Industrial Policy: Chinese Debates and Taiwan's Foundries

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Preliminary draft

1. Introduction

In this *Globalized Age*, the *efficacy* and *impact* of industrial policy are issues appealing not only to some theoretical economists, but also to both the aficionados of history and masters over geopolitical issues.

In the 660 pages of *Creating a Learning Society* (Stiglitz and Greenwald, 2014), two distinct views dominate. The authors (SG, hereafter) focus on the *dynamics* of learning. By observations and analysis, they emphasize how industrial policy *can* enhance learning and help to overcome coordination failure. On the other hand, in his comment, Solow stated that he and the experts at the McKinsey Global Institute he worked with (S-MGI, hereafter) found that in certain industries of *developed countries*, the *performance gaps* among the *firms* are attributable to the quality of managerial decisions (McKinsey Global Institute, 2003). This quality begins to erode if industries are protected from international influence, and the government bureaucracy rises with such protection. Thus, by implication, industrial policy *may be* unnecessary and unhelpful.[1].

To begin with, one might argue that these two views need not be contradictory, but complementary to each other, enriching the understanding of the discerning reader.

Economists often include among their intellectual forefathers the name François Quesnay: a founding light to economics and an authority to medicine in his day. It is easy to find affinities between these two non-experimental, applied fields where the same geniuses blossom. Medicine has no panacea; overdose means more harm than a placebo.

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[1] The comment of Kenneth Arrow (1921-2017) who was honored by that volume will be discussed in the Postscript.

The worthy observation that – on average – Industrial Policy brings misfortune,[2] ought to encourage the correct using of wonder drugs, rather than to avoid them.[3]

It is useful to note three points. First, S-MGI studies the *comparative statics* of firm performance among the developed countries, not the *dynamics* of achieving high performance in East Asia that interested SG in industrial policy. Second, the caution against *sustained* state intervention of S-MGI (typical in Latin America and India before reform) does not diminish the essential, *catalytic* role of the State in institution design and industry launching in East Asia, as considered by SG. Third, in the current globalized world economy, with extensive supply chains, fruitful industrial policy may unleash waves of innovation bursts (say, in sectors of Information Technology) that raise the productivity levels in a win-win outcome in many of the evolving economies.

Following up the academic discussions of SG and S-MGI, two cases showing the practical concerns of industrial policy – both related to China – are included below.

First, Rodrik (2006) focuses on the *efficacy* of Chinese industrial policy, often through instruments in use going beyond tariff and subsidy in the economics literature. He reports that information from McKinsey Global Institute indicates, China operates special economic zones (SEZ) with fine infrastructure and streamlined regulation. These serve as export platforms for foreign investors in consumer electronics, often in joint venture with local firms. Such SEZs are the most productive among the producers and dominate in exports. Such a policy raises Chinese labor productivity relative to the Mexican level, notwithstanding China has a per capita income much lower than Mexico.

Second, in *Ensuring Long-Term U.S. Leadership in Semiconductors* (2017)**,** a report by the American President's Council on Science and Technology (PCAST), PCAST characterizes the *impact* of the Chinese Industrial Policy as 'innovation-inhibiting'. Under it, the merger and acquisition programs may threat U.S. long-term leadership in semiconductors (PCAST, 2017). This represents a stereotypic view that the developing economy specializes in emulation and free-riding, while industrial policy might be an art of beggar-thy-neighbor.

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[2] As S-MGI appears to caution against.
[3] As SG seems to advocate.

Thus, in pragmatic terms, Rodrik testifies that Chinese industrial policy is *efficacious*; the PCAST report is concerned that its *impact* may damage American prosperity and security.

The next section turns to the on-going academic debate in China between two top economists, Justin Lin and Weiying Zhang, with some echo to the positions taken by SG and S-MGI.[4] Since their differences of opinion often involve how matters stand in reality, one ought to seek evidence from history. First, evidence from China will be considered for the case of High Speed Railroad (HSR). Next, for information outside PRC, the foundry sector of Taiwan is presented in Section 3. The fourth section concludes the paper with a summary of the findings.

2. Salient Issues in the Lin-and-Zhang Debate

2.1 The Lin-Zhang debate

Justin Lin is the founder of the Chinese National School of Development at Peking University and the former chief economist of World Bank. His critic and colleague, Weiying Zhang, was a primary force for Chinese market reform and a former dean of Guanghua School of Management at Peking University. Their debate, coached in broad academic terms and citing historical facts, nonetheless grew out of the challenges facing China, the world's largest trader and manufacturing GDP, also the most populous country.

Their debate is less known outside China. But both the importance of the Chinese economy and the relevance of some issues shared by both China and other economies make their debate worthwhile to consider.

There is much that Lin and Zhang agree, in rejecting the planned economy, also import-substitution industrialization, as well as recognizing both market failure and market incentives. Their difference of opinion is about what can and should be done by the State, especially when the latter has the current 'Chinese characteristics'.[5]

A succinct approach to review their difference in the multi-hour debate is to present Lin's position on industrial policy, first as in the summary report in CFEN (2016, where

[4] Regarding efficacy, Lin is closer to SG, and Zhang to S-MGI; about impact, Lin and Zhang focus on the developing economy side of the same coin of 'developing countries adopting industrial policy' versus Rodrik and PCAST on the developed economy side.

[5] In particular, the prominence of the government and the state-owned enterprises (SOEs).

Lin is much more optimistic, but not Zhang, in view of recent Chinese development),[6] and then augmented by his extensive discussions in *New Structural Economics* (Lin, 2012), before a selected review of the objections by Zhang.

(a) Lin's view in the debate, as summarized:

To 'catch up' with the more advanced economies, developing countries needs government-led *industrial policy*. He justifies this view conceptually with market failures, supports it with the Chinese boom over recent decades, and cautions that the key is such a policy must be 'appropriate' in the sense of 'comparative advantage following' (CAF), or not attempting something against the underlying economic forces.

(b) Lin's opinion on *appropriateness* (Lin, 2012):

Lin first distills two principles out of various considerations for the process of development, namely, *industry-upgrading* and *diversification*. Next, he cites a particular guideline – to select a 'compass economy' as target. The latter should share features of one's own economy in 'latent comparative advantages', but be more advanced, so as offering a successful example. There are also some additional practical criteria, namely, similarity in factor endowment, as well as having a successful track record in per capita GDP, but not being too advanced (with relative to oneself of more than twice richer).

He also gives examples:

- ✓ the 16th century: England targeted the Netherlands
- ✓ the late 19th century: US, Germany, and France targeted England
- ✓ the early 20th century: Japan targeted England
- ✓ 1960s and 1970s: The East Asian NIEs targeted Japan
- ✓ 1970s: Mauritius targeted Hong Kong
- ✓ 1980s: China targeted Korea, Taiwan, and Singapore.

(c) Lin's case against *comparative-advantage-defying* (CAD) (Lin, 2012, p.170):

Lin explains that the common case of policy failure is that the adopting a technology which is inappropriate to the latent comparative advantage of one's own. This causes State burden in supplying subsidy and protection. But due to information asymmetry, the State may not know how much protection and subsidy are necessary, and ends up in a situation of *soft-budget constraint* characterized by Kornai (1986).

[6] An abridged version in English appears in *South China Morning Post* (2016.11.12).

As rebuttal, Zhang's views in CFEN (2016) can be summed as follows:

The future is inherently uncertain. In addition, human cognition is limited. Therefore economic planning does not work. Industrial policy is simply a return to economic planning in disguise. The future should be left to market force and entrepreneurship, rather than the unneeded and futile attempt of picking winners, that can only dull entrepreneurship and interfere with the market mechanism, causing the inefficiency of bureaucracy, and opening to rent-seeking by treating different sectors differently.

Chinese failures in auto-making, solar panel and new energy cars are known examples. Furthermore, during the Great Recession, stimulation projects brought only temporary relief at the cost of high debt burden and subsequent over-capacities.

The selected statements of these two provide the following perspective. Lin conveys a nuanced position on issues that are intrinsically subtle, and far from clear-cut. Zhang is more concerned with avoiding impending costly policy failures, in a large, emerging economy with 'Chinese characteristics': state enterprises are huge, and the fledgling private sector is often plagued by politically related oligarchy.

2.2 The case of China's high-speed railroad project

An illustrative example for the industrial policy of China is its High Speed Railroad (HSR) program (Peters, 2017). This is a technology pioneered by the Japanese Shinkansen in 1964. Various European countries followed with their own versions.

In the 1990s, on a totally self-reliant basis, China launched the *China Star* high-speed railroad program and completed it in 2002. But this was given up immediately, as it would take too long to improve this technology to a satisfactory level.

The Chinese Ministry of Railroad, with two million employees, then tapped into the enormous foreign exchange pool available at that time, and used the well-known strategy of *market access for technology* in economic development, with some *slight* variation.

It attracted four competing consortia from Bombardier, Canada, Alstom, France, Kawasaki, Japan and Siemens, Germany, to agree in co-producing the equipment and transfer their high-speed railroad technology. The aim was to set up a single integrated Chinese system, supported by the mobilized engineering manpower of China. The new element is obvious for anyone familiar with elementary game theory: the name of the game is the Prisoners' Dilemma.[7]

So in one decade, China has completed a high-speed railroad system with a length equal to the rest of the world, at a lower cost and capable to attain a higher speed. Because of corruption and undue haste, there was the Wenzhou accident in 2011, the world's 3rd worst high-speed rail accidents so far, causing 40 lives and reputation. It also had a high fare that caused low ridership and financial loss, for parts of the system. In 2013, for corruption, the Minster of Railroad was sentenced to death-with-reprieve, and the Ministry of Railroad was broken up to encourage efficiency by competition.

But by all accounts, growing pains apart, the entire project is far from a white elephant. It ameliorated the income inequality issue between coastal and interior China, provided a safety valve for surplus labor in times of export slowdown, integrated China's continent-size market for resources and output, also yielded an exportable technology, which is attractive in the developing world and some developed market. It also becomes a backbone of half of China's One-Belt-One-Road (OBOR), girding the Eurasian continental mass, and it forms the basis of upgrading the Yiwu-London Railroad, that joins 14 Eurasian capitals to various metropolitan cities throughout China Certainly in a span of just a single decade, China has not quite caught up with Japan's achievement over 50 years. But it already runs faster at much lower cost on China's flatter land than on Japan's mountainous terrain, and improvement of the Chinese system is still expected.

In addition, waves of related Chinese patent applications quickly appeared, with Chinese export drives for infrastructure service soon following. Much international controversy on intellectual property rights broke out as well.

Next, one shall draw insights from this case into the various views on industrial policy discussed earlier.

2.3 The case history of HSR is informative

Like clinical record for medicine, the case history of Chinese HSR sheds much light into topics of the Lin-Zhang Debate, and views taken by SG and S-MGI, also the views of Rodrik and PCAST.

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7 For a formal analysis, complete with a game matrix, see Exhibit 4 in McKinsey & Company (2011, p.28).

The case of Chinese HSR corroborates Lin: both the latent strength of an economy, say, the domestic market size, and the record of a ‘compass economy’ may be assessed for policy decisions. For example, Meiji Japan raised tariffs to induce foreign suppliers of electric machines to invest and produce locally for domestic needs. This helped Japan, as a relatively backwardness country then, to acquire technology. In order to succeed, the role of the State must is inescapable: be it raising tariffs by Meiji Japan, or awarding railway contracts by PRC. Here, upgrading national competence is the goal, with trade activity as the means. Further, the ‘compass economy’ being targeted (Japan, here) may not welcome the development, perceiving the quick rise of a rival in trade. The adoption of (industrial) policy accentuates the need of a government at critical phases, but it does not imply any restoration of the planned economy, nor the giving-up of the market force. China disbanded the Ministry of Railroad for more market incentives. Japan eventually privatized the railroad that China may or may not adopt in the future. Taking the long view, the policy for Chinese HSR is certainly a success, even though some ‘growing pains’ like pollution, inefficiency and corruption are side-effects in development, some of which might be avoided.

This is in contrast to the views of Zhang that in economics, the future is unpredictable, industrial policy is not necessary and harmful on the average, while the remedy of market failure with government policy is not considered.

SG emphasizes the benefit of industrial policy from the gains in learning, and hence productivity, rather than trade. Therefore, even without the export of HSR projects that causes some controversy, the Chinese policy on HSR would still be rated as successful.

S-MGI deals with developed countries, rather than the Chinese HSR policy, which is carried out during the development phase.

Rodrik (2006) noted that similar policies of Chinese on ‘high tech’ products are efficacious in nurturing production technology and enhancing growth.

PCAST is the only view with much reservation on Chinese industrial policy, not because of its efficacy for China, but for its possible negative impact on trading partners such as America.

With all due respect, such important conclusion appears partial and unwarranted on industrial policy, perhaps due to certain special nature of the example of HSR. Therefore, the foundry sector of Taiwan will be reviewed below, to provide a more balanced picture.

3. Seeking Further Evidence from History: The Story of TSMC

3.1 The context — Three issues

In the Lin-Zhang exchange, both economists are concerned about policy debacles, caused by government missteps in picking winners, such as Chinese initiatives on solar panels and new energy automobiles, as cited by Zhang. Zhang sees no advantage for government involvement, which only causes bureaucracy and rent-seeking. Lin believes in assessing the latent strength of an economy, to avoid comparative advantage defying (CAD) projects. A special case for Lin is to target 'compass economies'. This reasonable principle gives up any opportunity to 'leap-frogging'. So the first unanswered question is naturally: is there any precedence for a developing economy to leapfrog?

To target a 'compass economy', a less developed economy tends to enter as a low-cost rival challenging the incumbent, causing the Thucydides Trap. So the second unanswered question is: can one succeed to reach a win-win solution?

Finally, industrial policy depends inevitably on the involvement of the government, which by nature runs the risks of government failures like bureaucracy and rent-seeking. So the third unanswered question is: is there scope to overcome market failures by relying on the government without courting undue risks of government failures?

To offer an affirmative answer to all these three questions, one needs to find a paradigm case, other than the Chinese HSR. This will be done below, by considering the dedicated foundries for semiconductors.

3.2 The sector of *dedicated* semiconductor foundries in Taiwan

In 1987, Taiwan Semiconductor Manufacturing Company (TSMC hereafter) from Taiwan was spun-off from the national laboratory ITRI[8], to be a producer[9] of

8 That is, Industrial Technology Research Institute.

9 Or 'foundry'.

semiconductors.[10] Under its charter provision, TSMC would only produce under customers' contract, but not design any 'chip' under its own brand.[11]

Taiwan is an economy of modest size (population: 23 million only), with its high growth period long gone, and no access to the last recourse of international finance.[12]

At the founder of TSMC, 30 years ago, Morris Chang was also then the president of ITRI. He assessed the relative position of Taiwan as weak in R&D, in design, in marketing, as well as in intellectual property rights, but with some latent strength in manufacturing. Even there its technology lagged behind the world's leading firms for 2½ generations (Patterson, 2007).

Yet, today, in terms of stock market capitalization, the value of TSMC is quite remarkable, in comparison with some other high-tech firms, worldwide:

Table 1 Market Capitalization (million USD)

Samsung Electronics	IBM	Intel	TSMC
240,699	170,303	169,807	154,062

Source: http://www.corporateinformation.com/Top-100.aspx?topcase=b, retrieved on March 6, 2017

With a market value at about 16% of the total local bourse, TSMC tops all Taiwan's firms. In technology, it has beaten Intel to supply mobile devices as tablet computers (Hruska, 2016), also edged out Samsung to be the sole supplier for Apple phones (Jenkins, 2016).

Why? The crux of the matter is that not only TSMC specializes in its own comparative advantage, that is to manufacture chips (rather than design them), but it also succeeds by *leap-frogging* with innovation, in particular, not in technology, but in its '*business method*', by the promise in its charter of not marketing anything under its own brand.

[10] Or 'chip'.

[11] This was the world's first dedicated semiconductor foundry (i.e., producer). Subsequently, other foundries (including two other firms from Taiwan, United Microelectronics Company, UMC and Vanguard International Semiconductor Corporation, VIS) also adopted the same provision of dropping their own chip-designing function.

[12] That is, World Bank and IMF, those 'Bretton Woods institutions which bailed South Korea out in 1997-1998.

Specifically, with insight, TSMC not only promises *non-competing* against its own clients,[13] that is, the chip-designers, but also offers them the readily verifiable way of having never marketed any product under its own brand, which is something that will become more credible over time, against the competition of later entrants.

Due to the particular nature of the microelectronic revolution, the institution of the *dedicated foundry* becomes an especially important innovation.

First, new goods and services have been introduced increasingly often in waves of creative destruction (Chue and Lim, 2005).

Second, the increasingly shortened product cycle makes the designers of chips eager to reduce the time-to-market (Tung and Wan, 2013).

Third, the fixed cost of the foundry equipment becomes increasingly unaffordable by chip designers, so that chips have to be manufactured by 'merchant foundries' (Rock's Law), namely, Independent Device Manufacturer, manufacturing excess capacity at a fee.

Fourth, the manufacturing process becomes ever more complex, so that intense consultation is needed between the chip designer and the foundry to expedite the delivery of chips, giving the opportunity for the foundry to acquire information about chip design, and hence the moral hazard for the foundry to free-ride on such information and produce its own competing goods (Walker, 2000; Perry, 2012).

Fifth, with the manufacturing process becoming ever more complex, litigating against the free-riding by a foundry becomes ever more costly, complex and uncertain, like in the case of Apple vs. Samsung.

All these would increase the demand for the service of the 'dedicated foundry' (See Appendix for a Game Theoretic Model).

As Morris Chang noted (Patterson, 2007) that, while on paper, the dedicated foundry has its intrinsic advantages, the services of the dedicated foundry often 'need the time to grow', especially in view of the low technology in earlier years. And Chang further explained that not all dedicated foundries make money. TSMC in some year earns 110% of the total profits of all dedicated foundries together (Patterson, 2007).

So, this is a case that leap-frogging is possible for a developing economy, using industrial policy.

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[13] As it is acclaimed in its charter, 30 years ago.

Next, TSMC was initially founded with Philips as a major stockholder, serving its needs for foundry service, but also enjoying the access of its other process technology under cross-license arrangements.

Subsequently, TSMC jointly developed processing technology with some of its clients. It acquires tools for clients' use, and arranged 3rd party consultants when needed. By such means, TSMC can achieve higher yield rate for its clients' product, and therefore earn higher ASP (Average Sales Price) than other foundries.

The existence of TSMC stimulated the development of many of its clients such as NVidia. That is why Morris Chang claimed that by introducing the dedicated foundry model, TSMC has helped to create hundreds of thousands American jobs, mainly in the fabless semiconductor sector but also some jobs inside the sector of Integrated Device Manufacturers as well (Eassa, 2017).

In this sense, the development of the foundry sector is a strategic complement for, rather than a strategic substitution against the developed economies, with the result of a *win-win outcome.* This is quite different from the class of cases of targeting the compass economy.

Finally, it is important to note that although industrial policy invariably involve government action to overcome the results from market failure, this does not necessarily increase the likelihood of government failure. For example, in the case of Taiwanese foundry sector, the firms involved, TSMC, UMC and VIS, were all spun-offs from ITRI, and they have not operated as State enterprises, and thus do not share the same types of *government failure*. In fact, the case of TSMC can serve as an example of privatization.

3.3 Contract manufacturing and export zones

Industrial policy resembles medicine, there is much uncertainty, but there is also much scope for learning. Assessing the reality is unlikely to be error-free, yet it has always been tried as it should be. But Industrial policy resembles the chess play even more. In chess, no two plays are likely to be identical, yet that does not make the books on past chess tournament worthless for learners in chess play. Much value can be distilled for the future from the past, though the past is never repeated in the future. By extracting the useful for replication, exact duplication is not needed. Thus one might scrutinize about the foundry sector of Taiwan. What then are the replicable facts?

Leaping-the-frog can be worthwhile and fruitful; innovation is feasible and not only practical for those who are initially superb in technology.

A win-win outcome is available in broad classes of circumstances. Zero sum is not the only game, especially under globalization when future development is within reach, with new goods and services, new markets and institutions open for exploration.

Initial steps, including public decisions made in the past, like opening to market, need not be repeated.

All the above elements are present for the dedicated semiconductor foundries, to make room for complementary innovations elsewhere. They are also present for the more prosaic operations of electronic manufacturing services,[14] excelled by contract manufacturing such as practiced by Hon Hai-Foxconn that also emerged from Taiwan in the aftermath of the special economic zones, in Kaohsiung, Taiwan and emulated in China, replicated at Shenzhen and elsewhere, following the earlier observation and efforts of Chinese premier, Zhou Enlai (Chen, 2008). In these, some government decisions are often important in the beginning, but market force would take care later, most of the time.

4. Concluding Remarks

What does the history of the foundry sector of Taiwan imply, about the Lin and Zhang debate in particular, and the broader issues on industrial policy, in general?

As an example, it demonstrates that:

A. Under appropriate industrial policy, even for developing economies with modest size and limited initial know-how, it is possible not only to achieve catch-up in technology but also succeed in leapfrogging.

B. To channel development effort, it is essential to assess realistically the relative position of an economy in the world market (In Lin's terms: 'CAF' is important).

C. For nurturing 'infant industries', government initiative is crucial (public funding is often needed, especially in launching industries).[15]

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[14] See the very informative study of van Liemt (2007), showing how outsourcing helps launching of new products.

[15] Left to local private firms, Taiwan's foundry sector could never be launched: a clear proof of the indispensable role of industrial policy (Tung, 2001).

D. Market force is important[16] and State micro-management must be avoided[17]. The spinning-off of firms from government labs has been a customary device in Taiwan, with clear signals that failed firms can expect no bail-out.[18]

E. For Taiwan's semiconductor foundries, a major source of technology for industry-upgrading is through joint R&D efforts among private firms across borders.

F. To upgrade the technological competence of a country, sometimes industrial policy may be deployed for a *win-win* solution for many others, at home and abroad.[19] Therefore, it is far from inevitable that the use of industrial policy would lead to international conflicts of the zero-sum type.

Finally, for economies of continental size, as for PRC, India or Japan, over-expansion of some sectors can be self-defeating and disruptive for trade partners. Part of the service of Japanese MITI (now, METI) is to serve as been a restraining force against over-expansion, when needed, something Korea does not have, and suffered in 1997-1998 as a consequence.

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[16] The prescient assessment of Taiwan's weakness and strength by Morris Chang provides a seminal example of Lin's emphasis in ascertaining the latent comparative advantage, against comparative advantage defying (CAF) programs. Within Taiwan's semiconductor sector, the difficulty of producing CPUs was testified by the failure of VIA, against the costly legal challenges by Intel; the problems of supplying memory chips was shown by the exit from that market of Vanguard, managed by Morris Chang himself (Clendenin, 2003).

[17] For TSMC, both the formal spin off from the government research lab (ITRI) and the investment by Philips of the Netherlands make the micromanagement by the government impossible.

[18] As Mathews and Cho (2000) documented, there were many spin-offs from ITRI, but only a few like TSMC and UMC still survive and thrive today.

[19] TSMC is certainly successful for Taiwan: its average rate of growth is much larger than the economy as a whole. How about other countries? Consider two countries Taiwan's foundries have most dealings, next. For the Netherlands, by Manners (2008), the initial investment by Philips has proved as an extremely successful deal. At the same time, for America, according to USITA (2016), on the one hand, 73% of the world's foundry business is in Taiwan, and 65% of the fabless firms are in America. On the other hand, America is the top supplier of semiconductor manufacture equipment with a 47% market share, and Taiwan is the largest buyer in that market. This supports Morris Chang' claim that TSMC created hundreds of thousands US chip-design jobs in America (Wu, 2017).

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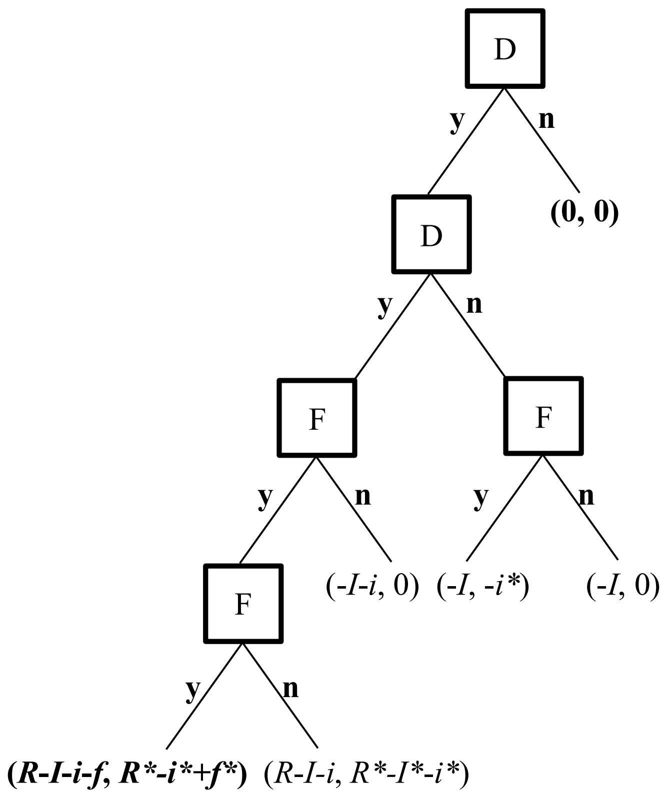
Appendix The foundry with ***im***pure-play as a 3-stage game of Designer vs. Foundry

Stage	Active Player	Action	Choice (**y**es or **n**o)
1	**D**esigner	Move alone	Make prior investment $I > 0$ or not
2	Both	Move simultaneously	Make joint investment $i > 0$ and $i^* > 0$ or not
3	**F**oundry	Move alone	Free-ride the Designer as rival



Assumptions:

a) Results of No free-riding: Returns to D: $R - I - i > 0$; Returns to F: $R^* - i^* > 0$.

b) Direct consequence of free-riding: for D: $-f < 0$; for F: $f^* > 0$.

c) Results of free-riding: Net returns for D: $R–I–i–f < 0$; Net returns for F: $R^*– i^* + f^* > 0$.

Proposition 1.

In a non-cooperative Nash pure strategy equilibrium, free-riding implies designer faces net loss, so that there will be no IC design, with (0, 0) as the pure strategy equilibrium.

Corollary 1.

The foundry will seek free-riding as a *fait accompli*, rather than any renegotiation.

Corollary 2.

A rational foundry with *impure* play will randomize, so some designer will acquiesce.

A Postscript Honoring Kenneth Arrow (2017.03.07)

Much of the recent revival of interest on *Industrial Policy* owes to the Stiglitz-Greenwald volume (2014), an outgrowth of the original Inaugural Arrow Lecture, 2008, in honor of Kenneth J. Arrow, who passed away, February 17, 2017.

Arrow's Comment in Stiglitz-Greenwald (pp. 504-8) honoring him emphasized the *processes* of learning, the spill-over effect, and its impact on economic growth, beyond either the concepts themselves, or the existing models in the literature about them. This may be viewed as an implied call to study what remains then unknown in real life.

As seen in the discussion of the dedicated semiconductor foundry in the paper, rather than magnifying the effect of learning on growth, real life spill-over can erode the motivation for R&D for innovative chip design, without some institutional remedy. This is precisely an example illustrating how complex are inter-related issues of learning, and growth in real life. It seems altogether proper to point out the fact in Arrow's honor.

Here, learning is contingent on R&D programs motivated by expected profit streams. Rising equipment cost causes chip designers to depend on chip foundries in fabricating the chips. Complexities in fabrication require close consultation between the chip designer who made prior investment in R&D, and the fab, thus increasing the extent of information spill-over. The spill-over encourages the free-riding of the fab at the expense of chip-designers. Product complexity further reduces the value of litigating against the infringement of intellectual property rights. Under Moore's Law, the exponential growth of the chip-density per integrated circuit shortens the expected product life and discourages the R&D for chip design.

All these make the model of *the dedicated foundry* an innovative business method by promising in charter statement, of marketing no product under its own brand – a readily verifiable means for confidence building that unleashes the growth of the fabless industry of chip-design.

The 'foundry model' makes competing fabs to compete for the same uncertain demand. This allows the more established fabs to demand from clients co-investments in capacity expansions in return for the long term availability of reserved foundry capacity. This ends up in a winner-taking-all equilibrium to charge higher ASP, leaving the less established foundries to suffer higher excess capacity.