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The Limits of Capital: Transcending the Public Financer – Private Producer Split in R&D

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Abstract

Despite a strong tendency in the privatization literature to prefer private sector solutions to public sector ones, in the case of R&D a near consensus has emerged that supports public R&D funding for private production as a solution to a host of market failures. This article explores theoretical justifications for a more expansive role for the state in R&D. Identifying three inherent problems of a straight financier/provider solution, principal-agent problems, cultivation of intrinsic motivations, and generation of cooperation, the paper contend that the state might, under some conditions, take it upon itself to intervene more directly. Drawing on the positive experiences of different states that have moved in recent years from the high technology industries' periphery to the center, the paper demonstrate how very different states successfully employ public sector solutions to common R&D problems. Analyzing these challenges the paper inquires into the advantages of state production of R&D as a possible response. Based on this analysis, we conclude that there is a strong theoretical and empirical case for state involvement in R&D that goes beyond mere funding, especially in industries that operate in the context of immature markets.

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Introduction

Few would argue with the contention that in the last three decades, the world has witnessed a steady increase in the salience of two very important economic phenomena: privatization and the growth of knowledge-based economic activities. In the post war years, public expenditure was constantly on the rise. Furthermore, public ownership of industries and utilities became common and in some places, the norm. However, since the early 1980s, the tide has turned and almost everywhere, governments implemented policies that transferred both ownership and control from the public to the private sector. During the same period, the pace of technological innovation, and its absorption by the economy, accelerated significantly. This development was not lost on many governments that actively sought to facilitate this process in order to bolster their domestic economies. Governments did this mainly by initiating and supporting local R&D operations.

Contemporary economic literature offers support for both privatization and the advent of the knowledge-based economy. Privatization proponents stressed that actors in the private sector are more efficient as they are more strongly motivated by material incentives than their counterparts in the public sector (Dixit 1997; Hayek 1944; Megginson 2005). Endogenous growth theory and institutional economics not only singled out the importance of technology and human capital for economic growth, but also explained why investment in R&D could shift the national economy to a higher growth curve, providing an economic justification for R&D investment (Arrow 1962; Grossman and Helpman 1994; Helpman 2004; Nelson 1993; Nelson and Winter 1982; Romer 1994)

Most importantly, in the minds of many economists the two phenomena were related: innovation and technological revolutions were far more likely to occur in the

dynamic private sector than in the rigid public sector. Privatization, it is argued, 'liberates' the entrepreneurial spirit that lies dormant in the public sector with the result of a technological leap forward (Baumol 2002; Helpman 2004; Rosenberg and Birdzell 1986; Shleifer 1998). Is this, in fact, a fair description of the relationship between innovation and privatization?

Various countries' experiences, as has been shown in numerous academic studies, have put into question the clear dichotomy of 'private-good' and 'public-bad' in the R&D field. States have not only subsidized private R&D, but have also structured private firms' institutional environment and in some cases have successfully led R&D ventures. State-led success in industrial R&D is puzzling from the perspective of mainstream privatization theory. Few theorists would make the claim that the private sector is superior to the public sector in all cases, but in an activity such as innovation in which risk-taking and flexibility are crucial for success, most theorists would argue that the private sector holds a distinct advantage.

In this article, we set out to explain why public-sponsored and public-led R&D can be as successful as private R&D as well as why privatization theorists have failed to recognize some of the unique advantages that the public sector posses with respect to R&D. In the context of privatization theory, we ask: for what reasons and under what conditions should the state consider public industrial R&D?

We argue that despite the existence of a well-developed economic literature that deals with different types of market failures (e.g., information asymmetry) and problems associated with incomplete markets, privatization theories have failed, to date, to adequately explain the success of state-led R&D. While the theoretical case has been

made for state subsidies for private R&D, especially non-applied research, the privatization literature has yet to address state-based innovation. If we are to understand why the state could succeed in the innovation business, it is important to pay closer attention, than is currently the case, to the following three sector-related issues in the study of innovation.

First, there is a strong case for government financing of private R&D within the economic literature. Government financing, however, creates a wide range of principal-agent problems between the state and private firms supported by government that market discipline does not necessarily resolve.

Second, contrary to one of the main assumptions of the economic privatization literature, one should not take for granted that the private sector holds an "incentive edge" over the public sector in innovation. Although it is difficult to argue with the view that the private sector possesses stronger economic incentives, we argue that is counterbalanced by the possible advantages that the public sector has with respect to non-material (also known as 'intrinsic') incentives.

Finally, it has been repeatedly shown that innovation is a collective endeavor, and hence, one of the perquisites for success is networks of collaboration between companies and companies and research institutions, side by side with fierce market based competition. Thus, without the existence of such informal institution the best efforts of the state as a provider will come to not. However, policy makers cannot assume the existence of such institutions. Moreover, market production of R&D is based on inter-firm competition – competition that undercuts network formation and weakens cooperation among firms and among non-government actors in general. Public

intervention in many cases, we argue, is essential for cementing cooperative interactions among private actors both on the domestic and the international levels.

All three concerns vary in the degree of their relevance depending on the national or sub-national economic environment, and alone might not tilt the field against the privatization equals more innovation argument. However, we contend that taken together these three concerns strengthen considerably the case for state involvement in R&D production, especially in economies that do not belong to the top tier of technological sophistication.

In the rest of the article, we first discuss the reasons why private sector production is considered superior to public sector production, both in general and in the specific case of R&D. Next, we explain why some commentators believe that the state should have a limited role as a financier of privately produced R&D. We then go on to argue that this is true but insufficient for the creation and sustenance of a flourishing R&D sector. Our thoughts on why state involvement should, under specific circumstances, be extended from financer to other, sometimes more direct, interventions are laid out in the third and final section.

Why go private

The economic literature has compared in depth the attributes of private sector firms to the public sector in general and in particular to State Owned Enterprises (SOEs).[1] In general, this literature has concluded that private firms are inherently more efficient than SOEs. This is the case for at least three reasons. First, private managers are motivated by stronger incentives than public managers (Megginson 2005). Both the

[1] The following discussions focus on SOEs, but the arguments are generalizable to all types of public sector production.

private manager's pay and job safety are far more dependent on the firms' performance than is the case for the public manager. Furthermore, the consequences of bad performance are far more disastrous for the private firm than for the SOE, and are felt directly by its manager and shareholders. Badly performing private firms face hostile takeovers and bankruptcies while, in contrast, the state tends to bankroll SOEs, creating the problem of soft budget constraint (Sheshinski and Lopez-Calva 1999). Theoretically, one could expect the shareholders of the SOE – the state's citizens – to punish its managers for its failures. However, public ownership is dispersed among many shareholders, weakening the incentive of each individual shareholder to monitor SOE managers and hold politicians answerable (Alchian 1965).

Second, the market not only provides discipline, and hence incentives, for firm managers and shareholders, it supplies them with information as well. Shareholders use market signals, especially stock prices, as a means of assessing how well their investment is doing. Private sector managers closely monitor prices of outputs and stock. The SOE is in most cases a monopoly, hence not only are stock prices irrelevant, but also product prices are of limited informational value (Le Grand 1991; Vickers and Yarrow 1991).

Third, the theory of Public Choice has focused theoretical attention on the negative implications of the diverging utility functions of politicians, civil servants, and the public. According to public choice theorists, we should assume that civil servants and politicians are no different from any other person in that they seek to maximize personal utility. At times, a politician or a civil servant maximizes utility by activities that have detrimental effects on social welfare (Niskanen 1971). This situation parallels the principle-agent problem in the private sector but with one major difference: in the public

sector, market discipline does not keep agents in line with the principal's aims. The conclusion is that SOEs are more vulnerable than private firms are to the type of principal-agent problems that lead to perverse managerial decisions (Wolf 1979).

These three aforementioned considerations – incentives, information, and the severity of the principal-agent problem – have led many theorists to the conclusion that private firms are inherently superior to SOEs (Buchanan 1978; Tullock 1965). Nevertheless, even economists who support privatization for these reasons are not blind to other considerations, both economic and moral, that could tilt the scales towards public ownership. In the case of R&D, however, the argument for privatization of state-owned R&D appears to be especially strong. Hart, Shleifer and Vishny created a model of private contracting that demonstrates that *the more important innovation is f*or a certain industry or service, *the stronger the rationale for privatization* (Hart et al. 1997). In a later article, Shleifer also argues that in fields in which innovation is important for reasons of quality, policymakers should prefer the private to the public sector *since private sector innovation tends to be of higher quality* (Shleifer 1998).

Justifying public involvement

Recognition of the superiority of the private sector in producing innovation does not necessarily entail a complete abandonment of the public sector. As far back as 1962, Kenneth Arrow argued that industrial R&D involves an inherent market failure (Arrow 1962). The central implication, from a policy standpoint, is that the state must invest in R&D to correct the market failure. Scholarship that is more recent is skeptical of Arrow's information-based market failure argument, yet still views state investment as a valuable

means of creating technological capabilities that are necessary for innovation absorption (Salter and Martin 2001).

The Developmental State theories, seeking to explain the critical role of the state in the emergence of late-late economic developers, primarily the East-Asian tigers, have stressed how states have not only financed but also produced R&D (Amsden 1989; Amsden 2001; Amsden and Chu 2003; Anchordoguy 1989; Cheng 1990; Chinworth 1992; Johnson 1982; Mathews and Cho 2000; O'Riain 2004; Samuels 1994; Wade 1990; Woo-Cumings 1999). Nevertheless, privatization theorists and researchers have not embraced this view. Munari and Sobrero for example, explore the relationship between privatization and R&D in European SOEs. Although privatization, according to their research, does make R&D more efficient, they recognize that exclusive reliance on privately funded R&D is problematic. Nonetheless, they still argue against direct state intervention:

> "However, a critical situation arises when the abandoned R&D activities, of limited interest for the company at least in the short term, but important in a more general sense for the industry or for society as a whole. A typical situation of market failure emerges and the intervention of the State should be requested in forms *that differ from ownership and control*." (Munari and Sobrero 2005. Pp. 40-41. Italics added).

On the one hand, the authors acknowledge that private R&D activity fails to address important areas, most prominently long-term and/or theoretical (non-applied) projects. On the other hand, the authors emphasize that the state should be careful to avoid direct ownership and control of R&D. The proper division of labor that most economists seem to have in mind is roughly a *financer-provider split* in which the state partially finances R&D activities and the private sector is the exclusive locus of R&D production. The state, in other words, should avoid direct involvement in R&D.

In this article we beg to differ. While we agree that the private sector have some distinct advantages over the public sector in innovation, we contend that under certain circumstances the public sector' advantages can be quite significant.

In the next section we set out to explain why under specific conditions – conditions that are quite common in new and high technology industries – direct public involvement in R&D and industrial innovation could make sense from a national economic growth standpoint.

R&D and Privatization – the Case for Government Action

The empirical privatization literature recognizes that there are significant differences in national experiences that researchers attribute to variation in institutional and economic factors. Unfortunately, empirical insights of this type have had only limited influence on privatization theory. In this section, we will draw together R&D experiences in specific national settings and theoretical perspectives on the appropriate public-private division of labor in R&D.

We argue that striking the proper balance between public and private R&D depends on technological development, market conditions, and social factors. Specifically, we make the following three contentions. First, because of the vast potential for severe principal-agent problems, it is a mistake to assume that a provider-supplier division of labor will work with the state supplying financing and support and private firms supply the needed R&D. The classic information asymmetry problem in which the agent – the private firm in this case – uses its superior knowledge to take advantage of the principal – the state – is highly relevant because of the significant knowledge superiority

'insiders' enjoy in R&D. One might expect market signals to mitigate this asymmetry by providing the principal information on firm performance. This, however, presupposes that a developed market for R&D exists that could provide the government with a reliable evaluation of private R&D ventures. This assumption is problematic in general and even more so in locales in which the industry in question is relatively undeveloped.

A second type of principal-agent problem is connected to the fundamental differences in objectives between governments, which aim to maximize the spillover effects of their R&D subsidies, and companies which aim to maximize profits and consolidate winning market positions often by exploiting quasi-monopoly rights over IP and tacit knowledge. We find that the more sophisticated private firms are, the better they are at preventing spillovers to competing firms, domestic firms withstanding. Obviously, this undermines the main rationale for government support: the creation of local positive spillover effects.

The issue of development level rises again in a third type of principal-agent problem. One of the main concerns of governments operating within the context of a global economy is that much of the prospective impact of their investment in private R&D ventures could be lost because private firms might eventually move some or all of their operations abroad. Furthermore, the risk of such relocations occurring is not distributed equally across nations.

Second, intrinsic incentives are seldom accounted for in discussions of privatization. We argue that some economies enjoy more than others the benefits of these incentives and that the effect of certain intrinsic incentives – patriotism in particular – is likely to be more pronounced in the public than in the private sector.

Finally, inducing cooperation in a competitive environment is a daunting task but essential for successful R&D development for at least five reasons. First, cooperation among diverse non-government actors is needed in order to spur and maintain the structural transformation required for becoming a high technology producing economy, specifically with regards to skills and the labor composition needed for successful and continuous progress of industrial R&D activities. Second, R&D is not a solitary exercise, but a collective endeavor, and as such benefits greatly from frequent professional interactions. Third, government finance of private R&D is largely intended to create positive spillover effects for third parties, however, the interests of private firms is to maximize their profit and win the market competition, and hence, will do their best to consolidate their market position by blocking technology and knowledge diffusion to other firms. Ironically, governments that strive to promote both competition and positive spillovers discover that the former comes at the expense of the latter if government' intervention goes no further than finance.

Fourth, cooperation is also important for capability formation through learning. Obviously, in a dynamic field such as R&D there is a need for constant learning. Individual firms, however, lack the means and even the drive to extensively train their workers. [2] State intervention can ameliorate this problem in ways that go beyond public finance of training. Fifth, even when firms are interested in cooperation, they face a trust problem: a problem that can be resolved through contractual means but at a price of high transaction costs. Recent literature on social capital highlights both how institutions that engender trust lower transaction costs and the extensive role of government in relation to

[2] Private firms face a free rider problem that leads to sub-optimal investment: one firm invests while others poach its trained workers (Culpepper and Finegold 2001; Finegold and Soskice 1991; Olson 1965).

such institutions (Herrigel 1996; Kenney 2000; Levy 1999; Morgan 1997; Whitley 1999). Furthermore, research has shown that states can address all of the above cooperation problems in a variety of ways (Breznitz 2005a; Lester and Piore 2004; Levy 1999). We focus on the key functions states have in the establishment and support of professional and business networks that create numerous advantages for private firms.

In what comes next, we discuss in turn the three general problems outlined above demonstrating how together they put into question the advisability of the proposed clear cut financer-producer division of labor between the state and private firms in R&D.

Principal-Agent Issues

The argument for state financial support for R&D garners broad backing, and is accepted by many in the neo-liberal camp. Nevertheless, the common neo-liberal wisdom is that state intervention should be limited to financing R&D. The state and private R&D firms should create a financier-provider division of labor where the state supplies financing and/or financial incentives (e.g., subsidies) for industrial R&D and private firms then provide the national economy with the needed innovation.

While this seems to be a clear cut case in theory, it is alas, significantly complicated by principal-agents problems. Below we discuss three such problems: information asymmetries, the agent's interest in curbing spillovers, and the problem of globally footloose private companies. The first problem emerges due to asymmetries of knowledge and the absence of reliable market signals that would narrow the information

gap between principal and agent. The state's main objective in financing R&D is the creation of new industries and innovation, hence, by definition, markets are either underdeveloped or not even yet in existence). Under these circumstances, how can the state rely on market signals to ensure that: a) its investments are used properly; and b) that its policies actually lead to the stated goal of creating new industries and capabilities in the national economy? This dilemma is more acute the less developed the economy as even proxies for market signals, such as venture capital investment and/or companies' valuation, are rare and distorted.[3]

The answer is that states cannot fully rely on the market for information, therefore, adherence to a pure financier/provider division could create significant information asymmetry' problems between the state and private R&D. Indeed, even in the world's most developed economies, the question of monitoring and principle-agent problems in R&D-based investment is not fully solved. In fact, it is now taken for granted in the economics of innovation literature that these problem can never be optimally resolved, and, therefore, that financing of new R&D-based companies is best handled by specialized financiers such as venture capitalist who use a variety of instruments to negate, but can never fully eliminate, these asymmetries of information problems (Avnimelech and Teubal 2004; Gompers and Lerner 1999). A short inquiry into how states try to solve this dilemma suggests that there are two broad answers: each should be seen as a continuum of more/less with different countries picking their specific positions on the two continuums. The first widely used solution is for the state to deeply involve

[3] See for example the stories of the development of the IT and VC industries in such diverse economies as Taiwan, Ireland, Singapore, South Korea, and Taiwan (Amsden and Chu 2003; Breznitz 2005b; Breznitz 2007a; Cheng 1990; Fields 1995; Fuller et al. 2003; Hong 1997; Kim 1997; Mathews and Cho 2000; O'Hagan 2000; O'Riain 1997; O'Riain 2000; O'Riain 2004; Park 2000; Woo-Cumings 1991)

itself in the picking and choosing of technologies, sometimes even products. The more detailed the demands of the state, the less leeway do private firms have for exploiting information asymmetries. The second solution is for the state to rely more on tying, or matching, the sponsored R&D activities of local companies with these of leading MNCs, based on the assumption that these leading MNCs have the requisite knowledge to evaluate the domestic firm's performance.

For example, Israel, which in some respects can be seen as the purist follower of the financer/provider division, has adopted a policy that intimately links its local industry with that of the US. As early as 1968, its main industrial R&D development agency, the Office of the Chief Scientist in the Ministry of Trade and Industry (OCS), launched a general-scope industrial-R&D financing program with ideas coming from the private market and conditional financing from the government. However, a few years later, in 1975, it followed with a specific program trying to match local companies with American MNCs. This program, known as the Bi-national Industrial R&D foundation (BIRD) concentrated on fostering and financing cooperation between Israeli and US companies (BIRD 2000; BIRD Various Years; Bizan 2001; Breznitz 2007a; Breznitz 2007b; Trajtenberg 2001; Yahalomi 1991) . Its mode of operation has been to fund projects co-designed by an American Company and an Israeli one, in which the R&D was done in Israel, but the marketing and product definition in the US. Throughout the 1980s and 1990s BIRD had also become crucial in the enticement of American MNCs to open an R&D subsidiary in Israel (BIRD 2000; BIRD Various Years; Bizan 2001; Breznitz 2007a; Breznitz 2007b; Yahalomi 1991)

It is important to note that due to the acute lack of private venture financing in Israel until the second half of the 1990s, BIRD and the OCS were key in sponsoring the local IT industry and almost every company that won an OCS award also applied to BIRD (Breznitz 2006; Breznitz 2007a; Breznitz 2007b; Breznitz 2007c). Hence, the Israeli government, without even realizing what is it that it was doing, mitigated the information asymmetries between itself and the private firms it sponsored by getting "outside" high quality evaluation of projects through the active matching of these companies with MNCs, who were willing to become clients for their proposed R&D outputs.

A different approach is the one taken by Taiwan where the state aimed to mitigate the problem of information asymmetries by undertaking the core R&D itself. This created a unique division of labor between state and industry in the case of the IT industry. In this division of labor, it is the public research institutions that do most of the R&D up to the level of a working prototype, and then diffuse the results to industry, which concentrates on final development and integrated design. The specificity of this division of labor stems from the extensive level of intervention the state has created in the development of the technological capabilities of the industry. Public research institutions not only make decisions about which technologies industry should acquire, but also develop them up to the level of working product prototypes before handing them over to industry. It is this division of labor that is considered responsible for Taiwan's leading role in the global information technology industry (Amsden and Chu 2003; Berger and Lester 2005; Breznitz 2005b; Breznitz 2007c; Fuller Forthcoming; Fuller et al. 2003; Mathews 2002; Mathews and Cho 2000; Meany 1994; Park 2000).

The most well known example is semiconductors where the state was the actors that started the first foray into the industry, opening a special lab within Taiwan's premier research institute, the Industrial Technology Research Institute (ITRI), acquiring the IC chip fabrication technology from the US, developing it in-house, and diffusing it to the private industry primarily through formal spin-offs (Fuller et al. 2003; Hong 1997; Mathews and Cho 2000; Meany 1994). Pervasive state involvement in R&D production is the key to overcoming the public-private principal-agent problem in the Taiwanese case.

A second kind of principal-agent problems arises because of the inherent conflict of objectives between private firms and the state. On one side firms would like to maximize profits, and thus, minimize knowledge and technological spillovers from their efforts in order to cement their market position, on the other side the state that would prefer to maximize spillovers within the national economy in order to fully exploit the economic growth effects of investment. However, as the solution to this problem relates to institutions that support cooperation in the economy, we will discuss spillovers in that part of the paper below.

The third set of principal-agent issues is related to the potentially conflicting goals pursued by domestic firms and their governments. While the government hopes to keep as much high value added business at home, commercial firms would relocate abroad if they deem such a move economically advantageous. The traditional economic viewpoint is that even if commercial firms indeed choose to pick up and leave, it is all for the best because the re-allocation of resources would be more efficient and benefit domestic consumers (Krugman and Obstfeld 1991. Pp. 266). Nonetheless, as the rational for state

investment in R&D is specifically to create positive spillover at home and this will not happen if both the R&D and the diffusion of its results are actually conducted abroad. Furthermore, recent work by Ralph Gomory and William Baumol, questions the classical economic rationale that does not see re-location as a problem. The two stress that contrary to the past, the United States is no longer just losing low-end production capacity to other countries, but also high value-added activities such as R&D. This means that the United States cannot hope, as it did in the past, that lost activities would be more than compensated for by the introduction of new activities that have greater value-added – today's losses tend to be net losses (Gomory and Baumol 2000).

Nevertheless, the United States does have one distinct advantage over all other countries: it is the largest market and as such benefits from the fact that many firms wish to work in proximity to their main market for several reasons: first, firms developing products find it useful, and sometime a necessity, to have direct and constant interactions with their customers. Second, with the US capital markets' dominance in the high technology industry, many companies feel the need to have constant and direct interaction with their financial analysts, financial service providers, and large investors/shareholder. Thirdly, many companies find it necessary to organize their sale, marketing, and at least partial services, operation in their main market. (Breznitz 2006; Breznitz 2007b). Small developed states, in contrast, neither offer their domestic firms an alluring domestic market, nor relatively cheap labor, nor deep and globally connected financial markets. As a result, firms in such countries experience a dual external pull: on the one hand, they benefit by moving operations to locales with cheaper labor, and on the other hand, they often move to the United States to enjoy the advantage of operating in

the world's largest market. Indeed, in recent years, private R&D operations have often shifted abroad. As a result, small states have lost R&D to both less-developed and more-developed countries. For example, the Israeli government has recognized the severity of offshore R&D leakage, both to the United States and East Asia, and is exploring different ways of bucking this trend (Knesset Israel 2005; Ynet 2004a; Ynet 2004b).

Countries that are directly involved in R&D, and are not merely private R&D financers, are less troubled by the R&D leakage problem because private firms are highly dependent on state-sponsored R&D and stand to lose much of their advantage by moving abroad. For example, many semiconductors companies in Taiwan find it beneficial to have close relationship with ITRI. Consequently, while Taiwanese companies are, by some estimates, responsible to over thirty percent of production in Mainland China, the semiconductors fabrication in Taiwan itself has continuously grown in the last five years. In comparison, semiconductor fabrication in countries with more of an arm's length approach to R&D have experienced stagnation and decline over this period (Berger 2006; Berger and Lester 2005; Fuller 2005; Fuller 2007; Fuller et al. 2003; ITRI 2005; Kenney and Florida 2004; Mathews and Cho 2000). Furthermore, apart from the growth of R&D operations on the Island, Taiwan itself is capturing much more of the high end manufacturing activities spillovers which are the result of these activities.

Incentives: The Material versus the Intrinsic Paradox[4]

[4] 'Extrinsic-intrinsic' is by no means the only dimension relevant for the analysis of incentives in the context of R&D. Another interesting dimension is one proposed by Baumol that distinguishes between incentives that lead entrepreneurs to focus on productive ends, such as technological R&D, and incentives that steer entrepreneurs towards unproductive ends such as war or rent-seeking. It is an open question whether the private sector is better than the public sector, or the other way round, in inducing productive entrepreneurship rather than rent-seeking, especially when public finance is available for both sectors. Although this is an intriguing issue, for now, we will reserve it for future research (Baumol 1990).

Beginning in the 1970s, and culminating in the last decade, a considerable body of literature that deals with the effects of intrinsic motivations, that is, the effects on behavior of non-material incentives, has emerged. Two of the general insights of this literature are of particular interest for this study.

First, not only are intrinsic motivations important, sometime more so than extrinsic, or material, motivations, but they also might lose out and disappear when competing against material incentives, with the end result of weaker more costly incentives needed to motivate agents to the same degree. The existence of this 'crowd-out' effect, where extrinsic incentives displace intrinsic ones, has received various psychological explanations: individuals feel that their altruistic sentiments are debased by the imposition of extrinsic incentives, therefore, they suspend their intrinsically driven contributions; or that the introduction of material incentives shifts an individual's cognitive conceptualization of a relationship from a normative to a commercial basis (Frey and Jegen 2001; Gneezy and Rustichini 2000; Titmuss 1970). Regardless of the exact psychological mechanism that underpins crowd-out, there is a substantial body of research that not only supports the proposition that it exists, but also shows that in several instances it makes the introduction of extrinsic incentives highly undesirable (Frey and Jegen 2001).

Second, researchers have fruitfully applied the extrinsic-intrinsic distinction to the comparative study of public and private sector differences. Several studies have argued compellingly that employees and managers in the public sector are far less motivated by monetary rewards than their private sector counterparts (Boyne 2002; Buelens and Van

den Broeck 2007) Conversely, private sector workers are less motivated than public sector workers by a concern for the public good (Boyne 2002; Wright 2007).

Put together, the latter two propositions suggest two important points. The first is that intrinsic motivations are important and not necessarily compatible with extrinsic motivations. Secondly, they suggest that that the public sector has an edge over the private sector with respect to intrinsic motivation.

Intrinsic motivations are not equally important across all activities and all nations. For instance, researchers have stressed the centrality of intrinsic motivations in fields such as education and healthcare where workers tend to identify with both the goals of the service and its recipients (Acemoglu et al. 2003; Franco et al. 2002; Jacob and Levitt 2003). Intrinsic motivation has different sources. One of four such sources mentioned by Brewer, Selden & Facer is patriotic sentiment. The intensity of patriotic sentiment varies across space and time. Some publics are more patriotic than others and as a result, in the proper context, they would be moved to act on behalf of the national good – actions which others, who do not share the patriotic sentiment to the same degree, would find less appealing. We argue that patriotic sentiment moves numerous individuals to contribute in the R&D field.

Furthermore, in line with the second proposition mentioned above – the motivation-related differences between the public and private sectors – these individuals are likely to treat public and private R&D ventures in a different way. While private R&D is likely to hold an advantage over public R&D with respect to material incentives, the public sector possesses an edge in eliciting patriotically, as well as scientifically motivated contributions. For example, entrepreneurs might decide to invest in R&D

because they predict profitable returns, but they might also view their efforts as the fulfillment of a national duty or calling, or as part of their duty to advance science.[5]

The close association between the public sector and the state increases the likelihood that individuals would link public R&D to the advancement of national interests more than is the case for private R&D. Moreover, given that motivational crowd-out is a possibility, private sector centered and led R&D ventures could very well unintentionally repress intrinsic motivations among those involved.

The relative importance of extrinsic versus intrinsic motives varies with the strength of patriotic sentiment and with the power of extrinsic motivation. In countries in which an industry is highly developed, hence monetary rewards are likely to be high, and patriotic sentiment is uncommon, R&D policy would do well to assume the primacy of extrinsic motivation. Conversely, in places in which industry still has a way to go before it becomes profitable, and therefore finds it difficult to offer lucrative material compensation for effort, and patriotic sentiment is high, governments should rely on and prioritize the cultivation of intrinsic motivations. The latter choice is expected to involve substantial state involvement in R&D, if not direct state production of R&D.

In a number of countries that fit the general mold of “undeveloped industries yet "highly patriotic” we indeed found considerable evidence to support our thesis. Despite the common view of entrepreneurs as individuals that are willing to go to considerable lengths and take risks to achieve their economic goals, we discover time and again that

[5] Probably the best known example of scientists undertaking state sponsored R&D for patriotic reasons is the enlistment of America's best physicists to the Manhattan Project during World War II. Although they received pay, the scientists were clearly not working for the money. For example *Plumbers who worked in Los Alamos received nearly three times the pay of some of the scientists.* Robert Oppenheimer, who headed the project, was reminded by his secretary six months into his work at Los Alamos that he had not yet received a salary check.(Bird and Sherwin 2005. Pp. 216-217).

many of them saw there activity as part of a national mission. Two relevant examples are the roles of the military in the development and sustenance of the Israeli software industry, and the role played by wealthy returnees and ex-patriots in the development of Taiwanese IT industry (Amsden and Chu 2003; Berger and Lester 2005; Breznitz 2005a; Breznitz 2007a; Saxenian and Hsu 2001) Even if the public sector does not directly produce R&D, its active involvement and sponsorship is necessary to achieve the participation of patriotically motivated entrepreneurs and private investors. State involvement, more than anything else, transforms R&D from a private enterprise into a national project.

Networks and collective learning

Starting in the 1980s and gaining pace since, a vast body of literature in all disciplines of social science has shown that innovation (that is the transformation of R&D into commercially viable products and services) is a collective endeavor. Therefore, for industrial innovation to flourish and result in long-term economic growth there is a need to accommodate close cooperation, a behavior that is in direct contradiction to the necessary competition between of the same organizations in the market place. Furthermore, while cooperation is an essential condition for achieving such access, there is ample evidence that shows that cooperation cannot be taken for granted, nor that it develops naturally with economic growth and industrial development (Ansell 2000; Antonelli 2000; Braczyk et al. 1998; Breznitz 2005a; Breznitz 2007a; Breznitz 2007b; Chebrough 2003; Cooke and Morgan 1998; Edquist 1997; Florida 1995; Herrigel 1994; Keeble et al. 1999; Kenney 2000; Koepp 2002; Lester and Piore 2004; Locke 1995; Lundvall 1992; Nelson 1993; O'Riain 2004; Olson 1965; Piore and Sabel 1984; Porter

1990; Porter 2000; Saxenian 1994; Sturgeon 2000; Sturgeon 2002)..In addition, a market environment might not be the optimal one for inducing cooperation and indeed the problem of cooperation within a market environment manifests itself in different ways. We will discuss several of these below and explain how the state addresses these cooperation failures, in particular by supporting professional networks.

First, the development of a high technology industry does not happen in an institutional vacuum. Many countries must undergo a fair amount of industrial restructuring before the conditions are right for high technology growth. For example, many 20th century economies valued workforce continuity and stability over flexibility. The advent of dynamic R&D-led industries has shifted the balance from a prioritization of stability to flexibility. Such a shift, however, could rarely be achieved by unilateral steps taken by employers. Success depends on cooperation between employers, worker' associations and other non-government actors that could both legitimize and facilitate flexibility-enhancing restructuring (Regini 1999; Traxler and Unger 1994). In theory, broad cooperation among different actors could be achieved without external intervention; however, this does not necessarily occur and even if it does, it could take considerable time. In different countries, the state has taken a leading role in the creation of forums that bring together actors from business, academia and politics.

Finland presents an interesting example of this phenomenon. In Finland, old neo-corporatist peak employer and labor associations that had been created long ago for collective bargaining and to resolve labor-capital conflicts were infused with a new mission as they were turned into institutions to regulate the transition from a manufacturing to a high-technology "new" economy (Ornston 2006; Ornston and Rehn

2006). Consensus among the old actors created a platform on which new dense inter-firm networks were built. A panoply of new public commissions and agencies pushed the old neo-corporatist partners towards agreement on new objectives for the economy and new channels for public expenditure; for example, the Science and Technology Policy Council, which subsequently gave rise to Tekes. These broad agreements legitimized the deep structural transformations involved and formed the bedrock of multi-polar networks on the local level. In the most successful cases of development of new technology industries in Finland, as for example in the city of Tampere, where Nokia has more than 4000 employees, new networks were constructed by combinations of previously-developed skilled labor, university strengths, industrial commitment, and municipal leadership.[6]

Second, states that rely solely on public funding to stimulate R&D growth could discover to their dismay, at least in the initial stages of development, that public funding is not optimally employed or even left unexploited by firms because of a capacity problem in the private sector. This problem is compounded by inter-firm competition that discourages professional cooperation across firms. This is a major problem in places where capabilities are scarce because R&D is a collaborative venture in which the interplay of different skills and ideas allows professionals to achieve together what would have been well nigh impossible on their own. Isolated professionals might well fail to make substantial breakthroughs, were the same professionals working in cooperation would have had a far better chance.

[6] For more on the case of Tempere, see Juha Kostiainen and Markku Sotarauta, "Finnish City Reinvented: Tampere's Path from Industry to Knowledge Economy" (Juha and Sotarauta 2002)

One possible solution is for the state to take the lead in R&D production and diffuse the resulting products to industry. Taiwan is a prime example of such a strategy, where most of the R&D in a vast range of IT technologies is conducted by public research institutions such as ITRI and then diffused into the industry which is in turn supported by various financial schemes (Amsden and Chu 2003; Berger and Lester 2005; Breznitz 2005b; Breznitz 2007a; Chang et al. 1999; Fuller et al. 2003; Mathews and Cho 2000). In this case, the state takes charge and concentrates scarce capacities and by so doing it overcomes the private non-cooperation obstacle.

An alternative strategy for dealing with the capacity-concentration challenge is for the state to create dense institutionalized professional networks. These professional networks achieve multiple goals associated with overcoming different cooperation problems explored in this section. We will discuss in some detail one major example of such a network – the Israeli military-based R&D network –and show how this network addresses a range of cooperation problems.

In Israel, collaborative public spaces were created, quite surprisingly, by the military and the defense apparatus. In Israel one of the military's main roles in the creation and maintenance of the IT industry has been by supplying it with collaborative public space (Breznitz 2005a).

The military in Israel enlists to its ranks, and extensively trains, the largest concentration of R&D engineers in the country. While on active duty these engineers work on a multitude of R&D projects in multidisciplinary teams. Thanks to the unique structure of reserve duty in Israel, former graduates who work in the civilian industry and technological experts from industry and academia regularly meet and collaborate with

one another, an experience that would not happen without the military.[7] Moreover, as the actors meet in the specific environment of reserve duty and in an atmosphere of patriotic camaraderie, the collaborative experiences in the military are more imbued with trust than similar ones initiated by industry associations or similar organizations. In addition, this regular routine of working together in the national interest helps to develop and maintain a deep sense of community.

This network, created under the auspices of the military, enables members and their companies to tackle and solve R&D problems that are beyond their present knowledge or skills. The military, therefore the state, has succeeded in solving the capacity concentration problem in Israel. Today, the private R&D sector in Israel has grown to the point that one can no longer argue that it suffers from a capacity problem although this was definitely an issue in the early stages of development. Nevertheless, the military network still benefits the industry as a whole by bringing the best and brightest into fruitful interactions. The existence of such dense and large networks gives the Israeli industry as a whole a distinct advantage.

A third cooperation-based problem is related to the spillover effect. There is an inherent conflict of objectives between private firms that would like to maximize profits and, thus, minimize knowledge and technological spillovers from their efforts in order to cement their market position, and the state that would prefer to maximize spillovers within the national economy in order to fully exploit the economic growth effects of

[7] Reserve duty is one of the prominent facts of life for most Israelis, especially males. Every Israeli citizen who has served in the military is required to serve for up to 30-40 days a year on reserve duty. Men usually serve until the age of 40-45. In the technology units, many of the reserve personnel are called to serve on a one or two days per week basis throughout the year, and hence, are constantly engaged with both the military active duty personnel and other reservists from all over the private industry and academia in Israel. Needless to say, without the military these interactions over a wide range of R&D projects would not have occurred.

investment. In the last few decades, states have become keenly aware of the problem and utilize two strategies. First, the state imposes certain legally binding obligations on companies that benefit from state R&D sponsorship. For example, the US Department of Defense required Intel to cross-license its technology. This is one of the main reasons that AMD managed to compete successfully with Intel, a development that benefited consumers (Lécuyer 2005). Second, the state encourages domestic firms to participate in a network of organizations working on the same set of problems and sharing the intellectual property rights resulting from these efforts.

The most common program of this kind is the state-backed research consortia, which, partly thanks to the Japanese government's immensely successful usage of them have become almost a regular policy staple across the globe. While a research consortia's aim is to solve the particular R&D problems of each national industry, for example entering already developed product markets in the case of Taiwan and Japan, or advancing generic research for yet to be developed products as in the case of the US and Israel, they are all being utilized to expedite a wider diffusion and sharing of the results of government sponsored industrial R&D (Anchordoguy 1989; Breznitz 2006; Breznitz 2007b; Chinworth 1992; Johnson 1982; Mathews 2002; Samuels 1994; Teubal et al. 1996).

Fourth, due to the public good quality of education, the importance of state financial support for education and training purposes has been oft-noted and we do not intend to repeat here familiar arguments. We argue, however, that R&D development benefits not only from state financed education and training, but also from the existence of professional networks that encourage learning and knowledge transfer. Once again, the

Israeli military network provides an excellent example The Israeli military provides major venues for collective learning. First, the military sponsors multiple activities of collective learning by creating and disseminating IT teaching and learning material. Small project teams usually carry out these collective learning activities. The teams are composed of active duty soldiers and civilian experts from a multitude of firms and academic institutions, doing their reserve duty, working together and sharing their knowledge in a way that would not be possible outside the military. Second, Israel's best experts in various IT and R&D fields teach and publish textbooks and instruction material only through reserve military duty. Third, the reserve personnel themselves are constantly exposed to knowledge gathered and created in the military, knowledge they take back to and utilize in their firms (Breznitz 2005a).

Finally, the spillover problem discussed above presents a situation in which private firms prefer to avoid cooperation despite the fact that cooperation would maximize collective welfare. There are instances, however, in which private firms realize that the benefits from cooperation with other firms could outweigh the costs. On the backdrop of competition, however, it is only to be expected that inter-firm collaborations would be laced with suspicion and distrust. Highly detailed and restrictive contracts that clearly state the obligations and rights of the contracting parties are one way of overcoming mutual suspicion. Unfortunately, such a relationship is predicated on high transaction costs that accrue to both parties due to the inflexibility such contracts entail and the legal costs involved (Williamson 1979; Williamson 1983)

Once again, state sponsored networks constitute an appealing alternative. On one level these networks offer parties the reassurance associated with state involvement. It is

one thing for a private firm to renege on promises made to another firm. It is quite a different matter to do so when the state, even if not a direct partner, is involved in the proceedings. In the latter case, private firms take into account that the state could respond with sanctions, not least among them cutting the firm out of the state sponsored network. On a deeper level, networks perform a much more important function: they engender trust among members in what would otherwise have been a very distrustful environment. The Israeli military network, for example, has developed an enormous stock of social capital in the high technology R&D sector. Entrepreneurs and workers may work in different firms but they benefit from a shared personal history in the military and they continue to interact on a regular basis in the framework of reserve duty. As a consequence, the R&D leadership and workforce not only know each other, they also trust each other. Hence, business interactions are facilitated by a high degree of trust that translates into low transaction costs.

All five cooperation challenges, or collective action problems in a competitive environment, can and are addressed by professional networks that foster trust, create collaborative space and support learning. Without such networks the best efforts of both the state as a financier and private industry as a provider will come to not. However, research suggests that the existence, maintenance, and development of such networks cannot be assumed to happen spontaneously. This suggests that the state as part of its role of providing public good can, and should, play a significant function in the building and institutionalization of such networks and collaborative public spaces.

Conclusion

In this article, we argue that the public financer – private producer division of labor in R&D is many times sub-optimal. Specifically, we argue that under certain conditions, a division of labor in which the state takes a far more active role on the R&D production end, can be more efficient. More interestingly, we explore the particular circumstances under which more extensive state involvement might be superior. Developing industries that suffer from weak market signals, low retention of value-added functions, limited professional capacities, and limited institutional thickness and networks, could benefit from direct state involvement in R&D production. Furthermore, we have found that once intrinsic and not just monetary/material incentives are taken into account, the private sector might actually prove inferior to the public sector.

What we *do not* argue, however, is that all economies, or even all developing economies, should opt for greater state intervention in R&D. As is true of state intervention in the economy in general, state intervention has its perils and two in particular stands out in the case of developing economies: rent-seeking, and crowding-out. State support of local infant industries until the 1980s in South America failed largely because of these problems. The South-East Asian states, in comparison, succeeded on the whole in averting this danger despite extensive micro level state intervention in the economy.

Therefore, this paper should also be seen as a call for more research, in particular it suggests two main directions: first, more research needs to be done to specify the exact conditions under which state should move beyond the public-financer/private-provider division of labor in their attempt to advance industrial R&D activities. This paper has demonstrated that such a case exists, that many countries have indeed successful moved

beyond this spilt, and proposed three main areas where problems with a straight forward financier-provider arrangements might be sub-optimal. However, before our argument can become fully applicable more research needs to be done to ascertain the particular cases in which the state will do well to more directly intervene in R&D production.

A second area for fruitful future research is in the particularities of solutions to the problems we identify in this paper. While we are the first to admit that prodigious amount of research have been done on state actions in sponsoring and stimulating R&D, the utilization of the framework put forward in this paper to systematically think about the problems that straight financing cannot solve, can allow for a more comprehensive and less case specific research. Such research will lead to both generalizable conclusions and applicable policy recommendations, both of which are in want.

It is therefore that we close by concluding that in the case of R&D, as this paper has shown, the theoretically clear cut solution of a financier/provider split leaves much to be desired in the case of R&D and industrial innovation. Furthermore, we have identified three main domains in which the state should carefully consider to intervene in order to overcome the inherent problems of the public-financier/private-provider division of labor. Nonetheless, we urge policy makers and social scientist alike to carefully analyze each specific national case before construction of more direct state intervention initiatives.

References

(2005). Law for the Encourgemnt of Industrial R&D - Amendment 3.

Acemoglu, D., Kremer, M., & Mian, A. (2003). Incentives in markets, firms and governments, *NBER Working Paper 9802*. Cambridge, Mass.

Alchian, A. (1965). Some Economics of Property Rights. *Il Politico*, 30, 816-829.

Amsden, A. (1989). *Asia's Next Giant: South Korea and Late Industrialization*. Oxford: Oxford University Press.

— (2001). *The Rise of "The Rest" Challenges to the West from Late Industrializing Economies*. Oxford: Oxford University Press.
Amsden, A., & Chu, W.-W. (2003). *Beyond Late Development: Taiwan's Upgrading Policies*. Cambridge, MA: MIT Press.
Anchordoguy, M. (1989). *Computers Inc.: Japan's challenge to IBM*. Cambridge, MA: Harvard University Press.
Ansell, C. K. (2000). The Networked Polity: Regional Development in Western Europe. *Governance*, 13, 279-291.
Antonelli, C. (2000). Collective Knowledge Communication and Innovation: The Evidence of Technological Districts. *Regional Studies*, 34, 535-547.
Arrow, J. K. (1962). Economic Welfare and the Allocation of Resources for Invention. In R. R. Nelson (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609-625). Princeton, NJ: Princeton University Press.
Avnimelech, G., & Teubal, M. (2004). Strength of Market Forces and the Successful Emergence of Israel's Venture Capital Industry: Insights from a Policy-Led Case of Structural Change. *Revue Economique* 55, 1265-1300.
Baumol, j. W. (1990). Entrepreneurship: Productive, Unproductive, and Destructive. *The Journal of Political Economy*, 98, 893-921.
— (2002). *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism*. Princeton: Princeton University Press.
Berger, S. (2006). *How We Compete: What Companies Around the World Are Doing to Make It in Today's Global Economy*. New York: Doubleday.
Berger, S., & Lester, K. R. (2005). Global Taiwan: Building Competitive Strengths in the New Economy. New York: M.E. Sharpe.
BIRD (2000). BIRD Foundation - Procedures Handbook. Tel Aviv: BIRD Foundation.
— (Various Years). Annual Reports. Tel Aviv: BIRD Foundation.
Bird, K., & Sherwin, M. J. (2005). *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer*. New York: Alfred A. Knopf.
Bizan, O. (2001). *Essays on the Economics of Research Alliances (Israel)*. Unpublished Ph.D., Northwestern University.
Boyne, G. A. (2002). Public and Private Management: What's the Difference? *Journal of Management Studies*, 39, 97-122.
Braczyk, H.-J., Cooke, P., & Heidenreich, M. (1998). Regional Innovation Systems: The Role of Governances in a Globalized World. London: UCL Press.
Breznitz, D. (2005a). Collaborative Public Space in a National Innovation System: A Case Study of the Israeli Military's Impact on the Software Industry. *Industry and Innovation*, 12, 31-64.
— (2005b). Development, Flexibility, and R&D Performance in the Taiwanese IT Industry - Capability Creation and the Effects of State-Industry Co-Evolution. *Industrial and Corporate Change*, 14, 153-187.
— (2006). Innovation-Based Industrial Policy in Emerging Economies? The Case of Israel's IT Industry. *Business and Politics*, 8, Article 3: 1-38.
— (2007a). *Innovation and The State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland*. New Haven: Yale University Press.

— (2007b). Novel Product Innovation as an Industrial Policy: Horizontal Technology Policies, Intensive Product R&D, and Industry-State Co-Evolution in the Growth of the Israeli Software Industry. *Research Policy*, Forthcoming.
— (2007c). Public Policy and Coopetition Strategies in the Creation of New High-Technology Industries in a Globalizing World: The Case of Israel and Taiwan. *Academy of Management Journal*, Under Review.
Buchanan, J. M. (1978). *The Economics of Politics*. London: Institute of Economic Affairs.
Buelens, M., & Van den Broeck, H. (2007). An Analysis of Differences in Work Motivation between Public and Private Sector Organizations. *Public Administration Review*, 67, 65-76.
Chang, P.-L., Hsu, C.-W., & Tsai, C.-T. (1999). A Stage Approach For Industrial Development and Implementation - The Case of Taiwan's Computer Industry. *Technovation*, 19, 233-241.
Chebrough, H. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harverd Business School Press.
Cheng, T.-j. (1990). Political Regimes and Developmental Strategies: South Korea and Taiwan. In G. Gereffi & D. Wyman (Eds.), *Manufacturing Miracles* (pp. 139-78). Princeton, NJ: Princeton University Press.
Chinworth, M. W. (1992). *Inside Japan's Defense*. Washington: Brassey's.
Cooke, P., & Morgan, K. (1998). *The Associational Economy*. New York: Oxford University Press.
Culpepper, D. P., & Finegold , D. (2001). The German Skills Machine: Sustaining Comparative Advantage in a Global Economy. Oxford: Berghahn Books.
Dixit, A. (1997). Power of Incentives in Private vs. Public Organizations. *American Economic Review*, 87, 378-382.
Edquist, C. (1997). Systems of Innovation: Technologies, Institutions, and Organizations. London: Pinter.
Fields, K. (1995). *Enterprise and the State in Korea and Taiwan*. Ithaca: Cornell University Press.
Finegold , D., & Soskice, D. (1991). The Failure of Training in Britain: Analysis and Prescription. *Oxford Review of Economic Policy*, 4, 21-53.
Florida, R. L. (1995). Toward the Learning Region. *Futures*, 27, 527-536.
Franco, L. M., Bennett, S., & Kanfer, R. (2002). Health Sector Reform and Public Sector Health Worker Motivation: A Conceptual Framework. *Social Science & Medicine*, 54, 1255-1266.
Frey, B. S., & Jegen, R. (2001). Motivation Crowding Theory. *Journal of Economic Surveys*, 15, 589-611.
Fuller, D. B. (2005). The Changing Limits and the Limits of Change: the state, private firms,international industry and China in the evolution of Taiwan's electronics industry. *Journal of Conteporary China*, 14, 483-506.
— (2007). Globalization for Nation-Building: Taiwan's Industrial and Technology Policies for the High-Technology Sectors. *The Journal of Interdisciplinary Economics*, 18, 203-224.
— (Forthcoming). Industry Co-Evolution: A Comparison of Taiwan and North America's Electronics Contract Manufacturers. *Journal of Conteporary China*.

Fuller, D. B., Akinwande, A., & Sodini, C. G. (2003). Leading, Following or Cooked Goose: Successes and Failures in Taiwan's Electronics Industry. *Industry and Innovation*, 10, 179-196.

Gneezy, U., & Rustichini, A. (2000). A Fine is a Price. *Journal of Legal Studies*, 29, 1-18.

Gomory, R. E., & Baumol, J. W. (2000). *Global Trade and Conflicting National Interests*. Cambridge, Mass: The MIT Press.

Gompers, P., & Lerner, J. (1999). *The Venture Capital Cycle* Cambridge, Mass: The MIT Press.

Grossman, G., & Helpman, E. (1994). Endogenous Innovation in the Theory of Growth. *The Journal of Economic Perspectives*, 8, 23-44.

Hart, O., Shleifer, A., & Vishny, R., W. (1997). The Proper Scope Of Government: Theory And An Application To Prisons. *The Quarterly Journal of Economics*, 112, 1127-61.

Hayek, F. A. (1944). *The Road to Serfdom*. Chicago: University of Chicago Press.

Helpman, E. (2004). *The Mystery of Economic Growth*. Cambridge, Mass: Belknap-Harvard University Press.

Herrigel, G. (1994). Industry as a Form of Order: A Comparison of the Historical Development of the Machine Tool Industry in the United State and Germany. In J. R. Hollingsworth, P. Schmitter & W. Streeck (Eds.), *Governing Capitalist Economies: Performance and Control of Economic Sectors*. New York: Oxford University Press.

— (1996). *Industrial Constructions: the Sources of German Industrial Power*. Cambridge, UK: Cambridge University Press.

Hong, S. G. (1997). *The Political Economy of Industrial Policy in East Asia: The Semiconductor Industry in Taiwan and South Korea*. Cambridge, UK: Edward Elgar.

ITRI (2005). *Bandaoti Gongye Nianjian (The Yearbook of Semiconductor Industry)*. Hsinchu: ITRI-ITIS.

Jacob, B. A., & Levitt, S. D. (2003). Rotten Apples: An Investigation of the Prevalence and Predictors of Teacher Cheating. *Quarterly Journal of Economics*, 118, 843-878.

Johnson, C. A. (1982). *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*. Stanford CA: Stanford University Press.

Juha, K., & Sotarauta, M. (2002). Finnish City Reinvented: Tampere's Path from Industry to Knowledge Economy, *MIT-IPC-LIS Working Paper 02-002*.

Keeble, D., Lawson, C., Moore, B., & Wilkinson, F. (1999). Collective Learning Processes, Networking and Institutional Thickness' in the Cambridge Region. *Regional Studies*, 33, 319-332.

Kenney, M. (2000). *Understanding Silicon Valley: the Anatomy of an Entrepreneurial Region*. Stanford, CA: Stanford University Press.

Kenney, M., & Florida, R. L. (2004). *Locating Global Advantage: Industry Dynamics in the International Economy*. Stanford, CA: Stanford University Press.

Kim, L. (1997). *Imitation to Innovation: the Dynamics of Korea's Technological Learning*. Cambridge, Mass: Harvard Business School Press.

Koepp, R. (2002). *Clusters of Creativity: Enduring Lessons on Innovation and Entrepreneurship from Silicon Valley and Europe's Silicon Fen*. Chichester: Wiley.
Krugman, P., & Obstfeld, M. (1991). *International Economics: Theory and Policy.* New York: HarperCollins Publishers.
Le Grand, J. (1991). The Theory of Government Failure. *British Journal of Political Science*, 21, 423-442.
Lécuyer, C. (2005). *Making Silicon Valley: Innovation and the Growth of High Tech, 1930-1970*. Cambridge, Mass: The MIT Press.
Lester, R. K., & Piore, M. J. (2004). *Innovation -- The Missing Dimension*. Cambridge, Mass: Harvard University Press.
Levy, J. D. (1999). *Tocqueville's Revenge: State, Society, and Economy in Contemporary France*. Cambridge, MA: Harvard University Press.
Locke, R. M. (1995). *Remaking the Italian Economy*. Ithaca: Cornell University Press.
Lundvall, B.-Å. (1992). National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. London: Pinter Publishers.
Mathews, J. A. (2002). The Origins and Dynamics of Taiwan's R&D Consortia. *Research Policy*, 31, 633-651.
Mathews, J. A., & Cho, D.-S. (2000). *Tiger Technologies: The Creation of a Semiconductor Industry in East Asia*. Cambridge, UK: Cambridge University Press.
Meany, C. S. (1994). State Policy and the Development of Taiwan's Semiconductors Industry. In J. D. Aberbach, D. Dollar & K. L. Sokoloff (Eds.), *The Role of the State in Taiwan's Development* (pp. 170-192). Armonk, N.Y.: M.E. Sharpe.
Megginson, W. L. (2005). *The Financial Economics of Privatization*. Oxford: Oxford University Press.
Morgan, K. (1997). The Learning Region: Institutions, Innovation and Regional Renewal. *Regional Studies*, 31, 491-503.
Munari, F., & Sobrero, M. (2005). The Effects of Privatization on R&D Investments and Productivity: An Empirical Analysis of European Firms, *FEEM Working Paper No. 64. 2002*.
Nelson, R. R. (1993). National Innovation Systems: a Comparative Analysis. New York: Oxford University Press.
Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, Mass.: Belknap Press of Harvard University Press.
Niskanen, W. A. (1971). *Bureaucracy and Representative Government*. Chicago: Aldine Atherton.
O'Hagan, J. W. (2000). The Economy of Ireland. Dublin: Gill & Macmillan.
O'Riain, S. (1997). An Offshore Silicon Valley? *Competition and Change*, 2, 175-212.
— (2000). The Flexible Development State: Globalization, Information Technology, and the "Celtic Tiger". *Politics and Society*, 28, 157-193.
— (2004). *The Politics of High Tech Growth: Developmental Network States in the Global Economy*. Cambridge, UK: Cambridge University Press.
Olson, M. (1965). *The Logic of Collective Action*. Cambridge, MA: Harvard University Press.

Ornston, D. (2006). Reorganising Adjustment: Finland's Emergence as a High Technology Leader. *West European Politics*, 29, 784 - 801.

Ornston, D., & Rehn, O. (2006). An Old Consensus in the 'New' Economy? Institutional Adaptation, Technological Innovation, and Economic Restructuring in Finland. In J. Zysman & A. Newman (Eds.), *How Revolutionary was the Digital Revolution?* Palo Alto: Stanford.

Park, P. H. (2000). A Reflection on the East Asian Developmental Model: Comparison of the South Korea and Taiwanese Experiences. In E. Richter (Ed.), *The East Asian Development Model: Economic Growth Institutional Failure and the Aftermath of the Crisis* (pp. 141-168). London: Macmillan Press.

Piore, M. J., & Sabel, C. F. (1984). *The Second Industrial Divide: Possibilities for Prosperity*. New York: Basic Books.

Porter, M. E. (1990). *The Competitive Advantage of Nations*. New York: Free Press.

— (2000). Location, Competition and Economic Development: Local Clusters in a Global Economy. *Economic Development Quarterly*, 14, 15-34.

Regini, M. (1999). Between De-regulation and Social Pacts: The Responses of European Economies to Globalisation. *Politics & Society*, 28, 5- 33.

Romer, M. P. (1994). The Origins of Endogenous Growth. *The Journal of Economic Perspectives*, 8, 3-22.

Rosenberg, N., & Birdzell, L. E. J. (1986). *How the West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books.

Salter, A. J., & Martin, B. R. (2001). The Economic Benefits of Publicly Funded Basic Research: A Critical Review. *Research Policy*, 30, 509-532.

Samuels, R., J (1994). *Rich Nation Strong Army*. Ithaca: Cornell University Press.

Saxenian, A. (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Saxenian, A., & Hsu, J.-Y. (2001). The Silicon Valley-Hsinchu Connection: Technical Communities and Industrial Upgrading. *Industrial and Corporate Change*, 10, 893-920.

Sheshinski, E., & Lopez-Calva, L. (1999). Privatization and its Benefits: Theory and Evidence., *HIID Development Discussion Paper 698 - Harvard University*. Cambridge, MA.

Shleifer, A. (1998). State versus Private Ownership. *The Journal of Economic Perspectives,*, 12, 133-150.

Sturgeon, J. T. (2000). Turnkey Production Networks: The Organizational Delinking of Production from Innovation. In U. Jurgens (Ed.), *New Product Development and Production Networks* (pp. 67-84). New York: Springer.

— (2002). Modular Production Networks: A New American Model of Industrial Organization. *Industrial and Corporate Change*, 11, 451-496.

Teubal, M., Foray, D., Justman, M., & Zuscovitch, E. (1996). Technological Infrastructure Policy: An International Perspective. Boston: Kluwer Academic Publishers.

Titmuss, R. M. (1970). *The Gift Relationship: From Human Blood to Social Policy*. London: G. Allen and Unwin.

Trajtenberg, M. (2001). Innovation in Israel 1968-1997: A Comparative Analysis Using Patent Data. *Research Policy*, 30, 363-389.

Traxler, F., & Unger, B., , (1994). Governance, Economic Restructuring and International Competitiveness. *Journal of Economic Issues*, 28, 1-23.
Tullock, G. (1965). *The Politics of Bureaucracy*. Washington D.C.: Public Affairs Press.
Vickers, J., & Yarrow, G. (1991). Economic Perspectives on Privatization. *Journal of Economic Perspectives*, 5, 111-132.
Wade, R. (1990). *Governing the Market: Economic Theory and the Role of the Government in the East Asian Industrialization*. Princeton: Princeton University Press.
Whitley, R. (1999). *Divergent Capitalisms: the Social Structuring and Change of Business Systems*. Oxford; New York: Oxford University Press.
Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics,*, 22, 233-261.
— (1983). *Markets and Hierarchies : Analysis and Antitrust Implications* New York: The Free Press
Wolf, C. J. (1979). A Theory of Nonmarket Failure. *Journal of Law and Economics*, 22, 107-39.
Woo-Cumings, M. (1991). *Race to the Swift: State and Finance in Korean Industrialization*. New York: Columbia University Press.
— (1999). The Developmental State. Ithaca, N.Y.: Cornell University Press.
Wright, B. E. (2007). Public Service Motivation: Does Mission Matter? *Public Administration Review*, 67, 54-64.
Yahalomi, L. (1991). *Promoting International Cooperation as a Strategy for Economic Development: A Case Analysis of Israeli and U.S. High-Technology Partnerships (United States)*. Unpublished Ph.D., University of Pennsylvania.
Ynet (2004a). The Government has Approved the New R&D Law, *Ynet Economy*.
— (2004b). Olmert: It would be Difficult to Stop the Escape of R&D Projects, *Ynet Economy*.

Working and Position Papers

1) Lach, S., "Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel", Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

2) Trajtenberg, M., "R&D Policy in Israel: An Overview and Reassessment", Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

3) Lichtenberg, F. R., "Sources of U.S. Longevity Increase, 1960-1997", Science, Technology and the Economy Program (STE) - Working Papers Series, November 2000.

4) Peled, D., "Defense R&D and Economic Growth in Israel: A Research Agenda", Science, Technology and the Economy Program (STE) - Working Papers Series, March 2001.

5) Trajtenberg, M., "Innovation in Israel 1968-1997: A Comparative Analysis using Patent Data", Science, Technology and the Economy Program (STE) - Working Papers Series, 2001.

6) Silipo, D.B. and Weiss, A., "Cooperation and Competition in R&D with Uncertainty & Spillovers", Science, Technology and the Economy Program (STE) - Working Papers Series, August 2001.

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Incubators in Israel", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-26-2005, March 2005.

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Economy Program (STE) Working Papers Series STE-WP-33-2006, May 2006.

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37) Schiff, Gil, " Information and Communication Technology (ICT) Investments in Israel", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-37-2007, March 2007.

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39) Antonelli Cristiano and Teubal Morris, "Knowledge-Intensive Property rights and the evolution of venture Capitalism", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-39-2007, September 2007.

40) Breznits, Dan and Zehavi, Amos, " The Limits of Capital: Transcending the Public Financer – Private Producer Split in R&D". ", Science, Technology and the Economy Program (STE) Working Papers Series STE-WP-40-2007, October 2007.

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