# A Theory of Innovation:
## Property Rights and Markets

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ABSTRACT

The aim of this paper is to specify a theory of innovation sufficiently general in scope to explain why market capitalist economies achieved a higher rate of innovation than Soviet-type command economies, and why market transition causes a shift to a higher level of innovation. Based on five propositions, our simple innovation model explains the interaction between market allocation, political involvement and innovation activity, and outcomes at the systems-level. For our empirical application, we focus on China's transition economy, which offers the ideal range of institutional environments to examine the causal effect of the repertoire of mechanisms in market forces on innovation by firms and entrepreneurs. The World Bank's Investment Climate Survey conducted in 23 Chinese cities in 2002 and 2003 provides firm-level evidence supporting our theory and derived hypotheses. In testing our theory of innovation, our results confirm that it is not simply competition, but the level of marketization as a distinct concept that drives both innovation efforts and the effectiveness of R&D activities.

Markets and Innovation: A Theory

In capitalist economies innovation powers the creative destruction driving the growth of profit-making opportunities. The innovative process—Schumpeter's (1942) "perennial gale of creative destruction"—is the recognition of opportunities for profitable change and the pursuit of those opportunities all the way through until they are put into business practice. For Schumpeter, the independent entrepreneur—distinct from the capitalist and businessman—is the purveyor of innovations. For Marx, in contrast, innovation is a systemic feature of the underlying competitive dynamics of market capitalism. This view of innovation as an outgrowth of the ferocity of competitive pressures on capitalists has attracted new attention in the research on innovation (Baumol 2002). Insofar as innovation is a social production involving cooperation and competition within a larger institutional structure, incentives are matters not only of individual-level motives and decisions, but also of that institutional framework (North 1990; Greif 2006). The focal question of research is not what optimizes the entrepreneurial behavior and incentive to innovate of individual actors, but why competitive markets matter in explaining innovation as a routine activity of firms.

Our approach differs from the endogenous growth literature explaining Schumpeterian creative destruction through the innovative activity of individual entrepreneurs and firms (Segerstrom et al. 1990; Grossman and Helpman 1991; Aghion and Howitt 1992; Stein 1997; and Aghion et al. 2001). The present paper is broadly complementary with this literature in a common focus on incentives in competitive markets, but our model examines the effect of markets at the systems-level. We maintain a theory of innovation needs to explain variability in innovation across dissimilar economic orders, not just its rate in capitalist economies. Two forms of modern economies—market capitalism and state socialism—competed during the Cold War in innovation projects not only in aerospace, nuclear power and armament industries, but in industrial development and economic might. The same theoretical propositions must explain why market capitalist economies achieved a higher rate of innovation, why Soviet-type command economies were prone to innovation failures, and why transition to a market economy causes a shift to a higher level of innovation. The characteristic feature of modern command economies is the reliance on state power to allocate resources—labor and capital—by the administrative fiat of government bureaucrats and party officials. Such non-market administrative allocation of labor and capital requires effective constraints on independent innovative activity by economic actors outside of the planned economy.

Soviet-type command economies were generally successful in promoting economic growth by relying on non-market bureaucratic allocation of resources (Olson 2000). Although in centrally planned economies inventions and technological expertise were plentiful, as reflected in the spectacular early successes of the Soviet space program in its launching of Sputnik and the first manned space capsules, the communist-era planned economies stagnated as the shift from agriculture to heavy industry ran its course and the extensive growth that had accompanied that shift slowed. By contrast, competitive pressures in advanced capitalist economies fueled an innovation "arms race" between rival firms in high technology industries (Baumol 1993).

While our aim is to specify a theory of innovation general in scope, our focal interest is to explain the rise of innovations caused by the shift to market allocation in post-socialist transitional economies. We focus on the emergence of competitive markets to examine the effect of variation in marketization level and state intervention on innovation. Hypotheses derived from our theory underscore the capacity of private enterprise in the transitional economy to innovate, explain innovation as outgrowth of the competitive pressures on firms in the most marketized regions and sectors of the economy, and highlight the role of networks in regional clustering of innovation linking universities and research institutes with firms. Such an approach is useful not only for the analysis of transitional economies, but it also provides a novel approach to track the influence that various types of capitalist economies may have on national innovativeness.

Our empirical application focuses on the rise of routine innovation in China's transition to a dynamic capitalism. It is in the transitional economy where one finds a wide-range in variability in the extent and scope of competitive markets. This offers the ideal context to examine the causal effect of the repertoire of mechanisms in market forces on innovation by firms and entrepreneurs. The World Bank's Investment Climate Survey conducted in 23 Chinese cities in 2002 and 2003 provides firm-level evidence supporting our theory and derived hypotheses on the interplay between marketization levels and rising innovativeness. In testing our theory of innovation, we confirm the shift to a dynamic capitalism in China in which innovation has become a routine activity of firms and maintain that the primary cause of China's shift to emphasis on innovation as a source of economic growth is the emergence of a competitive market economy.

## A THEORY OF INNOVATION

We proffer general propositions that specify mechanisms explaining the propensity to innovate (I-III), and then we lay out propositions (IV-V) that explain the increasing rate of innovations arising from marketization.

### *The Incentive Proposition*

In capitalist economies, the rules of the game of private property rights and decentralized markets provide powerful incentives for economic actors to innovate. Whether innovative activity is for the sake of the fruits of success, or for success itself, in price-making markets rewards are based on the competitive sorting and matching of quality and price. It is thus the restoration of consumer sovereignty in the process of market transition in post-communist economies, which activates incentives to innovate. For illustration, Figure 1 uses a "value map". A set of indifference curves signaling a range of price-quality combinations yielding the same utility level within each curve, with $U_1(x_1/p_1) < U_2(x_2/p_2) < U_3(x_3/p_3)$. Evidently, firm D's price-quality offer yields the highest utility level, so that customers will prefer D's price-quality combination over any other combination offered by firms A, B and C. Subsequently A, B, and C have incentives to innovate by either lowering costs or improving quality. In sum, our *incentive proposition* specifies:

> *I. Markets offer incentives to innovate insofar as rewards for performance depend on a match of quality and price or a match of cost and price.*

FIGURE 1 ABOUT HERE

***The Opportunity Proposition***

If an innovation is something that has never been carried out before, then the entrepreneur-as-innovator is the person who pursues opportunities that others forgo. Suppose firms in a market sector, say cell-phones, face perfect competition so that the equilibrium prices of products provide only razor-thin margins. An entrepreneurial action in this setting would be to innovate by coming up with a new product based on the hunch that its novel features will break out of the standard mold and fetch a higher price. Our entrepreneur has accordingly purposively sought an opportunity that other firms in the industry have either implicitly forgone or have assessed as too costly to pursue given the high-level of *ex ante* uncertainties of a comparable innovation. Hence, in this view the opportunity cost for forgoing investments in innovative activity is the *hidden cost* of firms pursuing the established business patterns and practices, which in our example locks them into a stable price structure. The market mechanism offers economic actors a means to assess the potential opportunities from an innovation for profit-making as well as the opportunity costs for failing to invest in innovation projects.

Consider the price-quality combination ($P_N$, $Q_N$) in Figure 1. Evidently producer N would not be in a viable position in the presence of producer D. But producer N may through product innovation and sufficient product differentiation reach new latent customer groups, here illustrated by indifference curve $U_n$. A firm's ability to realize ($P_N$, $Q_N$) rests on the identification of new consumer preferences which have not been served by the existing product portfolio. The opportunity proposition hence states:

> II. *The market mechanism provides opportunities for entrepreneurs and firms to identify new markets and prospects for profit-making.*

***The Competition Proposition***

Capitalism as an economic system provides powerful incentives for innovation through the ferocity of competitive pressures on capitalists. Innovation is a matter of life and death for rival firms facing fierce competition. In this arms race, innovation replaces price as the prime competitive weapon. Competitive market pressure in capitalist economies causes “routinization of innovation that transforms it from a sequence of fortuitous occurrences into a businesslike activity that can be relied upon and is reasonably predictable” (Baumol 2002:55). It is the routinization of innovation, Baumol argues, that is the source of capitalist economies’ sustained gains in productivity.

The competition effect can be conveniently illustrated by incorporating a supplier’s cost-quality curve into the value map (Figure 2). The cost-quality curve—a collection of lowest production costs for a given product—essentially signals the technological frontier and is assumed to be convex due to increasing marginal costs of quality improvements. In Figure 2, producer D’s cost-quality curve is $C_D$ where D enjoys a monopolistic status by $P_D$ - $P_{D'}$ (Connelly 2003: 910). If other producers of the same cost-quality schedule $C_D$ enter the market and compete with firm D, the price will gradually be driven down to $P_{D'}$. To escape the competitive pricing situation, producers have to innovate. By means of cost-saving innovations, for instance, firm E may be able to lower the cost-quality curve to $C_E$. Assuming effective patent protection, E will initially enjoy the gap between price $P_{D'}$ and its costs until rival firms discover a similar or even better technology. Eventually, a new price-quality equilibrium on $C_E$ will be reached. Alternatively, E can try to escape intense competition by choosing a different price-quality combination on the existing technological frontier, which may attract a new group of customers. This type of product innovation aims at the detection of market niches – for instance a move from D' to E'. In sum,

III. *The greater the market competition, the more firms are compelled to innovate or die.*

FIGURE 2 ABOUT HERE

***The Power Proposition***

In communist-era command economies, the state assumed monopoly power over the control and allocation of resources. All productive assets from farmland to factories were owned and managed by the state, which sets prices by administrative fiat to control the allocation of resources. Clearly, under the central plan government bureaucrats and party officials maintained an overwhelming advantage in power over economic actors.

The emergence and growth of a decentralized market economy necessarily involves reducing the scope of state controls over resource allocation, hence (according to market transition theory) diminishing the redistributive power of political actors, while economic actors—firms and entrepreneurs—gain power insofar as market transactions are based on voluntary agreement between buyers and sellers (Nee 1989). Moreover, the shift to market allocation causes changes in reward structure that offer incentives and opportunities for economic actors to engage in productivity-enhancing innovative activity.

*IV. Marketization diminishes the relative power of political actors and empowers economic actors—firms and entrepreneurs.*

Assume that a firm can improve the given profit situation by generating additional income from either economic or political sources:

$$T_j = C\pi_j + P\phi_j \tag{1}$$

where $T_j$ is firm *j*'s total payoff, *C* payoff from competitive advantage through innovation formalized in figures 1 and 2, *P* payoff from political sources, $\pi_j$ firm *j*'s probability to realize economic payoff through innovation, and finally $\phi_j$ firm *j*'s probability to generate income streams from political sources. In this model, a firm's expected payoff $T_j$ is determined as a linear combination between structural parameters of the market (i.e., *C* and *P*) and firm-level parameters (i.e., $\pi_j$ and $\phi_j$). For simplification we assume only one period and assume that failed efforts to pursue either innovation or political advantages yield no pay-off.

Further, the impact of the market mechanism on potential innovation gains and political rents implies

$$\frac{\partial C}{\partial m} > 0 \text{ and } \frac{\partial P}{\partial m} < 0 \tag{2}$$

where *m* is the overall degree of marketization, defined as an encompassing measure of market power measured through the role of private property rights, market allocation in product and factor markets and fair and unbiased state regulation. In other words, the firm's income generation moves away from political funds *P* to income generated by innovative activities *C* as market transition proceeds.

We also reasonably assume that firm's probability to generate income from innovation (i.e., $\pi_j$) or political funds (i.e., $\phi_j$) is a positive function of investment (including capital, time and efforts) in innovation $I_{ji}$ or investment in politics $I_{jp}$ by firm *j*:

$$\frac{\partial \pi_j}{\partial I_{ji}} > 0 \text{ and } \frac{\partial \phi_j}{\partial I_{jp}} > 0 \tag{3}$$

where $I_{ji}$ and $I_{jp}$ are constrained by a total investment budget $B_j$:

$$I_{ji} + I_{jp} = B_j \tag{4}$$

***The Politics Proposition***

Whether through informal or formal arrangements, the reward structure for political actors is skewed to encourage the pursuit of innovative rent-seeking rather than productivity enhancing innovations (Baumol 1993). Under the central plan, the incentive structure for enterprise managers discourages innovation. Managers are assigned annual production quotas. If they increase productivity through innovation, they risk increasing next year's production quota, but with no tangible increase in private gains for the manager. Political actors have an "encompassing interest" in economic development not only to maximize the political-military power of rulers (Olson 2000), but also for private wealth-maximization (Szelenyi 1983).  Especially during the early phases of economic reform, political actors have a time-limited redistributive interest to control and direct private wealth accumulation by assigning property rights to themselves and their cronies (Walder 2003). Rent-seeking in government-controlled political markets is often the more lucrative form of innovation.

Further, innovations entail intrinsic uncertainties, making the screening of innovation projects critically important given costliness of research and development. Government bureaucracies lack the commitment to hard budget constraints, and hence the capacity for effective *ex post* screening required for divesting from innovation projects that are not viable (Qian and Xu 1998). For this reason, bureaucrats tend to rely on *ex ante* screening, which result in rejecting promising projects and funding fewer numbers of projects, especially those involving higher uncertainties and less research in the initial stages of development. Bureaucracies not only make mistakes by rejecting promising projects, but they are prone to delays in bringing innovation projects to completion. Command economies were particularly weak in coordinating innovations in industries involving high uncertainties *ex ante*, where weak prior knowledge imposed insurmountable challenges for bureaucrats to select promising projects.

In discussing the previous proposition, we assumed for convenience fixed firm-level probabilities of achieving innovation or political advantages, $\pi_j$ and $\phi_j$, given an investment allocation between innovation $I_i$ and politics $I_p$. This simplification, however, overlooks the critical role incentive structures play in shaping economic activities and subsequent effectiveness for realizing innovation. It is particularly the difference between profit-maximizing private actors, and government actors, who typically pursue multiple goals, which deserves attention. Hence, firms will choose different effort levels to pursue either competitive advantages from innovation or political advantages.

*V. When political actors remain empowered to allocate resources in firms there will be fewer innovations and more delays in bringing innovation projects to new products*

Briefly, involvement of political actors dilutes both incentives and opportunities. Hence, the *politics proposition* implies that due to varying levels of competence the marginal increase in the probability of successful innovation by a unit increase in investment (i.e., $\frac{\partial \pi}{\partial I_i}$) will depend on the extent of political involvement in the firm. Such direct control and political involvement usually builds on the state's ownership shares, which allow direct and relatively cost-efficient interference in firm's activities (Jones 1985; Sappington and Stiglitz 1987; Shleifer and Vishny 1994). We therefore introduce *a* as the proportion of private property rights for the formalization of the *politics proposition*:

$$\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right) > 0 \tag{5}$$

Equation (3) specifies a positive effect of investment to innovation on the probability of successful innovation (i.e., $\frac{\partial \pi}{\partial I_i} > 0$ ). The *politics proposition* (equation 5) further implies that this investment effect will be the stronger the larger the private ownership share *a* and the less vulnerable the firm to political intervention by government. In addition, the *politics proposition* also implies that the marginal increase in the probability of achieving political advantage by a unit increase in investment to politics (i.e., $\frac{\partial \phi}{\partial I_p}\left[= \frac{\partial \phi}{-\partial I_i}\right]$) will decrease with the extent of private property rights *a*:

$$\frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_p}\right) < 0 \text{ or } \frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_i}\right) > 0 \quad (5)'$$

This proposition builds on the inherently different incentive structures between public and private firms. Essentially we hold that gains from innovative efforts or positive effects of investment in innovation are greater in private firms than in public enterprise.

## DERIVED HYPOTHESES

Given the payoff structure in equations (1) to (5)', a firm will choose an optimal allocation of the budget B between two investments $I_i$ and $I_p$ so that it maximizes the expected payoff *T*:

$$\frac{\partial T}{\partial I_i} = 0 \text{ and } \frac{\partial^2 T}{\partial I_i^{\,2}} < 0 \quad (6)$$

Let $I_i^*$ denote $I_i$ satisfying equation (6). In other words, $I_i^*$ is the optimal level of investment to innovation, for a given level of marketization (*m)* and a given proportion of private property rights (*a)*. Then, we can deduce

$$\frac{\partial I_i^*}{\partial m} > 0 \quad (7)$$

See Appendix A for proof. Hence, for any firm, the optimal investment to innovation increases with marketization. Accordingly, the probability of successful innovation also increases with marketization for *any* firm:

$$\frac{\partial \pi^*}{\partial m} > 0 \quad (8)$$

See Appendix A for details. Hence we can specify:

*Hypothesis 1: Investment in innovation, or successful innovation as its consequence, increases as markets develop.*

It is the growth of wealth-maximizing opportunities outside of the state-directed redistributive sector through marketization that triggers a shift towards innovation as a routine activity of rival firms, regardless of ownership form.

In this process, given budget limitations and risky investment outcomes, firms will increasingly rely on regional technical and research cooperation. The idea that geographical concentration generates positive externalities dates back to Marshall (1920). Causal theoretical explanations of positive externalities either build on the assumed information exchange and knowledge spillovers due to facilitated conditions for cooperation and backward and forward linkages (Saxenian 2006) or simply refer to intensified local competition, which motivates innovation activities (Porter 1990). Related to Hypothesis 1 we specify:

Hypothesis 2: *R&D networks increasingly help innovation as markets develop.*

Hypotheses 1 and 2 are general properties independent of the firm's ownership structure. However, from our politics proposition (i.e., equation (5)) we can derive that firms under tight political control or state involvement will be less innovative than independent firms. Formally,

$$\frac{\partial \pi^*}{\partial a} > 0 \tag{9}$$

The higher the proportion of private property rights in a firm, the higher a firm's probability to successfully realize innovation projects (see Appendix B for its proof). Thus

*Hypothesis 3: State-owned and collective owned firms show lower innovation levels than privatized firms or private de-novo firms.*

Equation (9) implies that state-owned enterprises will not over-invest in innovation so that its probability of innovation $\pi^*$ can keep up with that of private firms. The reason can be revealed by further examination of equation (6). First, in order to satisfy the requirement of $\frac{\partial^2 T}{\partial I_i^{\,2}} < 0$, we will reasonably assume concavity of both $\pi$ and $\phi$, that is we expect a *decreasing marginal improvement* in the probability of successful innovation / allocation of political funds with increasing investments in innovation projects / political efforts:

$$\frac{\partial^2 \pi}{\partial I_i^{\,2}} < 0 \text{ and } \frac{\partial^2 \phi}{\partial I_p^{\,2}}\left(=\frac{\partial^2 \phi}{\partial I_i^{\,2}}\right) < 0 \tag{10}$$

Naturally, this concavity assumption also implies an *increasing marginal degeneration* when investments are reduced.

Second, $\frac{\partial T}{\partial I_i} = 0$ in equation (6) or equation (A1) is equivalent to

$$\frac{C(m)}{P(m)} = \frac{-\partial\phi / \partial I_i}{\partial\pi / \partial I_i} \tag{6'}$$

Hence, with proceeding marketization income from innovative efforts $C(m)$ increase relative to income streams from political funds $P(m)$. As a consequence, a firm will therefore rebalance its investment portfolio in favor of innovation projects, until $\left(=\frac{C(m)}{P(m)}\right)$ equals the ratio between the marginal decrease in the probability of achieving political funds $\left(= -\partial\phi / \partial I_i\right)$ and the marginal increase in the probability of successful innovation $\left(= \partial\pi / \partial I_i\right)$. When $\dfrac{-\partial\phi / \partial I_i}{\partial\pi / \partial I_i}$ is smaller than $\dfrac{C(m)}{P(m)}$, the firm is under-investing in innovation and would benefit from a further reduction of investments in political rents. If in contrast $\dfrac{-\partial\phi / \partial I_i}{\partial\pi / \partial I_i}$ is larger than $\dfrac{C(m)}{P(m)}$, the firm is over-investing in innovation as additional payoffs from innovation projects no longer cover forgone income streams that could have been secured from political sources.

For a given investment $I_i$, the *politics proposition* (or equations (5) and (5)') implies that the marginal increase in the probability of successful innovation ($\partial\pi / \partial I_i$) for a government-controlled firm is smaller than that of a private firm while its marginal decrease in the probability of achieving political advantages ($-\partial\phi / \partial I_i$) is larger that that of a private firm. As a result, $\dfrac{-\partial\phi / \partial I_i}{\partial\pi / \partial I_i}$ is larger for a government-controlled firm than for a private firm. For government-controlled firms, the probability of achieving political advantage decreases faster than that of private firms, relative to the probability that successful innovation increases. As a consequence, given a certain level of marketization, if the government-controlled firm were to invest the same amount as the private firm, the government firm would be over-investing in innovation. The lower levels of innovation for government-controlled firms are therefore not only rooted in less effective innovative activity, but also attributable to a smaller volume of investment.

Our last hypothesis concerns how the positive effect of private property rights on innovation or $\frac{\partial \pi^*}{\partial a} > 0$ in equation (9) changes over the course of marketization. We deduce that this positive effect of private property rights is increasing with marketization when our *politics proposition* is qualified with two presumable conditions: [1] political involvement in a firm helps effective politics to the same extent as it hinders effective innovation[1]; [2] the degree of *decreasing marginal improvement* in the probability of successful innovation is larger, when political involvement is stronger. Formally, we deduce

$$\frac{\partial}{\partial m}\left(\frac{\partial \pi^*}{\partial a}\right) > 0 \tag{11}$$

when [1] $\frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_p}\right) = -\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right)$; and [2] $\frac{\partial}{\partial a}\left|\frac{\partial^2 \pi}{\partial {I_i}^2}\right| < 0$. See appendix C for proof. The first condition assumes the equal amount of effects of political involvement (or private property rights) between innovation and politics (or between (5) and (5)') while the second condition adds a nuanced effect of political involvement on innovation.

*Hypothesis 4: With rising marketization, political involvement (as typically present in state-owned firms) will have an increasingly negative impact on a firm’s innovativeness.*

[1] “Effective” politics (or innovation) is the extent of marginal increase in the probability of achieving political advantages (or successful innovation) by a unit investment in politics (or innovation), as is formalized in equation (5)' or (5).

Qualified with the above two presumable conditions, *hypothesis 4* extends *hypothesis 3* and implies that, with shrinking redistributive sectors and growing impact of market forces, continuing involvement of political actors discourages to draw investments back from realized political advantages (the first condition), further dilutes innovative effectiveness (the second condition), and eventually prevents from fully investing to superior profit-making opportunities that markets provide through innovation.

## THE TRANSITION TO DYNAMIC CAPITALISM IN CHINA

China embarked on a "dual-track" approach to economic reform, which emphasized the diversification of allocation mechanisms and property forms over shock-therapy replacement of socialist economic principles (Li 1997; Lin et al 1998; Lau et al 2000). Although central planning and planned prices were not immediately abolished, a "market-track" was introduced at the start of economic reform in 1978 to complement the "plan-track," which was then incrementally phased out in the 1990s. Under the dual-track system, producers were granted the right to market their surplus production on newly established free markets after fulfilling compulsory delivery obligations. Originally, the dual-track system applied mainly to rural households operating under the agricultural household responsibility system. But by the mid-1980s, inspired by the successes of rural reform, the implementation of a "contract responsibility system" allowed urban industrial state-owned enterprises to freely market their surplus (Groves et al. 1994). The strategy of a gradual cutback of mandatory production quotas allowed a smooth process of "growing out of the plan" (Naughton 1995). By 1990, with few exceptions, market allocation was the dominant mechanism in China. The proportion of agricultural products traded under plan prices fell from 94% to 37% between 1978 and 1985; for industrial products the share of plan price transactions fell from 100% before reform to 45% in 1990; and in retail sales, the percentage of market sales even reached 70% by 1990 (Lau et al 2000).

Once free markets operated alongside planned production, new non-state competitors responded to business and profit opportunities outside the state-sector. Market niches, particularly in light industries notoriously neglected under central planning, attracted entrepreneurial talents. Regulatory market entry barriers were gradually lowered and only few areas, such as finance, telecommunications, tobacco, selected heavy industries and high-technology sectors (the latter until 1999), remained off-limits for private enterprise. Competition further intensified in the 1990s when, after a decade of management and organizational reforms, reformers initiated wide-ranging ownership reforms of state-owned enterprises (SOE). During this period, small and medium-size SOEs were fully privatized through auctions and management buy-outs and key firms in strategic industries were corporatized, and as public corporations many were listed on the domestic stock markets. The corporatization strategy was aimed at limiting the state's influence in the firm's operational decisions. However, with the state as major and majority shareholder of listed firms, frequent political intervention both through corporate governance bodies and informal networks persisted (Nee, Opper, and Wong 2007).

Until the mid-1980s, new market entrants were mainly rural collectives (township and village enterprises) and foreign firms. Following deepening reforms and increasing legal acknowledgement and protection, the private enterprise economy rapidly developed into the main growth engine of China's economy. Driven by profit incentives and hard budget constraints, the private enterprise sector was quick to respond to consumer demand and to detect untapped market niches in the expanding consumer and light industrial sector. As market transition progressed in the 1980s, the founding of millions of new enterprises gave rise to a diversity of new organizational and ownership forms in China's transitional economy. Confronted with fierce market competition from these new start-ups, the contribution of state-owned enterprises decreased from 78% to only 35% of gross industrial production between 1979 and 2005 (Statistical Bureau). Start-up private firms spear-headed the development of China's new technology-based industries in electronic and computer appliances. For example, in computer production the total market share of state-owned enterprises is only 0.1%. In contrast, the private Lenovo Group, China's largest computer manufacturer, holds almost 35% of the market. With an unprecedented founding rate of non-state firms, China developed into one of the most competitive market economies, with comparatively low market concentration ratios. The five largest machinery builders in the US have a combined market share of 69%, in Japan the top five hold 42%, whereas the top five manufacturers in China have only 20% of the market (OECD 2002:403).

Between 1999 and 2003, national R&D-expenditures increased from 0.8% to 1.3% of GDP. The Ministry of Science and Technology projects that spending on R&D will increase to 2.5% of GDP by 2020 (Chong 2006a). For comparison, current R&D expenditures are 2.6% of GDP in the US, 1.9% in the UK, and 1.6% in Australia (National Bureau of Statistics/Ministry of Science and Technology 2005). In parallel, the locus of research shifted from government institutions to the firm. With more than 60%

of R&D funds provided by firms, the expenditure structure resembles that of advanced market capitalist economies.[2]

The rapid increase of R&D funds combined with structural reorientation to firm-based research facilitated the emergence of markets for innovation. This is seen in the development of inter-firm technological collaboration and regional innovation clusters as strategies to promote innovation. Not surprisingly, Silicon Valley has served as a model. Government-sponsored municipal technology and high-tech parks are key elements of China's emerging national innovation system. Fifty-three Chinese cities have established technology parks funded by the Torch Program, the key program of China's Science & Technology policy (Hu 2007). Industrial policy encourages cooperation between firms and government institutions and university institutes were explicitly supported. Hence, more recent initiatives have sought to speed up the founding of regional technology and science parks at China's institutions of higher education, bringing the total number of university-based science parks to 80 by 2010 (Chong 2006b).

A close link between marketization and growth investments in R&D can be readily inferred from bivariate scatterplots of provincial-level data from 1997(1998) to 2003 (Figure 3). The scatterplots show that R&D-activities increase considerably after reaching a certain threshold of marketization. A close relation between marketization and regional clustering in the capacity to innovate can also be inferred from a cross-provincial comparison of patenting activities (figure 4). Beijing, Shanghai, Guangzhou, Tianjin and Zhejiang, five of the eight municipalities with the most marketized local economies have emerged as national leaders in research productivity.

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[2] In the US, 63% of R&D funds are firm-based; in Germany 66% and in Switzerland 69% (National Bureau of Statistics/Ministry of Science and Technology 2005).

Insert figure 3 and 4

Despite the close link between competitive markets and rising innovativeness, firms with close government ties appear to fall increasingly behind in innovation output. A comparison of bivariate scatter-plots of state-owned industrial production and rate of innovation supports our *politics proposition*. At lower levels of marketization, all firms perform poorly in terms of innovativeness independent of state-ownership. In line with propositions 1-3, weak incentives, opportunities and weak competitive pressure are the probable causes. By contrast, at higher levels of marketization, innovativeness differs clearly across ownership forms. On average, less marketized regions dominated by state-owned enterprises have lower rates of innovation than regions where a robust private enterprise economy have gained ascendancy.  This correlation is consistent with our *politics proposition* and hypothesis 4, which predicts a growing gap in innovativeness between public and private ownership forms.

Insert figure 5

## DATA AND METHOD

To analyze the causal relationship between marketization and innovativeness at the firm level, we use data from the World Bank Investment Climate Surveys.  The 2002 survey includes firms in five middle-size and large Chinese cities (N=1,548) and the 2003 survey includes firms in 18 middle-size and large cities (N=2,400).[3] Both surveys share a set of core questions on innovation activities and firm characteristics. Participating firms were randomly selected in each city. The industry mix comprises both labor-intensive, traditional sectors and the new, more technology-intensive sectors across a broad spectrum of different production technologies and levels of competition (see table 1 for industry distribution). Importantly, the World Bank data enables comparative analysis of a diverse sample of organizational and ownership forms—private, hybrid and state-owned enterprises.[4]

Insert table 1 about here

In order to examine the effect of different levels of marketization on innovativeness, we employ a provincial-level marketization index designed by Fan et al. (2003) to construct three subsamples based on three-year averages of innovation activities. The index is a widely-accepted composite measure based on five sub-indices, covering government-business relations, development of non-state sectors, development of the commodity market, development of factor markets, and development of market intermediary institutions and legal environment. Table 2 shows the distribution of the survey cities across three marketization clusters.

Insert table 2 about here

[3] The five cities in 2002 survey are Beijing, Chengdu, Guangzhou, Shanghai, and Tianjin. Each city has about 300 firms in data. Cities in 2003 survey have 100 to 150 firms in our data. The complete list of cities is presented in Table 2 where cities are assigned to 3 clusters of marketization.

[4] An earlier study of innovation used a small sample of high-tech firms in Beijing's Haidian district (Hu 2001).

**Model Specification**

Our model seeks to test for the impact of market forces and political influence on innovation. Formally, our model is:

$$y_{ij} = \mathbf{X}_{ij}\boldsymbol{\beta} + \nu_i + \varepsilon_{ij}$$

where *i* denotes each city and *j* each firm. $\mathbf{X}_{ij}$ is a set of firm-level variables covering political control, research activities, competition and distinct firm characteristics and $\boldsymbol{\beta}$ is a vector of corresponding coefficients. $\nu_i$ denotes city-level effects while $\varepsilon_{ij}$ residuals. $\nu_i$ will be assumed fixed when we run models within each marketization cluster.[5]

**Dependent variable**

Schmokler's (1966) seminal work showed that patents provide a reliable measure of a firm's capacity for innovation. Following this tradition, we note whether a firm applied and received a patent in the last available survey year (i.e in 2002 and 2000). However, strictly speaking a patent is not an innovation until it is brought to the market (Baumol 2002). In addition, not all innovations at the firm level are patented. This is crucial in transition economies, where weak protection of intellectual property rights may not provide incentives for formal patenting. To capture the broader concept of firm innovativeness, we rely on three additional measures of innovation: (1) the introduction of new products, (2) the introduction of a new production process and (3) the introduction of new quality-control measures. The inclusion of the latter innovation-type responds to

5 The use of city-clustered standard errors provides the appropriate tool to capture within city correlations given relatively low intraclass correlation in our stratified sample of firms and the limited number of clusters (23).

Solow's (2007:18) warning not "to lapse into the tacit presumption that 'innovation' consists of new products and new technology only, whereas an important component is organizational innovation."

Overall, patenting activities and product innovation signal efforts to move a firm to a new cost-quality position, while process innovations and quality management are mainly cost reduction driven. In this sense, patenting activities and product innovation signal a stronger and riskier entrepreneurial effort responding to market opportunities than process innovations and new quality control measures. We label the first "strategic innovation" and the latter "passive innovation." For these innovation measures the 2002-survey provides information for the years from 1998 to 2000, while the 2003-survey provides information for the years from 1999 to 2002. Depending on varying response rates, the total number of observations differs across estimations.

**Independent Variables**

*Political Control*

To measure the intensity of political controls at the firm level, we first note whether a firm is legally registered as a state-owned enterprise. State-owned enterprises in general operate under softer budget constraints and are subject to ongoing political monitoring and interference. However, such firms are not necessarily wholly state-owned. Moreover, many firms listed in stock exchanges and joint-stock firms registered as private enterprises are partly or even majority state-owned. In order to capture such ownership effects, we differentiate four mutually exclusive levels of state ownership: (1)

up to 25%, (2) between 25% and 50%, (3) between 50% and 99%, and (4) 100%. Fully privately held firms serve as benchmark category.

*Research activities*

Whether a firm has invested in R&D over the last three years is specified by a dummy variable (Mairesse and Mohnen 2002; Kochhar and David 1996). The average ratio of R&D expenditures to total sales over the last three years serves as an indicator of R&D intensity. Jefferson et al. (2003) report a R&D-to-sales ratio of 2.2% in their sample of 22,000 firms, while our sample shows an average value of 2%.

Finally, we approximate the most recent stock of technological capital by noting whether a firm acquired patents over the preceding two years. This variable enables us to take into account the path-dependent process of innovation wherein past experience and success has a positive impact on future innovation.

*Research Network*

The emergence of innovation markets is measured through variables indicating the existence of contractual agreements for R&D cooperation in the last three years between the firm and (1) research institutes, (2) universities, and (3) other firms (Baumol 2002). Membership in business associations and location in industrial parks are proxies of the potential diffusion of innovations through networks. This source of regional advantage does not rely on formal contractual research agreement, but on reduced information costs due to propinquity (Arrow 2007).

*Competition*

Five variables measure competitive pressure: A dichotomous variable indicates a firm's domestic market share is more than 10%. We control for the perceived competition as the self-reported number of competitors in the main domestic market using a five point scale (1: 1-3, 2: 4-6, 3: 7-15, 4: 16-100, 5: more than 100).[6] Because a certain threshold of competitive market pressures may be required to stimulate innovation, we allow for a non-linear relation (Scherer 1967; Aghion et al. 2005) by specifying a square-term of the number of competitors. Whether firms participate in the export market is indicated by a dummy variable. Lastly, a set of dummy variables controls for 10 different industrial sectors. Industrial sectors serve as general proxies of competitive pressure, technological opportunity conditions, and average innovativeness (Mairesse and Mohnen 2002). They also control for industrial policy priorities, which may influence a firm's access to finance, information and public science and technology programs.

*Additional control variables*

Other specific firm characteristics—including age, size, financial leverage, and location—may correspond with a firm's innovativeness. A firm's age is generally believed to affect its adaptability and innovativeness (Hannan and Freeman 1989). Older state-owned enterprises are encumbered by more structural inertia. Hence these firms are likely to exhibit a structural disadvantage in an innovation "arms race." Furthermore, firm size reflects scale economies, access to finance and organizational features (Schumpeter 1942; Mohr 1969; Singh 1986; Acs and Audretsch 1987). To capture the size-effect, we include the natural logarithm of the average value of a firm's net assets over the last three years. Similarly a firm's financial leverage may determine the ability to fund R&D and

[6] Reliance on self-reported measures provides a more accurate assessment of a firm's market position in China's transitory economy than for instance industry specific concentration ratios, as competition is still affected by the uneven development of distribution channels, non-tariff trade barriers and local and provincial trading networks.

also the choice of R&D projects. Schumpeter ([1912]1934) observes that “credit” or bank loans are “fundamentally necessary” (p.70) in order to “[detach] productive means from the circular flow and [allot] them to new combinations” (p. 71). The average debt-asset-ratio over the preceding three years serves as an indicator of financial health. Finally we include city-controls, as firms may be subject to different local industrial policy guidelines and research environments. Appendix D provides information on correlation coefficients.

## RESULTS

To examine the impact of market forces on innovation, we provide separate estimates for the full sample of firms in 23 cities (model 1) and then for three regional clusters representing dissimilar levels of marketization (models 2-4). Hence, model 2 estimates innovation in the least marketized regions, and model 4 in the most marketized regions.

### *The race for new products – strategic innovation*

For patenting activities—patent grants in two preceding years, R&D research, and R&D to sales ratio (Table 4)—we find support for our prediction that competitive market pressures promote R&D investments in innovative capacity (*hypothesis 1*). In the most marketized region (model 4), we see a significant effect of the dummy for R&D research on patents granted. Although the intensity of research and development (R&D to sales ratio) shows no significant effect, a comparison of results across the three marketization clusters supports the view that routine investments in R&D contributes to the innovative capacity of firms.

Firms located in industrial parks, members in business associations and firms with formal R&D cooperation all enjoy innovation advantages (model 1). These advantages differ markedly, however, across the three marketization clusters. In the least marketized regions (model 2), location and different types of firm collaboration all provide significant advantages; these are no longer critical in more marketized regions (model 3 and model 4). In China's most marketized regions, only R&D cooperation with universities increases the success rate in patent production. This may reflect the growing role in research and development of China's key universities, which are all located in the most-marketized coastal regions of the country. In sum, we find evidence that supports the view that innovation markets have emerged in China, shown by the impact of research cooperation between firms and with research institutes and universities on patents granted (*hypothesis 2*).

We also find a negative effect of state-ownership on innovation strongly confirmed (model 1). All categories of state-ownership involvement show negative signs with a statistically significant disadvantage for wholly state-owned firms. The suggested inferiority of state-owned and collective firms in innovation is thereby supported (*hypothesis 3*). With regard to the development of state ownership-effects in maturing market economies, the cross-cluster comparison signals an even increasing disadvantage in comparison to private firms, which provides tentative support for hypothesis 4. While strong profit incentives lead to accelerating innovation processes for (surviving) private firms, state-owned enterprises–operating under soft budget constraints and multiple public goals—fail to detect and realize new market opportunities through innovation. Only wholly state-owned enterprises appear to be able to reduce the innovation gap with private firms (model 4). We suspect that the result most likely reflects a selection effect. Local governments typically do not divest from state-owned enterprises that demonstrate competitiveness in the market environment, even after the national policy promoting privatization. If the firm sample is to some extent affected by such a selection effect, this might explain the unexpected result for wholly state-owned firms (model 4).

The results we report for patents are mostly confirmed for the second type of strategic innovation, bringing new products to the market (Table 5). We find evidence consistent with the shift to routine firm-level involvement in efforts to innovate in China's industrial economy. The path-dependent development of innovation is strongly confirmed both in the full sample (model 1), as well as in all sub-samples (model 2-4). Firms that invest in research and development and already hold patents are likely to be granted new patents. Worthwhile noting is that research intensity, as measured by R&D-to-sales ratio, yields a significant impact on product innovation only in the most marketized regions. This reinforces the observation that innovation-oriented research gains in importance the more marketized the economy *(hypothesis 1*). In less marketized regions, where state allocation carries on, intensification of R&D activity may not play such a critical role since government rather than consumers are the main source of demand.

As with patents, research cooperation and networks play a consistently strong and significant role in product innovation (*hypothesis 2*). The emergence of innovation markets is confirmed in the significance of R&D cooperation between firms in all regions of China. Naturally, such cooperation will be important between upstream- and downstream firms. Cooperative agreements with universities and research institutes lose their positive impact on product innovation in the most marketized regions, however. This may suggest that product innovation, different from patents, has a stronger focus on the commercial use of inventions, which may explain the weaker role of university cooperation in this specific field of research.

State ownership of more than 25% appears to lower firm innovativeness (model 1). In support of our politics-proposition (*hypothesis 3*), firms with state ownership shares between 25% and 99% experience significant disadvantages in product innovation. The comparison of ownership effects across the marketization clusters reconfirms *hypothesis 4* that state-owned enterprises fall increasingly behind. Our estimates suggest an increasing innovation gap between public ownership (state-owned, collective and firms legally registered as state-owned) and private enterprise. However, hybrids (mixed ownership) and firms that are mainly privately owned seem to reduce their innovation disadvantage when compared with fully privately owned firms. This finding emphasizes the positive role of economic incentives and private decision-making in explaining innovation outcomes.

*The race for cost reduction – passive innovation*

Table 6 on innovation through introduction of new production processes is broadly consistent with the pattern we found for strategic innovations for patents and products. Historical patenting activity and routinization of R&D (*hypothesis 1*) have a positive and significant impact on developing new production technologies (model 1). This is confirmed for all three sub-samples (model 2-4). Also research networks and cooperation improve a firm's likelihood to implement process innovations (*hypothesis 2*). The pattern observed for product innovation is again confirmed, hinting at the superior role of the firm as the locus of innovation in a marketized environment. Again, at the highest marketization level (model 4) only R&D cooperation with other firms provide significant advantages, whereas all other forms of cooperation agreements lose their decisive influence on innovativeness. Also, spillover effects stemming from potential information advantages within business associations and industrial parks lose their positive impact in China's most marketized cities (model 4).

The impact of political control differs markedly from the previous findings on strategic innovation. Though we show negative coefficients for state ownership larger than 25%, none of the estimates is significant at conventional levels (model 1). Only in the less marketized regions (model 2 and 3) are there significantly negative effects for dominantly state-owned firms (with state ownership between 50% and 99%) thereby lending some support to our politics proposition (*hypothesis 3*). Our results, however, do not support the idea of increasing disadvantages of state-owned enterprises with deepening marketization. To the contrary, coefficients of state-ownership effects in the most marketized regions even turn positive, with significant effects of dominant state ownership (50% to 99%). *Hypothesis 4 is* thereby not confirmed.

As for our second measure of cost-saving innovation efforts – the introduction of new quality control measures - we confirm the importance of routinized R&D (*hypothesis 1*) and R&D cooperation (*hypotheses 2*) (Table 7). In comparison to process innovation, not only R&D cooperation with other firms, but also positive spillovers due to firm location in industrial parks and cooperation agreements with academic partners provide innovation advantages (model 2 to 4). Similar results as for process innovation are also estimated for political effects. While state-ownership effects are negative for the total sample (confirming hypothesis 3) and in less marketized regions (cluster 1 and 2), coefficient values turn positive for firms located in China's most marketized regions. For dominant state ownership (50 to 99%), our results even suggest significant innovation advantages (50% to 99%). It should be mentioned, however, that we cannot rule out a certain selection effect. As the concept of marketization itself also reflects progress in enterprise reforms, the most marketized regions may be characterized by stronger performance of state-owned firms in terms of cost-saving innovation, simply because the less successful firms have already been sold out.

While large market shares seem to increase the probability of product innovation, process innovation and new quality controls, we do not find significant effects in our three sub-samples (model 2-4). Among our remaining variables, only firm size yields consistent results across all estimations. Larger firms seem to benefit from scale effects, which help them to succeed in a wide range of innovative activities.

## Conclusion

In sum, in the area of *strategic innovation* (patents and product innovation), which represent a stronger and riskier form of entrepreneurial effort, our results provide consistent confirmation for our theory and derived hypotheses (tables 4 and 5). These results suggest that it is not simply competition, but the level of marketization as a distinct concept that partly drives the effectiveness of R&D-activities and the value of network cooperation. Further, effects of political control vary depending on the level of marketization. State-owned enterprises in general lag behind private firms in strategic innovation, and this gap widens as the level of marketization increases. This is consistent with our assumption that incentives, opportunities and competitive pressures serve as robust mechanisms the more marketized the environment. As China's market economy matures, the continuing diminishment of the effectiveness of political capital (*power proposition*) as a means for economic actors to secure market advantages can be expected to drive firms to intensify their innovation efforts.

By contrast, for *passive innovation*—the introduction of new production process and quality-control measures—state ownership and political controls did not lead to an increasing innovation gap with private firms. This finding is consistent with general evidence confirming productivity improvements of state-owned enterprises in the course of market reforms (Groves et al. 1994). Though further research will be needed, two alternative explanations seem obvious. First, cost-saving innovation strategies are by their very nature less entrepreneurial, less forward-looking and involve smaller risks than strategic innovations. Second, the implementation of cost-saving measures is easier to monitor for non-market participants. In this sense, the state as an owner may be in a better position to monitor and control the implementation of *passive* innovation strategies than in the case of forward-looking *strategic* innovations.

Schumpeter's ([1934] 1983) list of motives for entrepreneurs includes "the dream and the will to found a private kingdom," the "will to conquer: the impulse to fight, to prove oneself superior to others, to succeed for the sake, not of the fruits of success, but of success itself," and the "job of creating, of getting things done, or simply of exercising one's energy and ingenuity" (p. 93). Clearly, motives for entrepreneurial action are often complex and nuanced at the individual level. Our theory shifts the analytic focus away from incentives for individual firms or entrepreneurs to innovate towards specifying the features of the institutional framework that foster the innovative activities driving Schumpeterian creative destruction.

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**FIGURES**

Figure 1. Incentives and Opportunity to Innovate in Response to Market Customers.

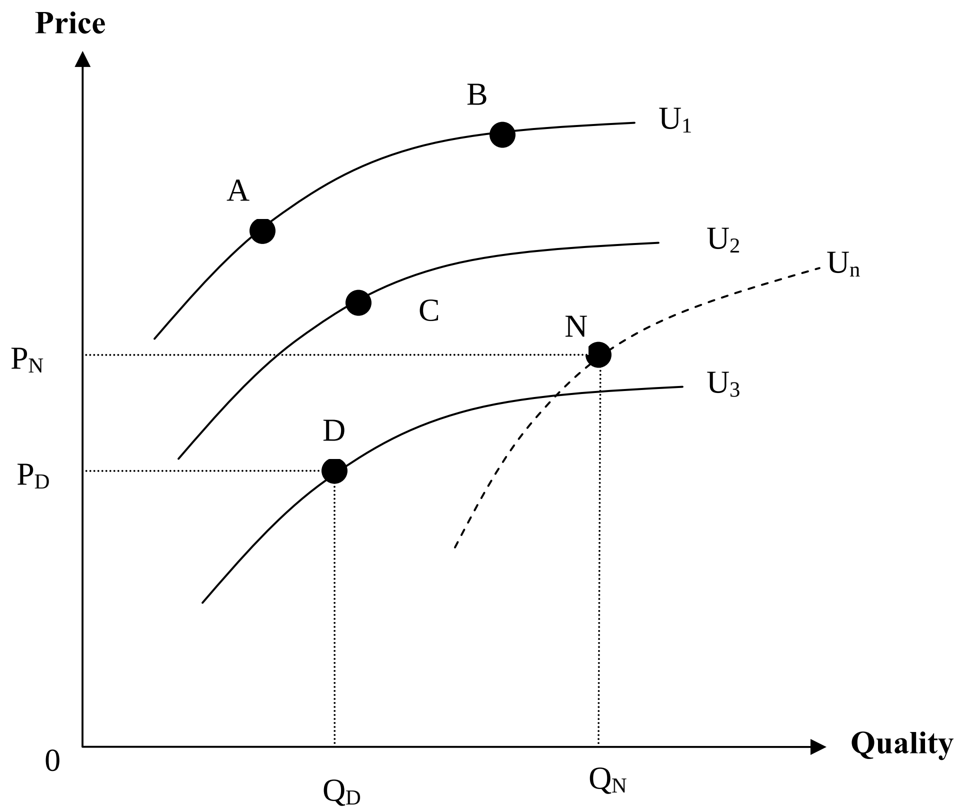


Figure 2. Development of Cost-Quality Frontier in Market Competition.

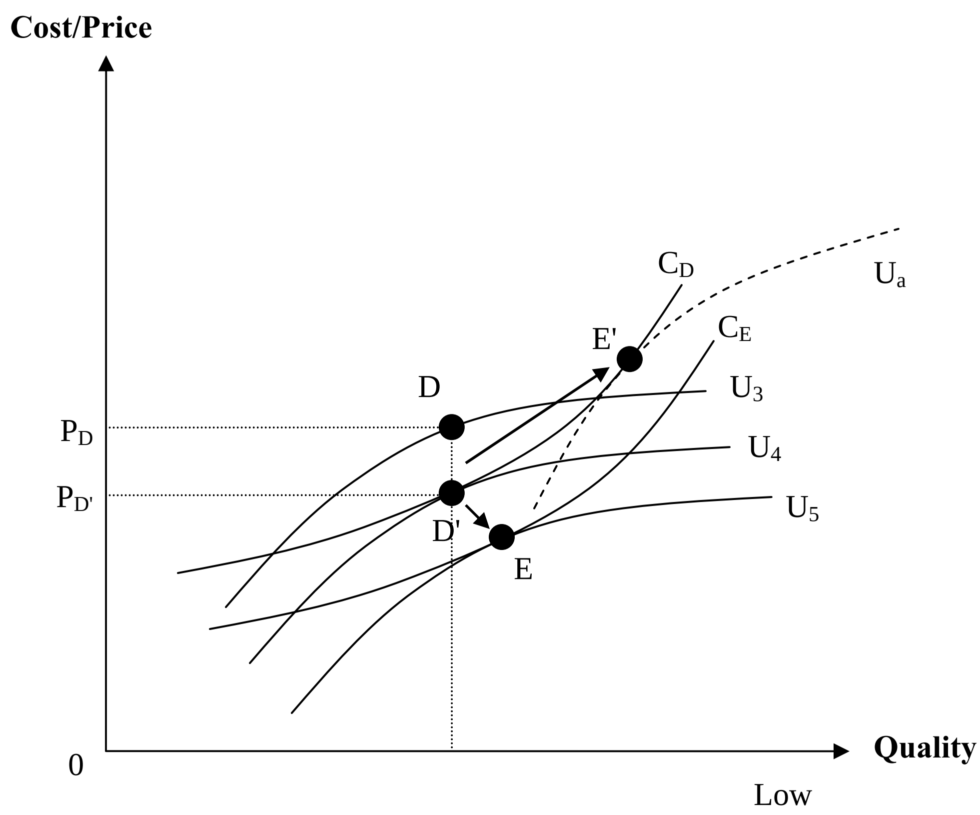


Figure 3: Innovation activities and marketization, 1997-2003

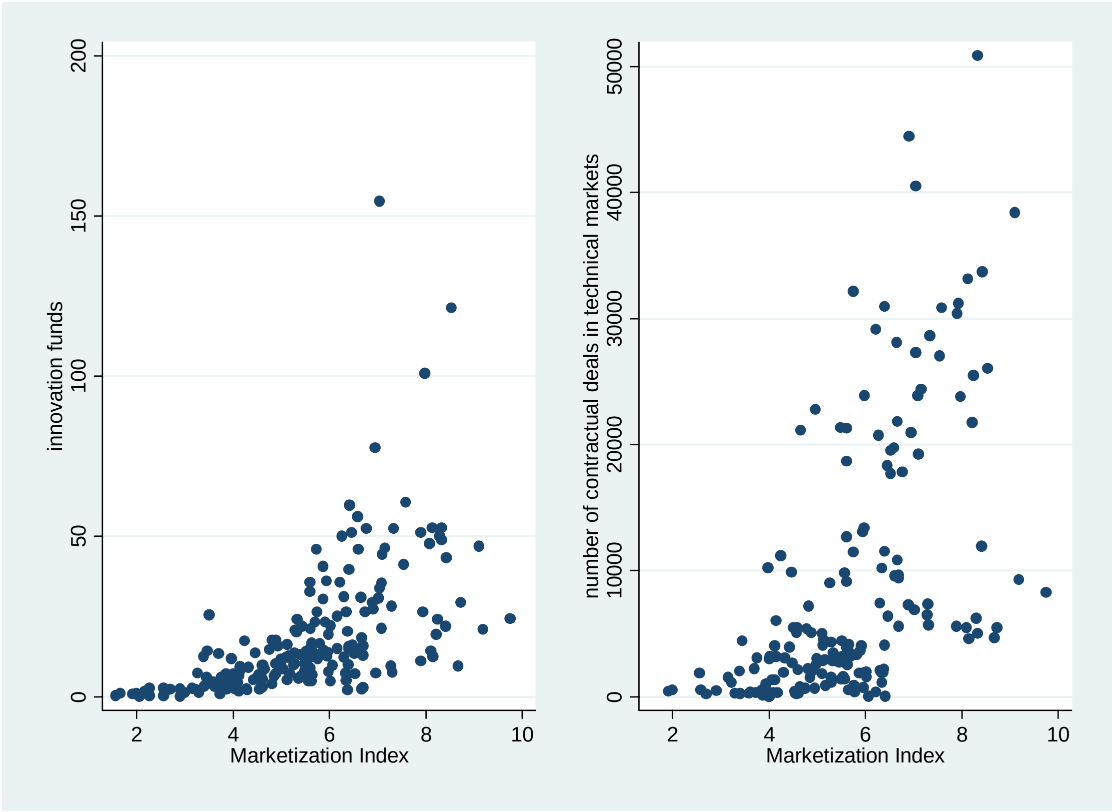


Figure 4. Patenting activities

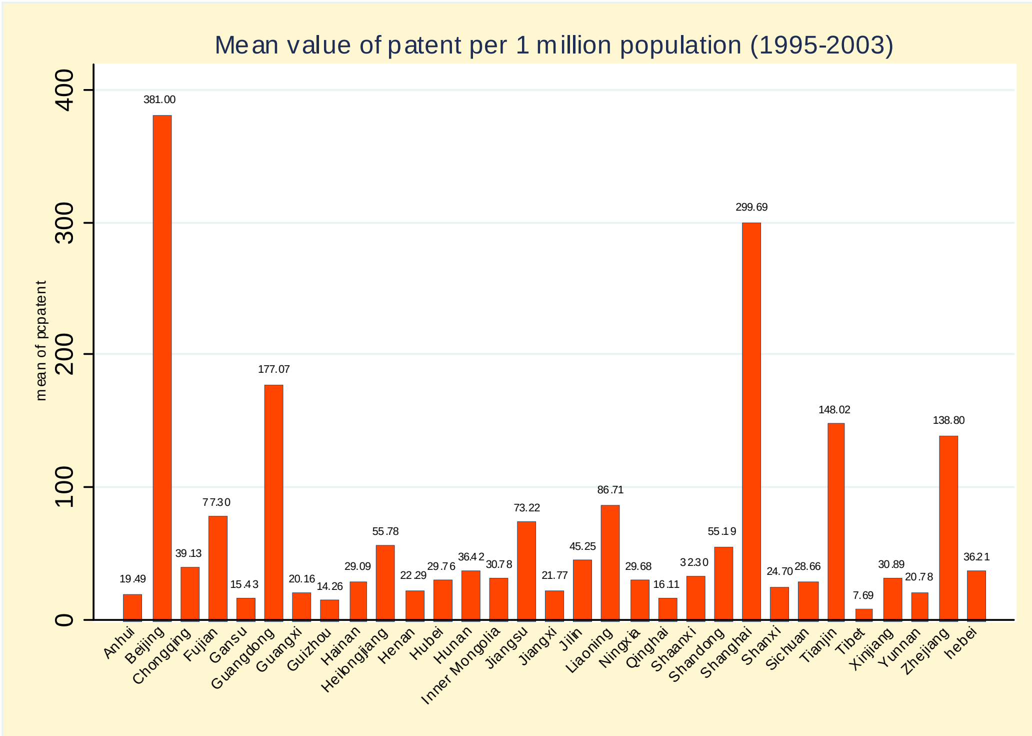
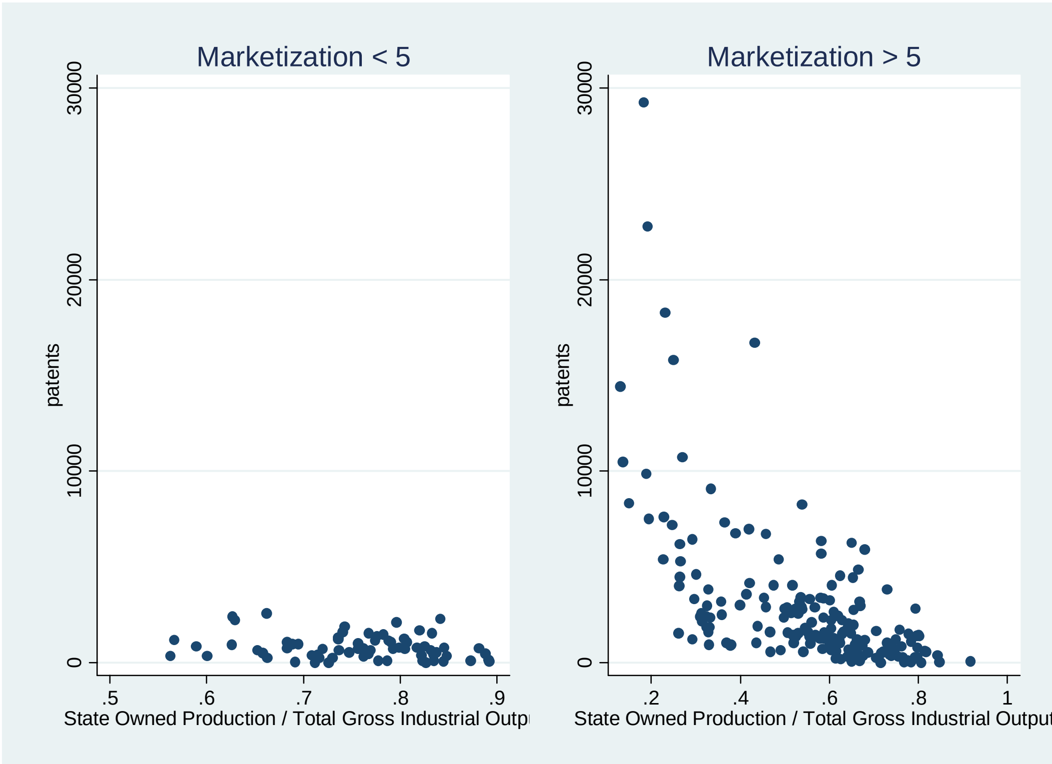


Figure 5. State-ownership, patenting and marketization, 1997-2003



## Tables

Table 1: Sector distribution of survey firms

| | Observations | Percentage |
|---|---|---|
| Accounting and related services | 269 | 6.81 |
| Advertising and marketing | 244 | 6.18 |
| Apparel and leather goods | 577 | 14.61 |
| Business logistics services | 385 | 9.75 |
| Communication services | 73 | 1.85 |
| Consumer products | 403 | 10.21 |
| Electronic components | 487 | 12.34 |
| Electronic equipment | 384 | 9.73 |
| Information technology services | 341 | 8.64 |
| Vehicles and vehicle parts | 785 | 19.88 |
| Total | 3948 | 100.00 |

Table 2. Clusters of Provinces by the Average Marketization Index for the Past Three Years.

| Cluster | N | City | Survey Year | Province | Marketization index |
|---|---|---|---|---|---|
| 1 | 150 | Guiyang | 2003 | Guizhou | 3.95 |
| 1 | 150 | Lanzhou | 2003 | Gansu | 4.04 |
| 1 | 150 | Xian | 2003 | Shaanxi | 4.29 |
| 1 | 150 | Haerbin | 2003 | Heilongjiang | 4.75 |
| 1 | 150 | Kunming | 2003 | Yunnan | 4.97 |
| 1 | 150 | Changchun | 2003 | Jilin | 5.01 |
| 1 | 150 | Changsha | 2003 | Hunan | 5.07 |
| 1 | 150 | Nanchang | 2003 | Jiangxi | 5.08 |
| 1 | 150 | Wuhan | 2003 | Hubei | 5.22 |
| 2 | 150 | Zhengzhou | 2003 | Henan | 5.32 |
| 2 | 150 | Nanning | 2003 | Guangxi | 5.41 |
| 2 | 300 | Chengdu | 2002 | Sichuan | 5.41 |
| 2 | 150 | Chongqing | 2003 | Chongqing | 5.97 |
| 2 | 300 | Beijing | 2002 | Beijing | 6.06 |
| 2 | 100 | Dalian | 2003 | Liaoning | 6.24 |
| 2 | 100 | Benxi | 2003 | Liaoning | 6.24 |
| 3 | 300 | Tianjin | 2002 | Tianjin | 6.49 |
| 3 | 300 | Shanghai | 2002 | Shanghai | 6.67 |
| 3 | 348 | Guang Zhou | 2002 | Guangdong | 8.45 |
| 3 | 100 | Hangzhou | 2003 | Zhejiang | 8.49 |
| 3 | 100 | Wenzhou | 2003 | Zhejiang | 8.49 |
| 3 | 100 | Shenzhen | 2003 | Guangdong | 9.22 |
| 3 | 100 | Jiangmen | 2003 | Guangdong | 9.22 |

Table 3 Descriptive Statistics of Variables in Analysis

| | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|
| Firm receives patent in 2002 | 0.1158 | 0.3200 | 0 | 1 |
| Product innovation | 0.4152 | 0.4928 | 0 | 1 |
| Process innovation | 0.3729 | 0.4318 | 0 | 1 |
| New quality control | 0.5504 | 0.4976 | 0 | 1 |
| Firm conducts R&D | 0.2933 | 0.4554 | 0 | 1 |
| Firm holds patents | 0.1258 | 0.3316 | 0 | 1 |
| Average R&D to sales ratio | 0.0179 | 0.5835 | 0 | 32.3695 |
| Located in industrial park | 0.2557 | 0.4363 | 0 | 1 |
| Member of business association | 0.5860 | 0.4926 | 0 | 1 |
| R&D cooperation with firms | 0.1431 | 0.3503 | 0 | 1 |
| R&D cooperation with universities | 0.1550 | 0.3620 | 0 | 1 |
| R&D cooperation with research institutes | 0.1126 | 0.3161 | 0 | 1 |
| Legally registered as SOE | 0.2464 | 0.4310 | 0 | 1 |
| State holds up to 25% shares | 0.0219 | 0.1463 | 0 | 1 |
| State holds between 25% and 50% | 0.0196 | 0.1387 | 0 | 1 |
| State holds between 50% and 99% | 0.0261 | 0.1593 | 0 | 1 |
| State holds 100% | 0.1853 | 0.3886 | 0 | 1 |
| Market share > 10% | 0.2441 | 0.4296 | 0 | 1 |
| Number of competitors in main business | 3.5851 | 1.3788 | 1 | 5 |
| Number of competitors in main business (squared) | 14.7533 | 8.8924 | 1 | 25 |
| Firm exports | 0.2432 | 0.4291 | 0 | 1 |
| Firm is founded before 1978 | 0.8086 | 0.3935 | 0 | 1 |
| Log of average firm assets | 8.8315 | 2.4178 | 0.6931 | 17.2814 |
| Average debt asset ratio | 1.0054 | 0.8388 | 0 | 7.29072 |

Table 4: **Patent granted in 2002, political control and markets**

| | Model 1<br>all | Model 2<br>Cluster 1 | Model 3<br>Cluster 2 | Model 4<br>Cluster 3 |
|---|---|---|---|---|
| ***Research activities*** | | | | |
| Patents were granted in both preceding years | 2.202*** | 2.769*** | 1.663*** | 3.032*** |
| | (0.342) | (0.371) | (0.447) | (0.531) |
| Conducts R&D | 0.138 | 0.057 | 0.011 | 0.478* |
| | (0.101) | (0.179) | (0.208) | (0.278) |
| R&D to sales ratio | -0.011 | -0.005 | 1.357 | 1.118 |
| | (0.021) | (0.022) | (1.723) | (6.105) |
| ***Research Cooperation / Networks*** | | | | |
| Located in industrial park | 0.217** | 0.412*** | -0.003 | 0.145 |
| | (0.099) | (0.151) | (0.071) | (0.264) |
| Member of business association | 0.177** | 0.107 | 0.389* | 0.158 |
| | (0.089) | (0.162) | (0.212) | (0.167) |
| R&D cooperation with firms | 0.243* | 0.384* | -0.089 | 0.249 |
| | (0.143) | (0.218) | (0.226) | (0.297) |
| R&D cooperation with universities | 0.196 | -0.051 | 0.472** | 0.726*** |
| | (0.165) | (0.302) | (0.207) | (0.266) |
| R&D cooperation with research institutes | 0.139 | 0.310 | 0.106 | 0.289 |
| | (0.161) | (0.257) | (0.199) | (0.266) |
| ***Political Control*** | | | | |
| Legally registered as SOE | -0.100 | -0.252 | -0.134 | -0.219 |
| | (0.140) | (0.226) | (0.337) | (0.290) |
| State holds up to 25% ownership | -0.224 | 0.167 | -0.279 | -0.689 |
| | (0.283) | (0.538) | (0.503) | (0.470) |
| State holds 25-50% ownership | -0.186 | -0.353 | 0.558* | -1.980*** |
| | (0.451) | (0.617) | (0.287) | (0.482) |
| State holds 51% to 99% ownership | -0.217 | 0.094 | -0.453 | -0.567* |
| | (0.249) | (0.352) | (0.325) | (0.337) |
| State holds 100% ownership | -0.309*** | -0.239* | -0.222 | -0.138 |
| | (0.102) | (0.144) | (0.250) | (0.564) |
| ***Competition*** | | | | |
| Market share >10% | 0.100 | 0.181 | -0.031 | -0.078 |
| | (0.100) | (0.182) | (0.166) | (0.266) |
| # of competitors in main business | 0.143 | -0.191 | 0.184 | 0.700* |
| | (0.131) | (0.176) | (0.194) | (0.364) |
| # of competitors in main business (squared) | -0.040** | 0.007 | -0.060* | -0.090** |
| | (0.020) | (0.027) | (0.032) | (0.044) |
| Firm exports goods | -0.113 | -0.001 | 0.119 | -0.318 |
| | (0.117) | (0.172) | (0.161) | (0.242) |
| Industry | YES | YES | YES | YES |
| ***Company characteristics*** | | | | |
| Founded before reform | 0.128 | 0.163 | -0.166 | 1.260*** |
| | (0.122) | (0.261) | (0.190) | (0.382) |
| Log value of assets | 0.079** | 0.147*** | -0.027 | 0.109 |
| | (0.033) | (0.025) | (0.068) | (0.086) |
| Average debt to asset ratio | 0.161*** | 0.156 | 0.276*** | 0.121 |
| | (0.059) | (0.099) | (0.092) | (0.182) |
| City | YES | YES | YES | YES |
| _cons | -2.095*** | -2.739*** | -5.466 | -5.071*** |
| | (0.446) | (0.565) | (0.000) | (1.162) |
| r2 | | | | |
| chi2 | . | . | . | . |
| N | 2278 | 1136 | 590 | 461 |

* p<0.10, ** p<0.05, *** p<0.01

**Table 5: Product Innovation, Market Incentives and Political Control**

| | Model 1 (all) | Model 2 Cluster 1 | Model 3 (Cluster 2) | Model 4 (Cluster 3) |
|---|---|---|---|---|
| **Research Activity** | | | | |
| Firm holds patent | 0.267*** | 0.492*** | 0.105 | 0.282** |
| | *(0.091)* | *(0.155)* | *(0.167)* | *(0.131)* |
| Firm conducts R&D | 0.502*** | 0.569*** | 0.536*** | 0.514*** |
| | *(0.060)* | *(0.095)* | *(0.121)* | *(0.107)* |
| R&D to sales ratio | 0.017 | 0.013 | -5.347*** | 3.700* |
| | *(0.029)* | *(0.029)* | *(0.992)* | *(2.089)* |
| **Network/Cooperation** | | | | |
| Located in industrial park | 0.145** | 0.276*** | -0.096 | 0.220*** |
| | *(0.060)* | *(0.092)* | *(0.079)* | *(0.080)* |
| Member of business association | 0.326*** | 0.418*** | 0.261*** | 0.215** |
| | *(0.047)* | *(0.042)* | *(0.090)* | *(0.094)* |
| R&D cooperation with firms | 0.468*** | 0.416*** | 0.547*** | 0.572*** |
| | *(0.065)* | *(0.071)* | *(0.164)* | *(0.118)* |
| R&D cooperation with universities | 0.231*** | 0.251** | 0.328** | 0.206 |
| | *(0.067)* | *(0.100)* | *(0.149)* | *(0.149)* |
| R&D cooperation with research institutes | 0.323*** | 0.388*** | 0.384*** | 0.234 |
| | *(0.078)* | *(0.120)* | *(0.056)* | *(0.259)* |
| **Political Control** | | | | |
| Legally registered as SOE | 0.030 | 0.153 | 0.201 | -0.273 |
| | *(0.098)* | *(0.129)* | *(0.144)* | *(0.215)* |
| State holds up to 25% ownership | 0.002 | -0.299 | -0.038 | 0.176 |
| | *(0.209)* | *(0.431)* | *(0.295)* | *(0.377)* |
| State holds 25-50% ownership | -0.307*** | -0.622*** | -0.095 | 0.012 |
| | *(0.114)* | *(0.181)* | *(0.143)* | *(0.385)* |
| State holds 51% to 99% ownership | -0.201* | -0.032 | -0.303* | -0.408** |
| | *(0.117)* | *(0.205)* | *(0.176)* | *(0.207)* |
| State holds 100% ownership | -0.064 | -0.010 | -0.221* | -0.091 |
| | *(0.100)* | *(0.171)* | *(0.134)* | *(0.203)* |
| **Competition** | | | | |
| Market share >10% | 0.170** | 0.258 | 0.076 | 0.204 |
| | *(0.080)* | *(0.174)* | *(0.089)* | *(0.153)* |
| # of competitors in main business | 0.291* | 0.207 | 0.357 | 0.308 |
| | *(0.152)* | *(0.179)* | *(0.374)* | *(0.189)* |
| # of competitors in main business (squared) | -0.055** | -0.043 | -0.075 | -0.044 |
| | *(0.024)* | *(0.028)* | *(0.059)* | *(0.031)* |
| Firm exports goods | 0.155*** | 0.053 | 0.137* | 0.220*** |
| | *(0.057)* | *(0.120)* | *(0.074)* | *(0.069)* |
| Industry | YES | YES | YES | YES |
| **Firm characteristics** | | | | |
| Founded before reform | 0.026 | 0.075 | 0.243* | -0.464** |
| | *(0.079)* | *(0.073)* | *(0.136)* | *(0.195)* |
| Log value of assets | 0.050*** | 0.004 | 0.095*** | 0.049** |
| | *(0.017)* | *(0.047)* | *(0.015)* | *(0.021)* |
| Average debt to asset ratio | 0.056 | 0.150 | 0.079** | -0.071* |
| | *(0.036)* | *(0.095)* | *(0.039)* | *(0.042)* |
| City | YES | YES | YES | YES |
| _cons | -2.008*** | -1.608*** | -2.249*** | -1.378*** |
| | *(0.235)* | *(0.446)* | *(0.469)* | *(0.463)* |
| r2 | | | | |
| chi2 | . | . | . | . |
| N | 3109 | 1141 | 1049 | 919 |

**Table 6: Process Innovation, Market Incentives and Political Control**

| | Model 1 (all) | Model 2 Cluster 1 | Model 3 (Cluster 2) | Model 4 (Cluster 3) |
|---|---|---|---|---|
| **Research Activity** | | | | |
| Firm holds patent | 0.308*** | 0.293*** | 0.398*** | 0.249* |
| | *(0.052)* | *(0.079)* | *(0.152)* | *(0.135)* |
| Firm conducts R&D | 0.426*** | 0.437*** | 0.599*** | 0.239*** |
| | *(0.056)* | *(0.092)* | *(0.148)* | *(0.082)* |
| R&D to sales ratio | 0.037* | 0.037 | -1.048 | -0.597 |
| | *(0.022)* | *(0.024)* | *(2.025)* | *(2.300)* |
| **Network/Cooperation** | | | | |
| Located in industrial park | 0.084** | 0.142** | 0.084 | 0.053 |
| | *(0.038)* | *(0.071)* | *(0.078)* | *(0.078)* |
| Member of business association | 0.185*** | 0.271*** | 0.206* | 0.024 |
| | *(0.055)* | *(0.085)* | *(0.116)* | *(0.100)* |
| R&D cooperation with firms | 0.381*** | 0.370*** | 0.341** | 0.586** |
| | *(0.099)* | *(0.126)* | *(0.161)* | *(0.273)* |
| R&D cooperation with universities | 0.138 | 0.127 | -0.012 | 0.321 |
| | *(0.096)* | *(0.092)* | *(0.140)* | *(0.276)* |
| R&D cooperation with research institutes | 0.425*** | 0.486*** | 0.463*** | 0.298 |
| | *(0.083)* | *(0.143)* | *(0.115)* | *(0.230)* |
| **Political Control** | | | | |
| Legally registered as SOE | 0.008 | 0.064 | -0.082 | 0.074 |
| | *(0.080)* | *(0.117)* | *(0.187)* | *(0.114)* |
| State holds up to 25% ownership | 0.234 | -0.140 | 0.623* | 0.095 |
| | *(0.207)* | *(0.543)* | *(0.344)* | *(0.326)* |
| State holds 25-50% ownership | -0.048 | -0.131 | -0.119 | 0.594*** |
| | *(0.135)* | *(0.256)* | *(0.144)* | *(0.120)* |
| State holds 51% to 99% ownership | -0.186 | -0.360* | -0.469** | 0.368*** |
| | *(0.168)* | *(0.196)* | *(0.197)* | *(0.130)* |
| State holds 100% ownership | -0.061 | -0.115 | 0.020 | -0.061 |
| | *(0.079)* | *(0.109)* | *(0.165)* | *(0.099)* |
| **Competition** | | | | |
| Market share >10% | 0.231*** | 0.172 | 0.221** | 0.299* |
| | *(0.075)* | *(0.144)* | *(0.106)* | *(0.159)* |
| # of competitors in main business | 0.283*** | 0.425* | 0.102 | 0.272 |
| | *(0.105)* | *(0.218)* | *(0.179)* | *(0.174)* |
| # of competitors in main business (squared) | -0.047*** | -0.078** | -0.018 | -0.034 |
| | *(0.017)* | *(0.032)* | *(0.034)* | *(0.027)* |
| Firm exports goods | 0.113 | -0.126 | 0.196 | 0.327*** |
| | *(0.083)* | *(0.105)* | *(0.152)* | *(0.118)* |
| Industry | 0.278 | 0.232 | 0.311 | 0.358 |
| | *(0.215)* | *(0.361)* | *(0.410)* | *(0.647)* |
| **Firm characteristics** | | | | |
| Founded before reform | 0.026 | 0.126 | -0.015 | -0.220** |
| | *(0.069)* | *(0.083)* | *(0.130)* | *(0.100)* |
| Log value of assets | 0.065*** | 0.044* | 0.060*** | 0.101*** |
| | *(0.013)* | *(0.023)* | *(0.019)* | *(0.023)* |
| Average debt to asset ratio | 0.024 | -0.059 | 0.014 | 0.108 |
| | *(0.038)* | *(0.054)* | *(0.072)* | *(0.071)* |
| City | -0.096** | | -0.062 | |
| | *(0.040)* | | *(0.072)* | |
| _cons | -2.868*** | -2.016*** | -2.650*** | -3.379*** |
| | *(0.266)* | *(0.487)* | *(0.578)* | *(0.469)* |
| r2 | | | | |
| chi2 | . | . | . | . |
| N | 3106 | 1140 | 1049 | 917 |

**Table 7: New Quality Control, Market Incentives and Political Control**

| | Model 1 (all) | Model 2 Cluster 1 | Model 3 (Cluster 2) | Model 4 (Cluster 3) |
|---|---|---|---|---|
| **Research Activity** | | | | |
| Firm holds patent | 0.143 | 0.204 | 0.142 | 0.119 |
| | *(0.089)* | *(0.133)* | *(0.229)* | *(0.126)* |
| Firm conducts R&D | 0.277*** | 0.245*** | 0.287*** | 0.259 |
| | *(0.067)* | *(0.073)* | *(0.075)* | *(0.231)* |
| R&D to sales ratio | -0.085*** | -0.086*** | 0.043 | 2.483 |
| | *(0.022)* | *(0.023)* | *(1.701)* | *(3.077)* |
| **Network/Cooperation** | | | | |
| Located in industrial park | 0.220*** | 0.162* | 0.262*** | 0.293** |
| | *(0.053)* | *(0.083)* | *(0.090)* | *(0.114)* |
| Member of business association | 0.233*** | 0.389*** | 0.192** | 0.076 |
| | *(0.046)* | *(0.051)* | *(0.094)* | *(0.075)* |
| R&D cooperation with firms | 0.285*** | 0.284*** | 0.324* | 0.346** |
| | *(0.074)* | *(0.090)* | *(0.177)* | *(0.171)* |
| R&D cooperation with universities | 0.211*** | 0.249*** | -0.030 | 0.559*** |
| | *(0.074)* | *(0.087)* | *(0.080)* | *(0.130)* |
| R&D cooperation with research institutes | 0.423*** | 0.256** | 0.615*** | 0.498 |
| | *(0.092)* | *(0.124)* | *(0.143)* | *(0.304)* |
| **Political Control** | | | | |
| Legally registered as SOE | -0.112* | 0.039 | -0.262** | -0.087 |
| | *(0.067)* | *(0.120)* | *(0.131)* | *(0.091)* |
| State holds up to 25% ownership | -0.054 | -0.261 | -0.002 | 0.025 |
| | *(0.153)* | *(0.396)* | *(0.236)* | *(0.271)* |
| State holds 25-50% ownership | -0.138 | -0.035 | -0.275*** | 0.191 |
| | *(0.116)* | *(0.262)* | *(0.105)* | *(0.246)* |
| State holds 51% to 99% ownership | 0.073 | 0.005 | -0.191 | 0.320* |
| | *(0.101)* | *(0.178)* | *(0.117)* | *(0.186)* |
| State holds 100% ownership | -0.100 | -0.298*** | -0.067 | 0.127 |
| | *(0.084)* | *(0.080)* | *(0.191)* | *(0.110)* |
| **Competition** | | | | |
| Market share >10% | 0.172** | -0.037 | 0.277*** | 0.239 |
| | *(0.083)* | *(0.157)* | *(0.076)* | *(0.176)* |
| # of competitors in main business | 0.132 | 0.100 | 0.121 | 0.111 |
| | *(0.097)* | *(0.169)* | *(0.202)* | *(0.198)* |
| # of competitors in main business (squared) | -0.023 | -0.026 | -0.019 | -0.011 |
| | *(0.015)* | *(0.026)* | *(0.032)* | *(0.031)* |
| Firm exports goods | 0.159** | -0.143 | 0.171 | 0.465*** |
| | *(0.076)* | *(0.096)* | *(0.104)* | *(0.125)* |
| Industry | YES | YES | YES | YES |
| **Firm characteristics** | | | | |
| Founded before reform | 0.278*** | 0.326*** | 0.325** | 0.082 |
| | *(0.079)* | *(0.106)* | *(0.143)* | *(0.152)* |
| Log value of assets | 0.078*** | 0.065*** | 0.119*** | 0.073* |
| | *(0.016)* | *(0.021)* | *(0.028)* | *(0.038)* |
| Average debt to asset ratio | 0.020 | 0.028 | 0.011 | 0.029 |
| | *(0.019)* | *(0.032)* | *(0.046)* | *(0.029)* |
| City | YES | YES | YES | YES |
| _cons | -1.909*** | -1.459*** | -2.189*** | -1.722*** |
| | *(0.205)* | *(0.195)* | *(0.338)* | *(0.491)* |
| r2 | | | | |
| chi2 | . | . | . | . |
| N | 3101 | 1137 | 1048 | 916 |

* p<0.10, ** p<0.05, *** p<0.01

**Appendix A. Proof for equation (7) or $\frac{\partial I_i^*}{\partial m} > 0$ and equation (8) or $\frac{\partial \pi^*}{\partial m} > 0$**

Equations (6) are equivalent to:

$$C\frac{\partial \pi}{\partial I_i} + P\frac{\partial \phi}{\partial I_i} = 0 \tag{A1}$$

and

$$C\frac{\partial^2 \pi}{\partial {I_i}^2} + P\frac{\partial^2 \phi}{\partial {I_i}^2} < 0 \tag{A2}$$

Note that *C* and *P* are functions of marktization *m* while $\pi$ and $\phi$ are functions of investment $I_i \left(= -I_p\right)$ and privatization *a*. Therefore, we can solve (A1) with respect to $I_i$ as a function of *m* and *a*. In other words, the optimal investment level given *a* and *m* $\left[I_i^* = I_i(a,m)\right]$ is implicit in (A1).

Plugging $I_i^* = I_i(a,m)$ into (A1) and differentiating both sides with *m*,

$$\frac{\partial}{\partial m}\left( C(m)\frac{\partial \pi\left(a, I_i(a,m)\right)}{\partial I_i} + P(m)\frac{\partial \phi\left(a, I_i(a,m)\right)}{\partial I_i} \right) = 0$$

After some algebra,

$$\underbrace{\frac{\partial C}{\partial m}\cdot\frac{\partial \pi}{\partial I_i}}_{(+)\times(+)} + \underbrace{\frac{\partial P}{\partial m}\cdot\frac{\partial \phi}{\partial I_i}}_{(-)\times(-)} + \underbrace{\left( C\frac{\partial^2 \pi}{\partial {I_i}^2} + P\frac{\partial^2 \phi}{\partial {I_i}^2} \right)}_{(-)\text{ by (A2)}}\frac{\partial I_i(a,m)}{\partial m} = 0 \tag{A3}$$

In (A3), the first two terms are positive by (2) and (3). At the same time, $C\frac{\partial^2 \pi}{\partial {I_i}^2} + P\frac{\partial^2 \phi}{\partial {I_i}^2}$ is negative by (A2). In order to make the total sum zero, $\frac{\partial I_i(a,m)}{\partial m}$ should be positive.

Therefore, equation (7) is proved.

Let us notate innovation capacity at the optimal investment by $\pi^*$:

$$\pi^* = \pi\left(a, I_i^*\right) = \pi\left(a, I_i(a,m)\right) \tag{A4}$$

Then,

$$\frac{\partial \pi^*}{\partial m} = \frac{\partial \pi\left(a, I_i(a,m)\right)}{\partial m} = \frac{\partial \pi}{\partial I_i} \cdot \frac{\partial I_i^*}{\partial m} > 0 \tag{A5}$$

by (3) and (7). Therefore, equation (8) is proved.

**Appendix B. Proof for equation (9) or $\frac{\partial \pi^*}{\partial a} > 0$**

First, we will show $\frac{\partial \pi}{\partial a} > 0$.

From (5),

$$\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right) = \frac{\partial}{\partial I_i}\left(\frac{\partial \pi}{\partial a}\right) > 0 \quad \text{(B1)}$$

if $\pi(a, I_i)$ behaves smoothly and has continuous second partial derivatives (Clairaut's theorem). Let $\frac{\partial \pi(a, I_i)}{\partial a} \equiv f(a, I_i)$. Then, (B1) can be re-written such that:

$$\frac{\partial f(a, I_i)}{\partial I_i} > 0 \quad \text{(B1)'}$$

We reasonably assume that innovation capacity is zero if there is no investment into innovation, regardless of privatization level. Namely,

$$\pi(a, 0) = 0 \text{ for any } a \quad \text{(B2)}$$

Trivially from (B2),

$$\frac{\partial \pi(a, 0)}{\partial a} = f(a, 0) = 0 \quad \text{(B3)}$$

From (B1)', $f(a, I_i)$ is an increasing function with $I_i$ wit an initial value zero by (B3). As a result,

$$f(a, I_i) > 0 \text{ or } \frac{\partial \pi(a, I_i)}{\partial a} > 0 \text{ for any } a \text{ and } I_i \quad \text{(B4)}$$

which completes the proof of $\frac{\partial \pi}{\partial a} > 0$.

Second, we will show:

$$\frac{\partial I_i^*}{\partial a} > 0 \tag{B5}$$

By plugging $I_i^* = I_i(a,m)$ into (A1) and differentiating both sides with *a*,

$$\frac{\partial}{\partial a}\left( C(m)\frac{\partial \pi\left(a, I_i(a,m)\right)}{\partial I_i} + P(m)\frac{\partial \phi\left(a, I_i(a,m)\right)}{\partial I_i} \right) = 0$$

After some algebra,

$$\underbrace{C\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right)}_{(+)\text{ by (5)}} + \underbrace{P\frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_i}\right)}_{(+)\text{ by (5)}'} + \underbrace{\left(C\frac{\partial^2 \pi}{\partial I_i^{\,2}} + P\frac{\partial^2 \phi}{\partial I_i^{\,2}}\right)}_{(-)\text{ by (A2)}}\frac{\partial I_i(a,m)}{\partial a} = 0 \tag{B6}$$

In order to make the total sum zero on the left side of (B6), $\frac{\partial I_i(a,m)}{\partial a} = \frac{\partial I_i^*}{\partial a}$ should be positive. Therefore, equation (B5) is proved.

Finally, we can prove (9) or $\frac{\partial \pi^*}{\partial a} > 0$ by (B4) and (B5) because:

$$\frac{\partial \pi^*}{\partial a} = \frac{\partial \pi\left(a, I_i(a,m)\right)}{\partial a} = \underbrace{\frac{\partial \pi}{\partial a}}_{(+)\text{ by (B4)}} + \underbrace{\frac{\partial \pi}{\partial I_i}}_{(+)\text{ by (3)}} \cdot \underbrace{\frac{\partial I_i(a,m)}{\partial a}}_{(+)\text{ by (B5)}} > 0 \tag{B7}$$

**Appendix C. Proof for equation (11) or $\frac{\partial}{\partial m}\left(\frac{\partial \pi^*}{\partial a}\right) > 0$ with qualifications**.

For interpretative convenience, we can decompose $\frac{\partial \pi^*}{\partial a}$ into two parts: a *main component* $\left(=\frac{\partial \pi}{\partial a}\right)$ plus a *correcting component* $\left(=\frac{\partial \pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}\right)$ in (B7). Then, $\frac{\partial}{\partial m}\left(\frac{\partial \pi^*}{\partial a}\right)$ also can be decomposed into two parts:

$$\frac{\partial}{\partial m}\left(\frac{\partial \pi^*}{\partial a}\right) = \frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial a}\right) + \frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}\right) \tag{C1}$$

It is clear that

$$\frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial a}\right) = \frac{\partial}{\partial I_i}\left(\frac{\partial \pi}{\partial a}\right)\cdot\frac{\partial I_i^*}{\partial m} > 0 \tag{C2}$$

because $\frac{\partial^2 \pi}{\partial I_i \partial a} > 0$ by (5) or (B1) and $\frac{\partial I_i^*}{\partial m} > 0$ by (7). In other words, the main component $\frac{\partial \pi}{\partial a}$ always increases with marketization *m*. The question is how the correcting component $\frac{\partial \pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}$ behaves with increasing marketization or what the sign of $\frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}\right)$ is in (C1).

To answer this question, we assume [1] $\frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_p}\right) = -\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right)$; and [2] $\frac{\partial}{\partial a}\left|\frac{\partial^2 \pi}{\partial {I_i}^2}\right| < 0$.

Those two assumptions are not arbitrary or convenient but presumable. The first one simply assumes that parameter *a* as the reverse degree of political involvement in a firm has the comparable effects between the effectiveness of innovation investment $\left(=\frac{\partial \pi}{\partial I_i}\right)$

and the effectiveness of politics investment $\left(=\frac{\partial \phi}{\partial I_p}\right)$ though the directions of those effects

should be opposite. The second assumption is a stronger form of our *politics proposition*

because political involvement not only decreases the effectiveness of innovation

investment, as is expressed by $\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right) > 0$ or by (5), but also accelerates the decreasing

marginal improvements in the probability of successful innovation, as is expressed by

$\frac{\partial}{\partial a}\left|\frac{\partial^2 \pi}{\partial I_i^{\,2}}\right| < 0$ or by assumption [2]. Note that assumption [1] is equivalent to

$\frac{\partial^2 \phi}{\partial a \partial I_i} = \frac{\partial^2 \pi}{\partial a \partial I_i}$ because $\partial I_i = -\partial I_p$ and thus we can derive

$$\frac{\partial^3 \phi}{\partial a \partial I_i^2} = \frac{\partial^3 \pi}{\partial a \partial I_i^2} \tag{C3}$$

by differentiating both sides of $\frac{\partial^2 \phi}{\partial a \partial I_i} = \frac{\partial^2 \pi}{\partial a \partial I_i}$ with $I_i$. Also note that assumption [2] is

equivalent to

$$\frac{\partial}{\partial a}\left(\frac{\partial^2 \pi}{\partial I_i^2}\right) > 0 \tag{C4}$$

because $\frac{\partial^2 \pi}{\partial I_i^2} < 0$ and thus $\left|\frac{\partial^2 \pi}{\partial I_i^2}\right| = -\frac{\partial^2 \pi}{\partial I_i^2}$ in assumption [2].

As a next step, we move to (A3) with simplifying some notations such that

$\frac{\partial C}{\partial m}\left(=\frac{dC}{dm}\right)=C'(m)$ and $\frac{\partial P}{\partial m}\left(=\frac{dP}{dm}\right)=P'(m)$ because both $C$ and $P$ only depend on $m$ in our model. Re-write (A3) with these notations:

$$C'\frac{\partial \pi}{\partial I_i}+P'\frac{\partial \phi}{\partial I_i}+\left(C\frac{\partial^2 \pi}{\partial I_i^{\,2}}+P\frac{\partial^2 \phi}{\partial I_i^{\,2}}\right)\frac{\partial I_i^*}{\partial m}=0 \tag{A3)'$$

Differentiate both sides of (A3)' with $a$:

$$\underbrace{\left(C'+P'\right)\frac{\partial^2 \pi}{\partial a \partial I_i}}_{\text{by [1]}}+\underbrace{\left(C+P\right)\frac{\partial^3 \pi}{\partial a \partial I_i^{\,2}}}_{\text{by (C3)}}\cdot\frac{\partial I_i^*}{\partial m}+\left(C\frac{\partial^2 \pi}{\partial I_i^{\,2}}+P\frac{\partial^2 \phi}{\partial I_i^{\,2}}\right)\frac{\partial^2 I_i^*}{\partial a \partial m}=0 \qquad \text{(C5)}$$

We will specify two alternative relationships between $C(m)$ and $P(m)$ as two substitutable components of the total payoff and show $\frac{\partial^2 I_i^*}{\partial a \partial m}>0$ in (C5) for each of the two relationships.

<u>Case 1</u>: If $C(m)+P(m)=k$ (constant) or if competitive and political payoffs are linearly substitutable, it follows that $C'(m)+P'(m)=0$ and (C5) can be simplified as

$$k\underbrace{\frac{\partial^3 \pi}{\partial a \partial I_i^{\,2}}}_{(+)\text{ by (C4)}}\cdot\underbrace{\frac{\partial I_i^*}{\partial m}}_{(+)\text{ by (7)}}+\underbrace{\left(C\frac{\partial^2 \pi}{\partial I_i^{\,2}}+P\frac{\partial^2 \phi}{\partial I_i^{\,2}}\right)}_{(-)\text{ by (A2)}}\frac{\partial^2 I_i^*}{\partial a \partial m}=0 \qquad \text{(C6)}$$

Therefore, in order to make the left side of (C6) zero, we conclude

$$\frac{\partial^2 I_i^*}{\partial a \partial m}>0 \qquad \text{(C7)}$$

<u>Case 2</u>: If $C(m)\cdot P(m)=k$ (constant), It follows that $C'P+CP'=0$ or $-\frac{C'}{P'}=\frac{C}{P}$ and (C5) can be re-written as

$$P'\left(\frac{C'}{P'}+1\right)\frac{\partial^2\pi}{\partial a\partial I_i}+P\left(\frac{C}{P}+1\right)\frac{\partial^3\pi}{\partial a\partial I_i^{\,2}}\cdot\frac{\partial I_i^*}{\partial m}+\left(C\frac{\partial^2\pi}{\partial I_i^{\,2}}+P\frac{\partial^2\phi}{\partial I_i^{\,2}}\right)\frac{\partial^2 I_i^*}{\partial a\partial m}=0$$

or

$$\underbrace{P'}_{(-)\text{ by }(2)}\underbrace{\left(1-\frac{C}{P}\right)}_{(-)\text{ if }C>P}\underbrace{\frac{\partial^2\pi}{\partial a\partial I_i}}_{(+)\text{ by }(5)}+P\underbrace{\left(\frac{C}{P}+1\right)}_{(+)}\underbrace{\frac{\partial^3\pi}{\partial a\partial I_i^{\,2}}}_{(+)\text{ by (C4)}}\cdot\underbrace{\frac{\partial I_i^*}{\partial m}}_{(+)\text{ by }(7)}+\underbrace{\left(C\frac{\partial^2\pi}{\partial I_i^{\,2}}+P\frac{\partial^2\phi}{\partial I_i^{\,2}}\right)}_{(-)\text{ by (A2)}}\frac{\partial^2 I_i^*}{\partial a\partial m}=0 \qquad \text{(C8)}$$

Therefore, if marketization is achieved enough to satisfy $C(m)>P(m)$, we again conclude $\frac{\partial^2 I_i^*}{\partial a\partial m}>0$ or (C7). In sum, we proved $\frac{\partial^2 I_i^*}{\partial a\partial m}>0$ for both relationships between competitive and political payoffs.

Revisiting the correcting component in (C1),

$$\begin{aligned}\frac{\partial}{\partial m}\left(\frac{\partial\pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}\right)&=\frac{\partial}{\partial m}\left(\frac{\partial\pi}{\partial I_i}\right)\cdot\frac{\partial I_i^*}{\partial a}+\frac{\partial\pi}{\partial I_i}\cdot\frac{\partial}{\partial m}\left(\frac{\partial I_i^*}{\partial a}\right)\\&=\underbrace{\frac{\partial^2\pi}{\partial I_i^{\,2}}}_{(-)\text{ by }(10)}\cdot\underbrace{\frac{\partial I_i^*}{\partial m}}_{(+)\text{ by }(7)}\cdot\underbrace{\frac{\partial I_i^*}{\partial a}}_{(+)\text{ by }(B5)}+\underbrace{\frac{\partial\pi}{\partial I_i}}_{(+)\text{ by }(3)}\cdot\underbrace{\frac{\partial^2 I_i^*}{\partial m\partial a}}_{(+)\text{ by (C7)}}\end{aligned} \qquad \text{(C9)}$$

which is likely to be positive if the first term $\frac{\partial^2\pi}{\partial I_i^{\,2}}(<0)$ is small or if $\left|\frac{\partial^2\pi}{\partial I_i^{\,2}}\right|<<1$. In other words, the correcting component of $\frac{\partial\pi^*}{\partial a}$ or $\frac{\partial\pi}{\partial I_i}\cdot\frac{\partial I_i^*}{\partial a}$ increases with marketization *m* if the decreasing marginal improvement in the probability of successful innovation or $\frac{\partial^2\pi}{\partial I_i^{\,2}}$ is *moderate*.

Considering (C9) together with the main component or $\frac{\partial}{\partial m}\left(\frac{\partial\pi}{\partial a}\right)>0$ in (C2), we finally reach the increasing positive effect of private property rights:

$$\frac{\partial}{\partial m}\left(\frac{\partial \pi^*}{\partial a}\right) = \frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial a}\right) + \frac{\partial}{\partial m}\left(\frac{\partial \pi}{\partial I_i} \cdot \frac{\partial I_i^*}{\partial a}\right) > 0 \qquad (11)$$

or our hypothesis 4:

> *With rising marketization* (so that *C*(*m*)>*P*(*m*) is fulfilled), *political involvement will have an increasingly negative impact on a firm's innovativeness*

when [1] the effect of political involvement in a firm helps effective politics to the same extent as it hinders effective innovation (i.e., $\frac{\partial}{\partial a}\left(\frac{\partial \phi}{\partial I_p}\right) = -\frac{\partial}{\partial a}\left(\frac{\partial \pi}{\partial I_i}\right)$); and [2] the degree of decreasing marginal improvement in the probability of successful innovation is larger, though still *moderate*, when political involvement is stronger (i.e. $\left|\frac{\partial^2 \pi}{\partial I_i^{\,2}}\right| << 1$ and $\frac{\partial}{\partial a}\left|\frac{\partial^2 \pi}{\partial I_i^{\,2}}\right| < 0$).

Note that our formal model and appendices did not conveniently assume any concrete functional forms except for the two alternative relationships between *C*(*m*) and *P*(*m*) in appendix C.

## Appendix D: Correlation Matrix

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Patent in 2002 | 1.00 | | | | | | | | | | | | | | |
| 2 | Product innovation | 0.219 | 1.000 | | | | | | | | | | | | | |
| 3 | Process innovation | 0.241 | 0.512 | 1.000 | | | | | | | | | | | | |
| 4 | New Quality control | 0.156 | 0.375 | 0.456 | 1.000 | | | | | | | | | | | |
| 5 | Firm holds patents | 0.792 | 0.246 | 0.273 | 0.176 | 1.000 | | | | | | | | | | |
| 6 | Firm conducts R&D | 0.242 | 0.385 | 0.332 | 0.272 | 0.285 | 1.000 | | | | | | | | | |
| 7 | Average R&D-to-sales ratio | 0.004 | 0.027 | 0.031 | -0.017 | 0.058 | 0.050 | 1.000 | | | | | | | | |
| 8 | Located in industrial park | 0.145 | 0.208 | 0.177 | 0.196 | 0.152 | 0.254 | 0.044 | 1.000 | | | | | | | |
| 9 | Member of business assoc. | 0.122 | 0.210 | 0.151 | 0.152 | 0.135 | 0.181 | 0.020 | 0.059 | 1.000 | | | | | | |
| 10 | R&D coop with firm | 0.080 | 0.229 | 0.195 | 0.161 | 0.058 | 0.162 | -0.002 | 0.143 | 0.104 | 1.000 | | | | | |
| 11 | R&D coop with university | 0.245 | 0.270 | 0.215 | 0.199 | 0.259 | 0.305 | 0.002 | 0.214 | 0.162 | 0.249 | 1.000 | | | | |
| 12 | R&D coop with research inst. | 0.182 | 0.268 | 0.271 | 0.222 | 0.227 | 0.268 | 0.004 | 0.163 | 0.148 | 0.334 | 0.406 | 1.000 | | | |
| 13 | Legally registered as SOE | -0.062 | -0.001 | -0.039 | -0.084 | -0.076 | -0.024 | -0.013 | -0.159 | 0.073 | -0.029 | -0.003 | 0.000 | 1.000 | | |
| 14 | State holds up to 25% shares | 0.031 | 0.037 | 0.047 | 0.028 | 0.083 | 0.045 | -0.003 | -0.005 | 0.021 | 0.036 | 0.036 | 0.038 | -0.065 | 1.000 | |
| 15 | State holds 25-50% shares | 0.019 | 0.024 | 0.045 | 0.026 | 0.052 | 0.048 | -0.004 | 0.015 | 0.034 | 0.039 | 0.030 | 0.009 | 0.015 | -0.018 | 1.000 |
| 16 | State holds 51-99 % shares | 0.025 | 0.016 | 0.011 | 0.025 | 0.021 | 0.037 | -0.004 | -0.024 | 0.010 | -0.006 | 0.039 | 0.022 | 0.004 | -0.022 | -0.020 |
| 17 | State holds 100% shares | -0.056 | -0.014 | -0.047 | -0.084 | -0.059 | -0.033 | -0.013 | -0.145 | 0.061 | -0.048 | -0.021 | -0.034 | 0.627 | -0.065 | -0.060 |
| 18 | Market share > 10% | 0.229 | 0.214 | 0.209 | 0.165 | 0.250 | 0.258 | -0.004 | 0.163 | 0.096 | 0.049 | 0.170 | 0.128 | 0.005 | 0.048 | 0.054 |
| 19 | Number of competitors | -0.207 | -0.221 | -0.206 | -0.163 | -0.225 | -0.256 | 0.012 | -0.167 | -0.020 | -0.071 | -0.151 | -0.147 | -0.020 | -0.064 | -0.052 |
| 20 | Number of competitors (squared) | -0.221 | -0.246 | -0.230 | -0.179 | -0.243 | -0.283 | 0.014 | -0.180 | -0.031 | -0.083 | -0.171 | -0.157 | -0.014 | -0.062 | -0.060 |
| 21 | Firm exports | 0.157 | 0.165 | 0.154 | 0.162 | 0.176 | 0.172 | -0.008 | 0.165 | 0.089 | 0.020 | 0.066 | 0.092 | -0.090 | 0.058 | 0.082 |
| 22 | Founded before 1978 | 0.041 | 0.000 | -0.010 | 0.079 | 0.041 | -0.019 | 0.013 | 0.168 | -0.132 | 0.023 | -0.000 | -0.007 | -0.422 | -0.021 | 0.002 |
| 23 | Log value of average assets | 0.172 | 0.240 | 0.238 | 0.210 | 0.200 | 0.320 | -0.004 | 0.105 | 0.254 | 0.065 | 0.156 | 0.162 | 0.296 | 0.081 | 0.116 |
| 24 | Average debt to asset ratio | 0.031 | 0.038 | -0.016 | -0.011 | 0.037 | 0.031 | 0.002 | 0.026 | -0.058 | 0.018 | 0.059 | 0.012 | -0.118 | 0.001 | -0.035 |

Correlation Matrix, ctnd.

| | | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | State holds 51-99 % shares | 1.000 | | | | | | | | |
| 17 | State holds 100% shares | -0.073 | 1.000 | | | | | | | |
| 18 | Market share > 10% | 0.063 | -0.040 | 1.000 | | | | | | |
| 19 | Number of competitors | -0.031 | 0.020 | -0.393 | 1.000 | | | | | |
| 20 | Number of competitors (squared) | -0.033 | 0.028 | -0.393 | 0.985 | 1.000 | | | | |
| 21 | Firm exports | 0.014 | -0.086 | 0.145 | -0.139 | -0.151 | 1.000 | | | |
| 22 | Founded before 1978 | -0.047 | -0.405 | -0.022 | 0.009 | 0.006 | 0.071 | 1.000 | | |
| 23 | Log value of average assets | 0.080 | 0.214 | 0.219 | -0.231 | -0.245 | 0.245 | -0.270 | 1.000 | |
| 24 | Average debt to asset ratio | -0.024 | -0.082 | 0.009 | -0.033 | -0.045 | -0.064 | 0.103 | -0.363 | 1.000 |