates. The time that passes between any two successive updates,  $T_n$  and  $T_{n+1}$ , is the same.

Production costs are assumed constant in both production locations from  $T_2^*$  onwards. Thus,  $\Pi_{(APL,APL)}(t)$ ,  $\Pi_{(APL,PPL)}^1(t)$ , and  $\Pi_{(APL,PPL)}^2(t)$  are also constant. In addition,  $H(t)$  is a function solely of whether the cartel is in effect or not. If there is a cartel, then  $H(t)$  leads to  $S(t)$  less than  $N(t)$ . If no cartel is in place, then  $S(t)$  is greater than  $N(t)$ . This is the situation described by Graph 5.

In the first stylized game, the updates take the form of a statement regarding whether or not the cartel is ending prior to the next update. In order to simplify the algebra, the interest between two successive announcements is denoted  $r'$ :

$$r' = e^{-r(T_{n+1} - T_n)}$$

The probability that any given update will contain the end of the cartel is  $b$ .

Net flow profits to changing production location,  $\Pi_{(APL,APL)}(t) - rK$ , are less than net flow profits to not changing,  $\Pi_{(PPL,PPL)}(t)$ , as  $M(t) < N(t)$ . Therefore,  $I(t)$  is greatest just after an announcement without any information regarding the end of the cartel. This is because new information that induces the costly production location change is not available for the largest amount of time—until the next announcement.  $I(t)$  falls smoothly until the next production location change announcement. Therefore, the  $I(t)$  of interest,

<sup>41</sup> If change is induced at any point between  $T_{N+1}$  and  $T_{N+2}$ , then it occurs at  $T_{N+1}$ ; any later move could not be an equilibrium as it would be preempted.

the one most likely to induce production location change, is just prior to an announcement. Assuming that  $b$  is not large enough to induce production location change, the value of  $I(t)$  just prior to an announcement,

$\lim_{t \rightarrow T_n}$  is:

$$I(t) = (bL + (1-b)\alpha) + (1-r')(1-b)(bL + (1-b)\alpha) + (1-r')^2(1-b)^2(bL + (1-b)\alpha) + \dots$$

where  $L = \frac{1}{r} \Pi_{(APL, APL)}$  -K, the net present value of both firms moving production to the APL at time  $t$ ,

and  $\alpha = \frac{1-r'}{r} \Pi_{(PPL, PPL)}$ , the net present value of profits each firm earns by not changing production

location prior to the next announcement.

Simple algebra can be used to simplify the above equation to:

$$I(t) = \frac{bL + (1-b)\alpha}{1 - (1-r)(1-b)}$$

which is decreasing in  $b$ , and is characterized by  $\lim_{b \rightarrow 0} I(t) = N(t)$ . Therefore, with  $S(t), A(T^*_1) < N(t)$ , there exists some  $b > 0$  S.T.  $S(t) < I(t)$  for all  $t$  in expectation, and  $I(t) > A(T^*_1)$ . In other words, if firms are very uncertain about when the cartel is going to end, i.e.  $b$  is very small, then production location change is not induced prior to  $T^*_2$ , nor prior to an announcement ending the cartel.

Of course, production location change is induced as soon as the end of the cartel is announced. With  $b > 0$ , this certainly occurs at some point. Because this announcement occurs after  $T^*_2$ , both firms immediately begin preparations to change production location upon hearing the announcement: with the announcement, not changing production location is not sustainable,  $S(t) > N(t) > I(t)$ .

In the second stylized game, the updates take the form of a statement regarding the future end of the cartel. The updates are either in the form of no new information or a statement of the exact date the cartel will end. The probability that an announcement that gives the ending date will state that the cartel will end at any point  $t$  is evenly distributed over all points  $t$  after the announcement. The probability of an update with new information is  $b$ .

Any announcement of the end of the cartel leads to immediate production location change preparations.

Production location change would occur if neither firm changed location before then. However, this later move could not be an equilibrium as it would be preempted.

Mathematically, this situation is identical to the first stylized game. Therefore, there is some  $b > 0$  S.T.  $S(t) < I(t)$  for all  $t$  in expectation and  $I(t) > A(T^*_1)$ , which means that production location change is not induced prior to  $T^*_2$ . The intuition for this game is slightly different, however. Specifically, it suggests that firms change production location as soon as they get a good indication of when in the future the cartel will end. Rather than an actual government announcement, this update could take the form of the creation of a consensus regarding political support for the cartel or other factors.

## Conclusion

The thesis of this paper is that competition is likely to make many types of socially beneficial investment unprofitable, and that this situation is more likely to occur in rapidly changing markets than in slowly changing ones. In a situation in which investment is clearly going to be unprofitable, there is no reason to assume that it will occur. On the other hand, the prospect of profitable investment can be created through market opacity. Therefore, market opacity can play a productive role, particularly in rapidly changing markets.

While there is an element of collusion in not investing, this type of collusion is quite different from the actions described in many price collusion models; the non-investment equilibrium described in this model is renegotiation proof. Once a firm has made an investment, the competitive environment has completely changed; all competitors are now competing at a strictly larger disadvantage relative to the investing firm than was previously true. This change of environment makes the 'punishment' (rivals also investing) that is necessary to ensure collusion is not only credible, but also the *only* possible response.<sup>42</sup>

On the other hand, the same is not true in a price collusion model. In price collusion models, a deviation that would need to be responded to with punishment to enforce collusion does not intrinsically change the competitive environment; all elements in the game except for the history can be identical the moment before and after a non-collusive price is set. Thus, the punishment strategy is much less concretely defined than in the investment model presented here.

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<sup>42</sup> In a multiple-firm version of the model, multiple equilibrium could still be possible after one firm has invested. However, competing firms are still at a competitive disadvantage after investment occurs.

This is not to say that the repeated nature of competition does not lead to 'collusive' prices that are not sustainable in one-shot games. Rather, this suggests the following: setting prices higher, and particularly much higher, than those sustainable in the one-shot game requires managers with a very high level of sophistication regarding strategic interaction.<sup>43</sup> Not making an unprofitable investment, on the other hand, requires very little management sophistication. Therefore, all that non-investment requires to be actualized in the real economy is managers that understand that if their firm invests, then their opponents will have no choice but to also invest soon after, and the resulting situation will be lower net profits for everyone. In other words, non-investment is an even more 'reasonable' equilibrium than is pricing at non-repeated game levels.

In fact, with only this limited sophistication necessary to enact the non-investment equilibrium, it is reasonable to consider the effects of this model in the macroeconomic context used in several parts of this paper.

Small firm managers as well as very large firm managers such as those in the paper industry consider the strategic elements discussed in this paper. For example, a manager at a relatively small (approximately 120 employee) non-destructive inspection and marking system firm emphasized these elements during an interview.<sup>44</sup> The firm went to great lengths to determine the financial ability of competitors to match a production location change they were considering. They concluded that their primary competitors would not be able to financially able to follow them. Therefore, they did go through with the location change, (without their primary competitors following.)

This manager said that the likelihood of their moving production would have been significantly lower if they felt their competitor would have been able to follow. This is because, '*if they both moved, competition would lead to prices dan dan decreasing, and this would make it unprofitable.*'<sup>45</sup> Of course, he could not answer a counter-factual with certainty.<sup>46</sup>

Although it is not included in the body of this paper, analysis of how price collusion and investment decisions interact is interesting. A discussion of some of the critical elements in any such analysis is

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<sup>43</sup> See Farrell and Maskin (1989) for more discussion of this topic.

<sup>44</sup> Matsuo (1998).

<sup>45</sup> Translated from Japanese.

<sup>46</sup> A representative of a different company interviewed on this topic did suggest that management at that firm did not consider the elements presented in this paper. However, they also suggested that the firm did not consider rivals at all when making investment decisions. Although this statement was later retracted, they remained adamant that no person in the company understood how any particular investment decision was made. Perhaps the first-mover advantage this type of anarchy must lead to can explain how the firm became one of the largest, most profitable automobile manufacturers in the world.



included in 'Appendix 3: Combined Model—Does Investment Lead to Price Wars?'

However, the most interesting aspects of investment are highlighted in the model presented in the body of this paper that solely considers investment choice. Price collusion is likely limited to relatively narrow ranges in many, if not most, real world circumstances. Consideration of firm activity without price collusion as was done in this paper is a good approximation in these circumstances.

In addition, minimal price collusion and investment inductions both result from imperfect monitoring. However, the relevant monitoring is on different dimensions: maximum price collusion is decreased when firms have less information about opponents' prices. Investment is induced when firms have less information about their opponents' investment plans. It is quite possible that competitors have perfect information regarding an opponents' price but have no information regarding their investment activities, or vice versa. It is therefore possible to consider the model presented in this paper as describing various investment strategies in the limit as the ability to collude on price goes to zero.

Some economists may argue that modeling investment in infinitely repeated game is not reasonable. However, many investments increase the benefits that accrue to all future activities, not just those directly associated with the investment. For example, experience with a simple technology increases the efficiency with which more sophisticated technology is implemented later on. In this type of circumstance, the benefits to investment truly do have an infinite horizon. For other investments, market actors are initially very uncertain as to when the benefits accruing from an investment will end. This also requires an infinite horizon model.

Most technology adoption and investment models suggest that investment will necessarily occur. However, many authors have argued that a large number of beneficial technologies are not adopted and opportunities that offer significantly increased efficiency are often not taken. For example, in the introduction to Farzin et al. (1998,) evidence that not all versions of technology improvements are adopted is presented. In addition, one translation of the 'North-South' question in the international trade and development literature is that production does not occur at the most efficient locations.<sup>47</sup> The model presented in this paper can explain such large-scale non-investment.

A caveat to the benefits of inducing investment is necessary, however. Some of the investments that would not occur in a transparent market are not beneficial from a social welfare standpoint. This is because part of the incentive to invest comes from the ability to steal market share from competitors which, by itself, provides no benefit to society. However, other investment that would not occur if not induced would be

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<sup>47</sup> See, for example, Krugman (1993) for more description of the North-South question.

beneficial; they would result in true cost savings or more desirable products. Although solely an opinion, it seems likely that, on a macroeconomic scale, the benefits of inducing investment far outweigh the costs of inducing inefficient investment.

Before finishing up, it is important to note that this paper can be misinterpreted rather easily. For example, it could be used to suggest that a country could increase growth rates by limiting foreign direct investment. This paper does show that by not allowing foreign direct investment and therefore breaking Assumption 4, import substitution that would not have occurred can be induced. However, this will only occur in this model in situations in which a new domestic competitor will be less efficient than a foreign firm that creates a subsidiary in the country. Therefore, while correcting for one inefficiency, barriers to foreign direct investment create others. If a new domestic competitor would be more efficient than a foreign subsidiary, then this model does not apply.<sup>48</sup>

In addition, this paper suggests that another element can also induce import substitution—at the same time as it induces other investment. This element is, specifically, market opacity.

Lastly, it is important to note that this paper does not suggest that general opacity is beneficial. For example, the lack of regulatory transparency that is one aspect of the ‘crony capitalism’ in several Southeast Asian economies plays no role in this model. Therefore, this model presents no defense for this type of activity.

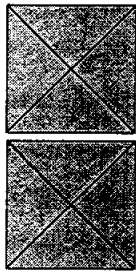
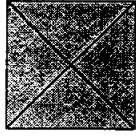
This paper only notes the benefits of general opacity when considered from an economic history perspective. In particular, this model suggests that the *market opacity* element of the general opacity facilitated the investment that was necessary for the high-speed economic growth experienced prior to the Asian crisis. These benefits should be considered when making policy recommendations. In conclusion, the primary problem with the calls of other authors for increased transparency is with their lack of analysis of the effects of what they are calling for, and in their own opaque definition of ‘opacity’.

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<sup>48</sup> A caveat to this statement may be necessary, however. Japan, for example, was able to achieve its incredible growth with only minimal foreign direct investment. Perhaps the Japanese economic system during the Japanese high-speed growth era was able to limit the social welfare losses to decreased FDI while benefiting from the increased import substitution. See, for example, Ramstetter (1996) for a comparative discussion of FDI into Japan.

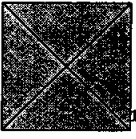
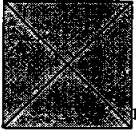
## Appendix 1: The Meaning of Smooth Submodularity in this Model

By using Topkis' characterization theorem (Topkis 1998) as presented in Milgrom and Roberts (1990), it is obvious that the addition of the following three assumptions are enough to guarantee smooth submodularity:

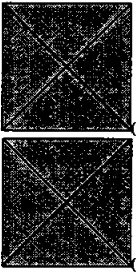

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 • **Assumption 5A:**  $\Pi_{(APL,PPL)}^1(t) > \Pi_{(APL,PPL)}^2 \quad \forall t \text{ S.T. APL has lower costs than PPL.}$
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 •  $\Pi_{(APL,PPL)}^1(t) < \Pi_{(APL,PPL)}^2 \quad \forall t \text{ S.T. PPL has lower costs than APL.}$

This is easily derived from the idea that decreasing one firm's costs increases industry profits:

$$\Pi_{(APL,PPL)}^1(t) + \Pi_{(APL,PPL)}^2(t) - 2\Pi_{(PPL,PPL)} > 0 \quad \forall t \text{ s.t. } \Pi_{(APL,PPL)}^1(t) > \Pi_{(APL,PPL)}^2(t)$$

- 
 • **Assumption 5B:**  $\Pi_{(APL,PPL)}^1(t) - \Pi_{(APL,PPL)}^2 > \Pi_{(APL,APL)}^1(t) - \Pi_{(PPL,PPL)} \quad \forall t \text{ S.T. APL has lower cost}$
- 
 •  $\Pi_{(APL,PPL)}^1(t) - \Pi_{(APL,PPL)}^2 < \Pi_{(APL,APL)}^1(t) - \Pi_{(PPL,PPL)} \quad \forall t \text{ S.T. PPL has lower cost}$

This states that a decrease in industry costs does not increase industry profits "too much." Competition between firms selling substitutes in demand is necessarily characterized by a limit on any increase in profits that result from industry-wide decreases in costs. That limit is that individual firm profits increase less than the change in marginal cost times equilibrium output at the new costs; decreased profits are certainly not ruled out. Although this is not quite the same as the above assumption, it is equivalent to the extent that they are both stating that falling costs do not increase industry-wide profits "too much." Many demand systems satisfy this assumption including the simple linear cournot competition and Hotelling competition.<sup>49</sup>

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 • **Assumption 5C:**  $\Pi_{(APL,APL)}^1(t) > \Pi_{(APL,PPL)}^2 \quad \forall t \text{ S.T. PPL has lower cost than APL}$
- 
 •  $\Pi_{(APL,APL)}^1(t) > \Pi_{(APL,PPL)}^1 \quad \forall t \text{ S.T. APL has lower cost than PPL}$

This assumption simply states that any decrease in firm flow profits that result from industry-wide decreases in costs is not "too large." In particular, a firm's decrease in flow profits is mitigated by their decrease in production costs. This comes directly from the same set of situations that led to Assumptions two and three.

## Appendix 2: Bayesian Perfect Equilibrium Details

- \* Once both firms have moved, there are no more strategies to consider.
- \* Once one firm has changed production location

<sup>49</sup> Justman and Mehrez (1996) finds that this holds for a fairly wide range of specific functional forms; they do not find any specifications for which it does not hold.

\* The remaining firm moves when it is most profitable. Therefore, the Bayesian perfect strategy is



\* This can be announced or not.

\* If neither firm has changed production location yet, then

\* At any  $t$  S.T.  $A(t) > N(t)$  prior to  $T_2^*$

\* At least one firm necessarily moves. Prior to  $T_2^*$ , the best response for the other firm is to not move. Therefore, the Bayesian perfect strategies are

\* 'move' for one firm; this can be announced or not after  $T_2^*$ , but must be pre-

announced earlier.

\* 'do not move' for the other

\* At any  $t$  S.T.  $S(t) > N(t)$   $T_2^*$  or after

\* At least one firm necessarily moves, and, after  $T_2^*$ , the best response to one firm moving is for the other one to move as well. Therefore, the Bayesian perfect strategies are:

\* 'move' for both firms, either announced or not

\* In the period prior to a move by one or more firms, firms are likely to be tempted to 'preemptively' move.

\* In a period  $T_2^*$  or after, it is necessarily Bayesian perfect for at least one firm to pre-emptively move: they would receive  $S(t)$  which is greater than  $A(t+H(t))$  by waiting for the next period. The best response to one firm moving is for the other to also move. Therefore, the Bayesian perfect strategies are:

\* 'move' for both firms

\* In a period  $t \in [T_1, T_2^*)$ , one firm is tempted into preempting. Moving first would lead to payoff  $A(t)$ , while not moving would lead to  $F(t+H(t))$  for one of the firms. (Just prior to  $T_2^*$ , both firms would receive  $A(t)$  in the next period.)

Therefore, Bayesian perfect strategies are:

\* announced 'move' for one firm

\* 'do not move' for the other

\* Prior to  $T_1$ , it is no longer profitable to preemptively move. Therefore, Bayesian perfect strategies are:

\* 'do not move' for both firms

\* If both  $A(t)$  and  $S(t)$  lie below  $N(t)$  at all points during the game

- one Bayesian perfect strategy is 'do not move' for both firms
- the other is as described above.

### Appendix 3: Combined Model— Does Investment Lead to Price Wars?

Although only an overview of the elements are provided here, the intuition comes from the tools described in Abreu, Pearce, and Stacchetti (1990). The term 'simple price model' refers to a strictly price-collusion model with no investment options, while 'simple investment model' refers to the model presented in this paper. 'Combined model' refers to a model allowing firms to choose both whether to invest and how to set prices.

The basic intuition is that the ability to collude along multiple dimensions reinforces the ability to collude along each dimension. Most interesting, however, is that investment can seem like it leads to a price war.

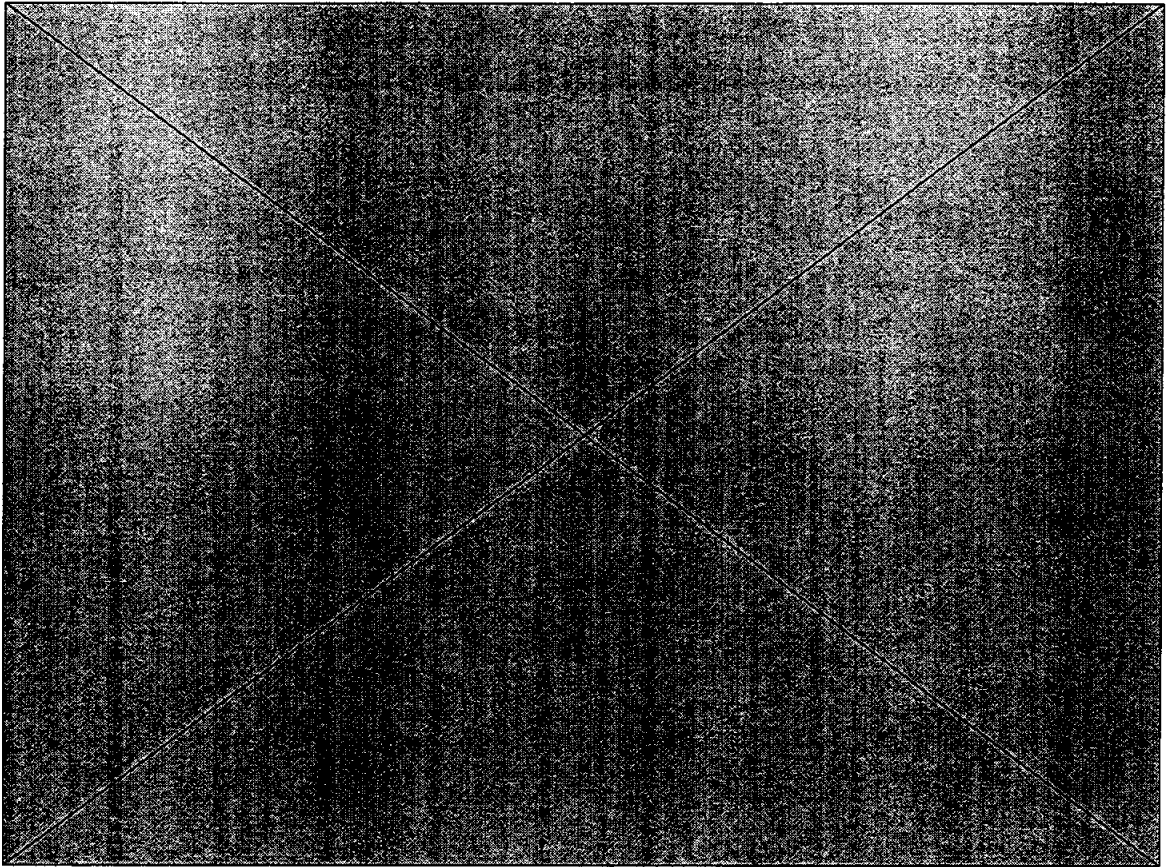
Monopoly profits increase as costs falls. Therefore, by allowing firms to obtain a greater share of monopoly profits, simple price models are likely to be characterized by a greater increase in profits as industry-wide costs fall than in the simple investment model. Thus, some investments that would lead to lower net present value of profits in the simple investment game would increase profits in the simple price game by more than the cost of the investment. In this situation, if an equilibrium in the simple investment

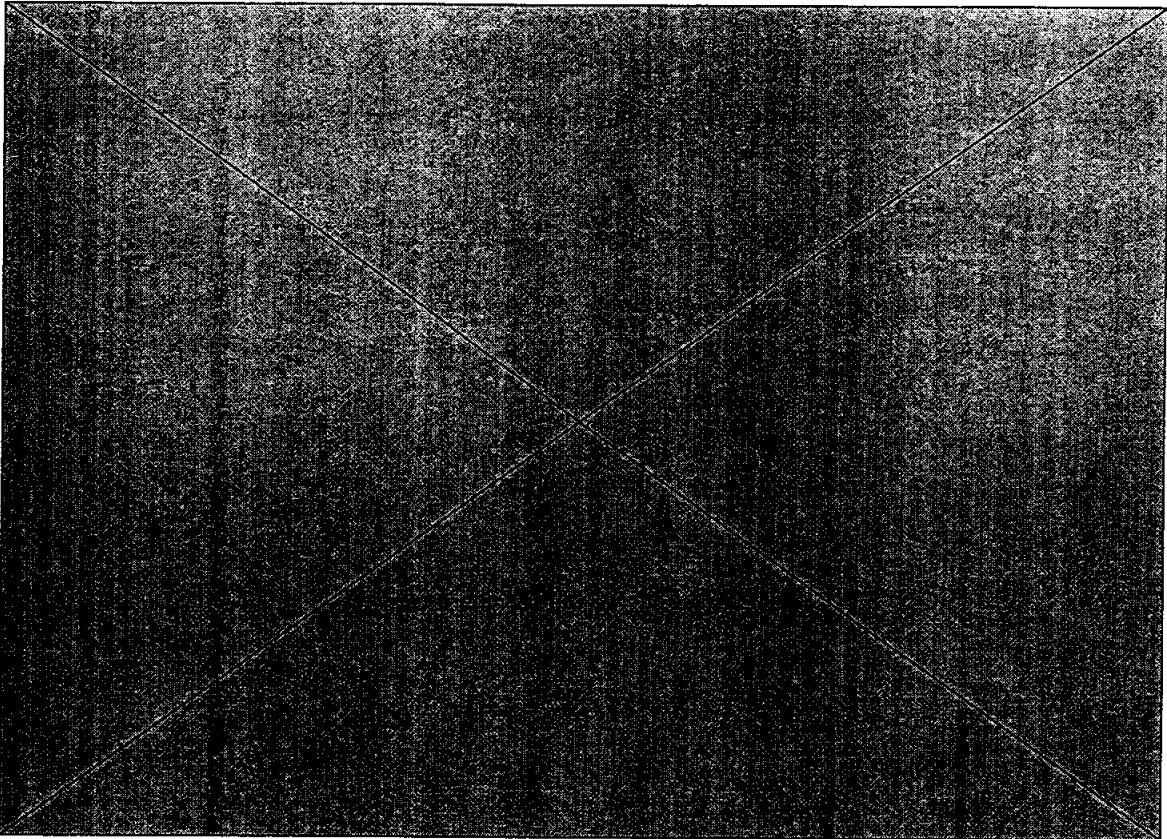
game is for the investment to not occur, then the credible threat of not investing can be used as a punishment for deviation from collusive pricing levels in the combined model.

Thus, investment will occur along the most profitable equilibrium path of the combined model, and, until the investment occurs, prices charged will be even closer to monopoly levels than in the simple price model. The direction of causation is that the option of not investing leads to greater price collusion. However, the greater price collusion occurs prior to the investment. Therefore, it is likely to look like the opposite causation— investment leads to lower markups. In other words, while the option of not investing is allowing greater collusion, it seems like investment leads to a price war

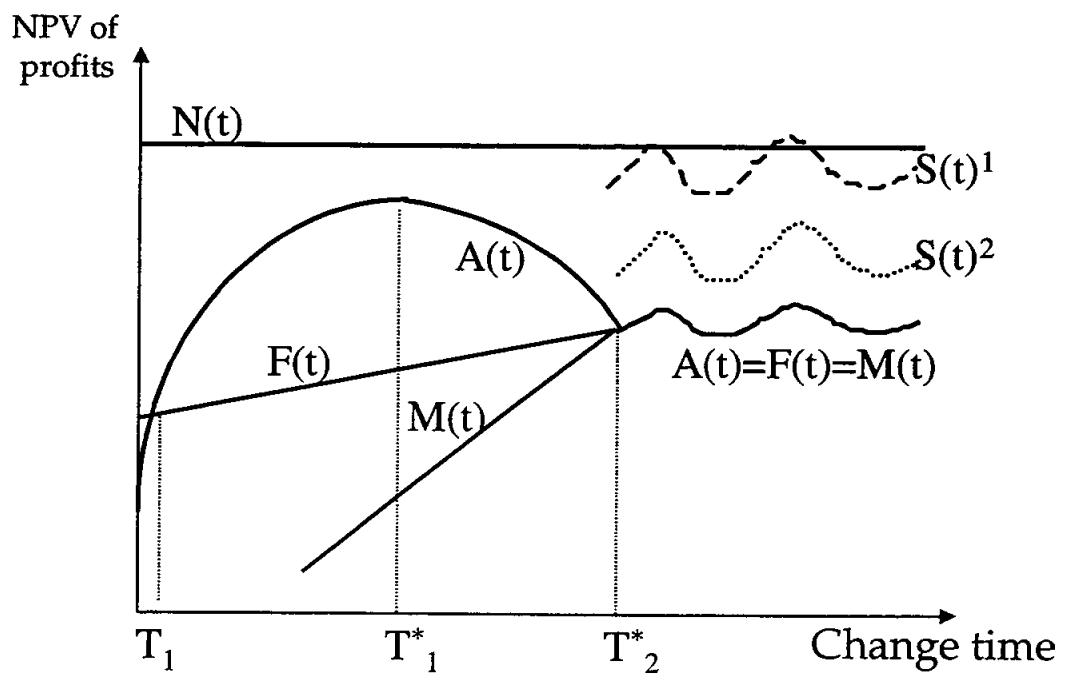
While there are likely to be price changes in the periods leading up to the investment in this most profitable equilibrium, it is not clear whether prices will be increasing or decreasing. The option of investing is the most powerful reward just prior to optimal investment timing. However, the harshest credible punishment, particularly for early in the game, is also likely to include investment; for punishment, investment would mean switching to an equilibrium in which investment does not increase the profits of the competing firms despite its occurrence. Thus, it is not clear whether the total difference between the most and least profitable sustainable equilibrium will be increasing or decreasing up to the point of investment.

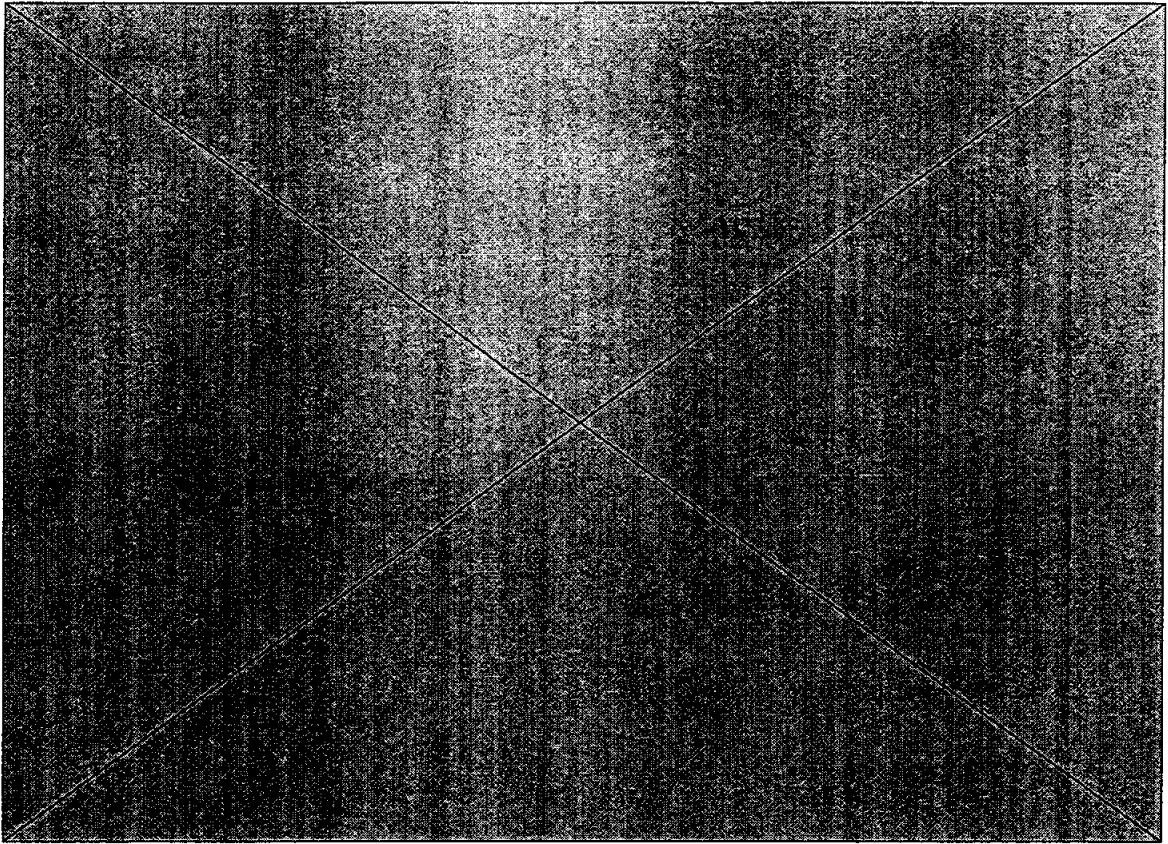
For other types of investment, the increase in the maximum profits obtainable in the simple price game as a result of investment occurring will be less than the cost of the investment. In this case also, greater price collusion is possible: the ability to credibly threaten a strategy in which investment does occur as punishment for non-collusive pricing increases the ability for firms to collude on prices. Similarly, the credible threat to punish any investment by a switch from the most profitable set of equilibrium prices without investment to the least profitable set of equilibrium prices with investment increases the sustainability of equilibria without investment.





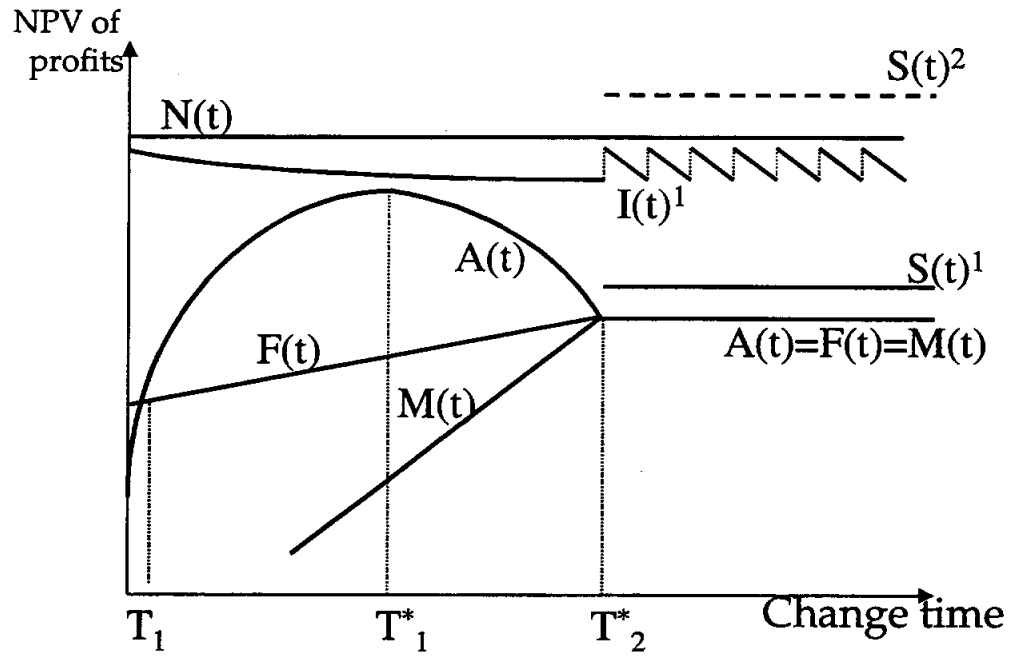
## Graph 4: Greater Difference







# Graph 5: Information Flows



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