

Revisiting the National Innovation System in Developing Countries

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WORLD BANK GROUP

Equitable Growth, Finance and Institutions Global Practice Group

Office of the Chief Economist

October 2017

Abstract

The paper argues that there is a greater commonality of approach between the National Innovation Systems approach and mainstream economic analysis than is often asserted, and that a better dialogue between the two could strengthen both perspectives. To this end, the

paper uses an off-the-shelf neoclassical model to provide a tentative structure for what a National Innovation Systems schematic might look like and where its boundaries should be. Simulations from the model suggest how present benchmarking techniques may be misleading.

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Revisiting the National Innovation System in Developing Countries¹

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JEL: 032, 038, B52, L2, O47

Keywords: National Innovation Systems, Technological Diffusion, Firm Capabilities, Innovation Benchmarking.

¹ My thanks to Jose Miguel Benevente, Laura Chioda, Xavier Cirera, Charles Edquist, Keun Lee, Bengt Åke Lundvall, and Juan Rogers for very thoughtful comments. This work partially financed by the Knowledge for Change Trust Fund.

1. Innovation Systems

A very influential literature on National Innovation Systems (see among others Freeman 1987, Lundvall 1992, 1997, Nelson 1993, and Soete 2010 et. al.) seeks to understand the institutions, human capital and interactions among them that facilitate the creation and diffusion of knowledge.² As such, it speaks directly to the developing country growth agenda and offers a wealth of insight into how innovation, and then growth, happens.

Though very heterogeneous, the literature is distinguished by a skepticism of mainstream neoclassical economics. In particular, it rejects the idea of fully rational and omniscient firms, is doubtful of the optimality of the observed market outcome, and tends to dismiss the policy approach of identifying market failures and resolving them with targeted economic interventions. Correspondingly, it sees the state and institutions as central to facilitating the accumulation of firm capabilities and technological transfer more generally. The critiques are profound and merit close consideration by the mainstream. That said, the reluctance to engage with more market-based frameworks makes dialogue difficult with the many policy economists for whom neoclassical economics constitutes their principal analytical toolkit.³

Without attempting to address all the points of disagreement in the two literatures, this paper argues that there is more common ground than often portrayed- increasingly so over the last decades- and that this offers an opportunity to advance that dialogue. On the one hand, while the bounded rationality of firms has long been at the center of the National Innovation System (NIS) literature, new mainstream literatures have empirically opened the black box of the firm and confirmed great

² See Freeman 1995 and Lundvall et al. (2002) for a discussion of the origins of the term. Freeman traces the origin of the concept of a National Innovation System originated with Friedrich List's (1841) discussion of the system of institutions and policies, most related to the learning about new technology and applying it, to Germany's catch up with England. See also Smits et al (2010) for a recent review as well as Lee (2013) in the context of leap frogging in Asia and Latin America.

³ OECD (1997, 2004) has also worked to bring the two perspectives together. As OECD (2004) notes, "A common perception of the NIS approach has been that it focuses on systemic failures rather than market failures. This perception has led to an 'anti-market' bias, leaving the NIS approach difficult to apply for policy purposes. However, markets and market failures may be included more explicitly in the NIS approach on the grounds that any of the key institutional forms are essential for innovation and knowledge flows, and that policy makers need to make use of all of them, and indeed understand how they interact." (p. 15) That is, the market is treated as a complementary institution. This paper works from the other end- modeling the market in the mainstream economic tradition and trying to see how the institutions are resolving market failures.

variation in managerial practices, and discussions of institutions are now central to the mainstream growth debate as well. On the other, even if not accepting optimality, an important current of the NIS literature does, in the end, acknowledge the centrality of the market and market incentives as the principal allocator of resources.

Attempting to build on this common ground, the paper first highlights features of a simple mainstream neoclassical model that can capture and are consistent with many of the NIS literature concerns. The resulting framework offers insights into the range and importance of factors complementary to knowledge accumulation and where we should “draw the circle” around the NIS— what elements should be considered critical to include in innovation discussions. Second, the framework suggests an important reconsideration of how we benchmark NIS performance and illustrates using cross country data how common benchmarking approaches can be importantly misleading.

2. The centrality of the firm and the importance of capability building

A central tenet of the NIS literature is the centrality of the firm (see, for example, Nelson, 1993 and Lundvall, 2007). This merits highlighting first because of the commonality of focus with the neoclassical literature, and second because this point can get lost in discussions of innovation institutions themselves. The firm, not laboratories, nor universities nor government, takes ideas to market and creates value added. Nelson and Rosenberg (1993), for example, use the term ‘innovation’ to encompass “the processes by which *firms* master and get into practices, product designs and manufacturing processes that are new to them, whether or not they are new to the university or even to the nation.” (p. 349 Italics mine)

However, Lundvall articulates a common rejection in the NIS literature of the firm as a rational, omniscient actor in favor of entrepreneurs who must acquire capabilities and learn in a profound way how to learn and innovate. He is critical that “If, at all, agents are allowed to learn in a neo-classical model, learning is either understood as getting access to more or more precise information about the world or it is a black-box phenomenon as in growth models assuming ‘learning by doing.’⁴ The

⁴ Lee (2013) argues against the neoclassical view of just offsetting innovation related market failures in his discussion of the Asian miracles. “However, a problem with this market failure view is that it assumes that firms are already capable of

fundamental fact that agents-individuals as well as firms- *are more or less competent* in what they are doing and that they may learn how to become more competent is abstracted from in order to keep the analysis simple and based upon representative firms and agents.”⁵ Students of innovation working in a more evolutionary tradition such as Nelson (2006) argue that firms suffer from bounded rationality and, rather than re-optimizing constantly over the entire global information set, they engage in certain culturally and historically conditioned *routines* that help manage information, but at the same time, limit their innovative activities. Advance occurs through an evolutionary process where weak forms of operation disappear and more successful models take over rather than rational actors cruising a perfect foresight path to the frontier.

These critiques have led to skepticism about the usefulness of the market and the presumed optimality of its outcomes. As an example, in the recent *Handbook of Innovation Systems and Developing Countries*, led by Bengt-Åke Lundvall et al. (2009), Cimoli, Dosi, Nelson, and Stiglitz (2009) argue that “market omniscience” is a misleading point of departure and that “In a profound sense, when judged by standard canons, the whole world can be seen as a giant market failure” (p.339). While these authors at least frame the problem through the market failure lens, Altenburg (2009) in the same volume notes that the innovation systems literature “rarely explores the role of markets or market-enhancing systems in a systemic way... What is more, neo-classical research is rarely quoted, or challenged.” (p. 43) Hence, the state is assigned a much larger task of “influencing the nature of the knowledge base of firms and to increase absorptive capacity” as well as fomenting coordination among various market and non-market actors (Soete, 2010).

3. Areas of convergence

Arguably, despite these seeming irreconcilable approaches, there are important areas of convergence, particularly in the area of firm capabilities and the role of the market and institutions. This section explores these with the goal of clearing some common ground for NIS thinking going forward.

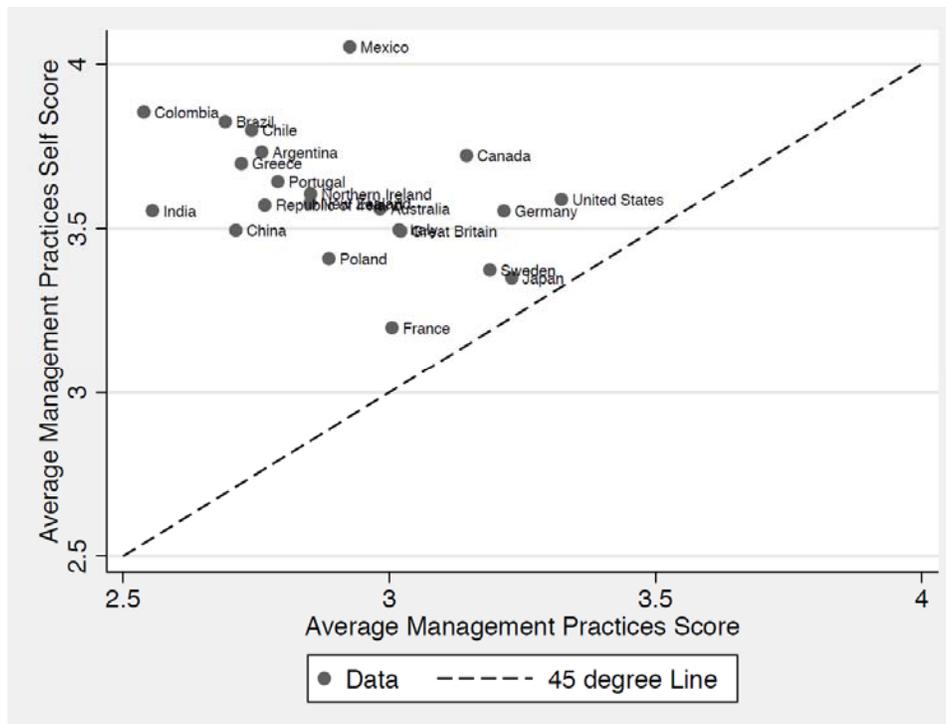
conducting R&D, and it is concerned only about the sub-optimality of R&D activities. In other words, the reasons for sub-optimality are found outside the firm, such as in the capital market or risk market. However, the reality in a typical developing country is that private firms do not know how to conduct in-house R&D and thus view it as a very uncertain endeavor with uncertain returns.”

⁵ New growth theory may allow for learning by doing but in order to remain a member of the neoclassical family it has not allowed itself to give up the basic assumptions about rational profit maximizing representative firms (Lundvall p. 23).

Firm capabilities

There has long been a business and management literature on the development of firm capabilities (e.g., Teece 1994 and 1997), and it has found great resonance in the literature on the Asian miracles (see Kim 1997, Lee 2013). Sutton (2000) in his Keynes Lecture argued that scarce firm capabilities in the Nelson-Winter sense were the primary drivers of global income polarization. Most recently, the work by Bloom and Van Reenen (2007) and the World Management Survey they have pioneered has suggested large differences in management practices across firms and countries, in their abilities to identify new technologies, and to define long term goals and human resource strategies that are prerequisites for significant technological adoption or R&D.

Figure 1: Measured and Self-Evaluated Management Practices Score



Source: World Management Survey and author's calculations.

Further, they find very limited connection between firms' subjective opinion of their managerial opinion, and their actual measured score. As Figure 1 shows, not only do entrepreneurs in most countries over estimate their abilities, but also the magnitude of their overconfidence increases with

distance from the managerial frontier.⁶ Firms increasingly do not seem to know what they do not know about the frontier technology of even running their firm -- they are, in fact, only “more or less competent” as Lundvall put it- and they are certainly not using full information to locate it.

Optimality and the role of the market

It is not obvious that these deviations from rationality dictate discarding the market and the neoclassical framework that simplistically attempts to model it. It is important to stress that “more or less competent” does not imply “incompetent,” that “bounded rationality” does not imply “irrationality.” Interviews with firms suggest that however badly they score on the World Management Survey, they do broadly adopt practices that are consistent with profit maximization, that is, they weigh the costs of inputs, think of how best to combine complementary factors to produce output, etc., and they respond to incentives set by the market. Even while questioning what can be said about the overall “optimality” of the resulting market outcome- a concern shared by many neoclassical economists schooled in the theory of the second best- it is not obvious that government functionaries (or international bureaucrats) have so much better information or capability to replace it. There are writers in the NIS literature who appear to broadly accept this view. Despite the scale and ubiquity of the market failures, many of which Stiglitz details in his Nobel lecture, Cimoli, Dosi, Nelson and Stiglitz (2009) make a plea for consensus based on a “pragmatic view of markets.” Chaminade and Edquist (2010) working firmly in the NIS tradition, argue that “Innovation policy – or other kinds of public intervention – should be complementary to the market, not replace or duplicate it.”

Nonetheless, important voices in the NIS literature, including Nelson in other writings, are skeptical about the value of mainstream analytical tools and thus form part of a long standing and much broader debate about where psychological and behavioral insights will lead economics. Rabin (2013) and Harstad and Selten (2013) in a recent and balanced discussion in the *Journal of Economic Literature* explore both the limitations of new bounded rationality models, and the incipient progress integrating bounded rationality in mainstream optimization models. What emerges is that key pioneers in introducing psychological insights into economics and exploring bounded rationality, such as Rabin, still see the core of microeconomic theory and empirics as having been a success and hence see

⁶ The subjective scale ranges from 1-10 and the objective from 1-5. We have simply divided the former by two and this may lead to a misalignment of means. However, the downward slope would remain however we center the data.

abandoning the approach as premature and costly in lost analytical insight. Even if agents do not fully incorporate all information or refer to particular reference points, for example, they are still optimizing *something* and respond to relevant incentives in ways that can be modeled.⁷ Sutton (2001) in his work on *Technology and Market Structure* argues that we can go a long way in analyzing industry structure and equilibria if we assume that only some firms are fully and optimizing while the mass are perhaps boundedly rational. Krugman (1996), himself willing to step away from models assuming full blown optimization, in his *What Can Economists Learn from an Evolutionary Perspective?* concludes after surveying the literature that evolutionary theorists more broadly viewed in fact “make use of maximization and equilibrium as modelling devices as useful fictions about the world that allow them to cut through the complexities” and that, in the end, are not so different from modest economists.

Citing neoclassical luminaries who relax the assumptions of full rationality and optimization, but nonetheless continue working in the tradition, does not “settle” anything. It does suggest, however, that the sharp dichotomy between evolutionary and neoclassical perspectives is overdrawn, setting up an unnecessarily Manichean intellectual turf battle.⁸ Nelson’s work, while rejecting literal optimization, full rationality and equilibrium, does engage many algebraic tools of modern economics and values many core elements of the paradigm:

I want to note, highlight, that most of what is valuable in the standard contemporary tool kit of concepts and understandings is not tied to the assumptions of neoclassical theory. I include here such concepts as “public goods” and “externalities”. These concepts surely are extremely valuable in organizing thinking about issues of technology policy. So also is the proposition that for the most part competition is an important vehicle for advancing the public interest, and monopoly or collusion something to be avoided if possible. The argument that “incentives matter” and that, in many cases, designing policies to shape incentives appropriately is a more effective strategy than trying directly to mandate behavior, is built deep within the traditions of today’s standard economics, and almost surely generally provides good guidance. (2007 p. 3)

Fine, but he is staking out a huge middle ground of shared concepts for innovation policy, whatever label you want to put on them. Public goods and externalities result from missing markets and hence social impacts not captured in prices. The basic principal of market competition is shared as a device

⁷ More generally, Thaler (2015) argues that without this rational framework, we cannot even claim these anomalies to be “misbehavior.”

⁸ The historian of technology Joel Mokyr pushes back against the wholesale dismissal of neoclassical economics, arguing that “evolutionary thinking cannot and should not displace much of the economics we are familiar with. The theory of the firm, of the household, of prices and markets and the way we think of economic behavior can perhaps learn something from evolutionary thinking, but they are not in such a state of disrepair that a new “paradigm” can just move in because there exists some kind of intellectual vacuum in economics as it is practiced today.” (P. 4)

for advancing, (if not maximizing), public interest (if not welfare). Incentives matter. From the point of view of making policy, the line becomes extremely unclear between Nelson and say Stiglitz, who works firmly in the neoclassical tradition, while criticizing excessively simple models of development that assume that the failures of the market, including full rationality and information, are second order. Going forward, there is no necessary aversion to formalization of economic relations in the NIS tradition and there is common value placed on market competition, incentives and what the neoclassical tradition calls.

Market failures: Wrong, or just too little?

Cimoli, Dosi, Nelson and Stiglitz (2009) suggest that it is the perceived underestimation by the mainstream of the magnitude of market failures, particularly those relating to firm learning, that drives the frequent dismissal of market failure analysis in the NIS literature, rather than disagreement on principle with that mode of analysis (see Soete 2010 for a discussion). But given the weak capabilities of LDC firms now documented, the idea that simply finding the right subsidy would generate the socially optimal level of innovation can seem a bit of Washington Consensus era Pollyannaism. That said, viewing the apparent success of widespread firm upgrading services globally and of recent random control trials demonstrating a dramatic impact on productivity through a market failure lens would prompt us to ask: “if it is so profitable for firms to upgrade and learn, why don’t firms do it themselves?”⁹ As one response, the European Commission’s *Study of Business Support Services and Market Failure* focused precisely on two types of market failure, both relating to information. First, adverse selection issues when SMEs lack the scale to choose among available services or assess their value or the quality of providers. This asymmetry could prevent the emergence of a support industry even if firms desired to upgrade. The second, is, consistent with biased self-evaluations found by Bloom and Van Reenen, that firms simply do not know what they do not know and hence do not perceive the value of investing in themselves.¹⁰ McKenzie and Woodruff, examine several additional hypotheses

⁹ Recent work suggests that in India, firms receiving managerial consulting from Accenture gained in productivity 11% in one year, more than enough to cover the full cost of Accenture’s intervention and far more than the cost of a local firm service. The prevalence in the advanced countries of large subsidies and programs dedicated to this upgrading (See Ezell. Atkinson 2011, Maloney 2012) suggests that they, too, believe the returns are high.

¹⁰ As Petar Stojic, the former Director of Business Support Policy for Britain’s Department for Business, Innovation and Skills (BIS), which oversees the Manufacturing Advisory Service, comments: The market failure we are trying to address is the information asymmetry market failure. SMEs do not always know what they do not know, and they do not know how useful business expertise can be. And even when the SME manufacturer knows it has a problem, it does not always know how to procure the right solution. After they have worked with MAS, they understand the value of lean principles and/or better innovation practices and the value of external expertise in general, so when they have to pay the full rate in the future, they now know what to look for and have greater confidence in approaching the market. p. 34. In reality, far

ranging from deficient information, to credit and insurance markets. Placing the upgrading question within a market failure framework helps to identify appropriate policy interventions. If it is a credit problem, then creating a government institution to train managers is not the obvious solution.¹¹

Institutions vs the Market?

In a similar way, the “institutional vs. market” dichotomy seems, again, a bit overdrawn. The work by North (1990), Besley (2011), and Acemoglu and Robinson (2012) has put long run institutional analysis at the heart of the neoclassical growth debate and, for instance, Nelson’s insightful work on the necessary co-evolution of supporting “social” technologies or institutions that permit firms to take advantage of technological progress could find a common cause with them. But again, clarifying the failure that justifies these institutions helps in their design and allows us to move beyond policy by organogram. The developing world is replete with public research institutes and universities which look great on paper but whose unclear mission and poor design make them ineffectual players in the NIS. The NIS literature itself struggles to some degree with how much focus should be placed on the institutions themselves vs. the functions they play. Edquist (2004), in an explicit attempt to impart more rigor to the concept of the NIS, has argued that we should focus on functions, including R&D, competence building, incubating activities and consultancy services, and finance, acknowledging that there are numerous ways of resolving the market and coordination failures that may emerge. A focus on “services” that the market is not generating leads us to designing mechanisms/institutions to accomplish tasks or create missing markets.

This is not to downplay the role of trust and personal relations, that are only weakly regulated by economic incentives. These are indeed important currencies circulating among the various nonmarket relations governing Polanyi’s Republic of Science and the multiple helixes. Nor the importance of flows of tacit knowledge that may be less easy to intermediate through market mechanisms. Nor does it deny the historical path dependence that leads to distinct constellations of institutions across

from supplanting private market advisory services, countries’ manufacturing extension services tend to help SME manufacturers understand the value of those cited in Exell and Atkinson (2011).

¹¹ The vast resources spent by Japan, Singapore, the Republic of Korea, and Taiwan, China, on firm upgrading/ 5S/ Kaizen type programs for SMEs, in spite of reasonably functioning credit markets suggests that this is probably not sufficient, and that the kind of interventions necessary may be more analogous to public schooling. But the point is, identifying the failure disciplines the policy design.

countries. However, *a grosso modo*, as Nelson states, incentives matter, too. For instance, the optimal level of basal financing, matching grants, private contracts to ensure quality and alignment with private sector needs for public research institutions or universities- is also recognized as a central issue and market failure analysis informs how we approach the question.¹²

4. Mapping an NIS from a simple model of technological transfer

To explore these likely areas of commonality in a more systematic way, this section offers a sketch of a stripped down neoclassical model by Klenow and Rodriguez-Clare (2004) that can formalize some NIS insights and generates some important implications for both traditions, particularly in what we think should be included in our conception of the NIS, and in how we benchmark innovation performance. Readers are referred to the original for a complete presentation.

We begin simply assuming that firms produce goods combining labor (L), physical capital (K), human capital (h) and knowledge (A). Adopting a standard mathematical simplification, firm i 's production function is given by

$$Y_i = K_i^\alpha (A_i h_i L_i)^{1-\alpha}$$

The terms α and $(1-\alpha)$ capture output elasticities of capital and labor respectively¹³ and dictate constant returns to scale. Here there are no behavioral assumptions, this is simply a statement about how goods are produced physically.¹⁴

¹² At one extreme, many Latin American research institutes often had poorly defined mandates, full basal financing and hence little incentive to produce research relevant to, or engage with the private sector. At the other extreme, New Zealand's Crown Research Institutes at one point had very little public funding and hence there was a short changing of public goods provision in favor of a more consulting firm approach. In between, perhaps, is VTT of Finland, which has more or less one-third state financing, a third private sector contracts, and a third matching grants.

¹³ In this model, the sum of output elasticities with respect to capital and labor add up to one, which in turn implies constant returns to scale, meaning that doubling the usage of capital (K) and labor (L) will also double output (Y).

¹⁴ The production function as specified embodies assumptions about how factors of production augment and substitute for each other To isolate the effects of technological progress, A , we let $k \equiv h(K/Y)^{\alpha/(1-\alpha)}$ as the "composite" capital-output ratio that incorporates both physical and human capital. We can further write $y \equiv Y/L = Ak$, so that labor productivity (per capita income) is the product of the technological progress and the capital-output ratio.

Beginning with such a standard formulation highlights several key issues. First, as most of the NIS and neoclassical literature agrees, the central actor in innovation policy must be the generator of wealth, the firm which appears on the left hand side of figure 2a. Second, it critically argues that first, technological progress augments both capital (K) and labor (L) and allows us to produce more output for each. Third, in the same way that we think about K and h as accumulating physical or human capital, innovation can be thought of as accumulating knowledge capital (A) that includes all of the learning and firm capabilities stressed by the NIS literature. Our production function also implies that production decisions are made jointly, that is a decision to “innovate” is also likely to imply investments in machinery (K) and training (h). Hence, innovation is not a free-floating factor outside of the production process, but needs to be thought of as part of it.

Hence, at the top of figure 2a we show three arrows linking sources of factors and the firm that graphically attempt to capture these complementary types of accumulation. The first is physical capital (K), the supply of which we are not concerned with here. Human capital (h), the higher levels of which we can think of as being supplied by the universities, think tanks and the like, is the first item on the left side. Knowledge capital (A) is also drawn from this supply and includes support to firm capability upgrading, the domestic science and technology system, and the international NIS which, for developing countries, supplies most of the knowledge. We draw this arrow between the firm and sources of knowledge to have two heads, crudely capturing the fact that there is a retro-alimentative dynamic between firms and the institutions formally shown as supplying knowledge and could embody the helix type relationships discussed in the literature.

Accumulating knowledge capital

How is knowledge (A) accumulated? There is general agreement that while rich countries need to invent new knowledge, firms in developing countries can benefit accessing the existing stock of knowledge in the world (A^*) and applying it to the home stock of knowledge, A (that is, Schumpeterian catch up). The degree of technological lag can be expressed as A/A^* where 1 implies the country is at the frontier and less than 1 implies room for catch up. The potential for knowledge accumulation through transfer is $(1-A/A^*)$.

However, as the NIS literature has stressed, this transfer does not occur automatically- the firm needs to identify and adapt this technology to its particular context. To formalize this intuition, the change (accumulation) of knowledge, \dot{A}_i , is given by

$$\dot{A}_i = \lambda R_i (1 - A_i/A^*),$$

where, R_i (R&D broadly considered) is the investment in knowledge capital made by the firm and the efficiency of that effort is denoted by λ , which we assume is the same for all firms. Therefore, the λR term captures the productivity of firms in the country in producing innovation from innovation related expenditures.

We could think of both terms as partly reflecting the capabilities of firms listed as the second group of factors under “the firm” in figure 2a. The firm’s demand to accumulate any factor will depend on its capabilities ranging from its core competencies to its particular capability to identify and absorb new technologies. But then weak management or a lack of technological familiarity can result in misspent innovative effort. Sending workers to trade shows without a plan to integrate the accumulated knowledge into the firm will lead to little gain. Taking advantage of an innovation subsidy without the necessary ability to plan or staff a true innovative effort will similarly be wasted.

Eq. 1a further complicates the technology adoption equation by allowing for R&D externality: a firm’s knowledge capital (A) benefits not only thanks to its own R&D but also thanks to R&D performed by other firms in the economy.

$$\dot{A}_i = [(1 - \mu)\lambda R_i + \mu \lambda \bar{R} (1 - A_i/A^*)] \quad (1a)$$

where μ (constrained between 0 and 1) captures R&D externalities; $\mu = 0$ and $\mu = 1$ imply no and full externalities, respectively. In particular, in a full externality scenario, knowledge capital accumulation by firm i equally benefits all the other firms in the economy. Therefore, for all firms, A_i would be equal to the average R&D efforts among all the firms in the economy, denoted by \bar{R} .

How do firms decide how much to invest in knowledge and physical capital?

Without assuming that managers have perfect foresight, they probably are “more or less competent” in how they combine factors to make a product, and would reasonably seek to do so in the least costly way possible. Broadly speaking, they are maximizing profits. Whether they are not fully “optimizing”, either because of lack of capability or information, can be debated, but they do respond to incentives. To simplify notation, we will omit the firm subscript i and abstract from labor and just posit that the firm needs to make a decision about how much to accumulate in physical capital and knowledge capital. Hence, the profit function faced by the firm is given by:

$$\text{Profits} = Y - pI - R \quad (2)$$

Y is the output of the firm, without loss of generality, we normalize the cost of investment in knowledge capital (R) equal to 1 and p captures the relative cost of investment in physical capital (I). Hence, how much accumulation in knowledge capital (innovation) they undertake will reflect both its contribution to output and its cost. Furthermore, since adopting a new technology often requires complementary investments in the form of new machines and training for the workers (that is, accumulation of physical and human capital), then underlying our NIS is the interaction of the demand and supply for all these factors of production jointly.¹⁵

However, as postulated by NIS, an array of factors can impede accumulation (investment in) physical and knowledge capital. These factors can be grouped into two set of variables: those affecting the overall profitability of the firm, denoted by τ , and those acting as taxes/barriers *specific to knowledge capital investment* (R), denoted by ϕ . Therefore, the firm i profit function, which now can encompass some key NIS insights, is now given by

$$\text{Profits} = (1 - \tau)Y - pI - (1 + \phi)R \quad (2a)$$

τ affects the profitability of the firm and therefore affects the accumulation of *all* factors- physical and knowledge. Forces captured by τ may include the factors discussed above such as macro-economic context (stability, distortions), barriers to trade or absence of trade networks. However,

¹⁵ The full equation is $\int_t^\infty ((1 - \tau)[Y - \omega] - pI - (1 + \phi)R) e^{-r(s-t)} ds$. Above we abstract from labor costs

they may also include impediments to any kind of accumulation- thin capital markets, weak property rights, uncertain contract resolution mechanisms, high barriers to entry and exit, costly, unmanageable systemic risk- and these are captured in the middle panel as barriers to accumulation or allocation. Figure 2b places these between the demand and supply for factors.

ϕ , by contrast, captures factors that may be barriers or “taxes” specific to the accumulation of knowledge capital, for instance weak intellectual property rights, deficient risk capital, labor regulations that penalize labor displacement due to technological upgrading which are captured in the lower center panel of figure 2b. But it can also arguably include weaknesses in all the institutions on the supply side that are necessary to meet firm demand for knowledge that often feature in the NIS literature. On the left hand side of figures 2, the first set of these institutions is the basic supply of human capital, from the worker level to the entrepreneur. The second set of institutions supports firm capability accumulation. These include productivity and quality extension services, facilities to disseminate new technologies or best practice, and higher end consulting services in specialized topics, again, in increasing sophistication and particularity to the firm. The next set, the Science and Technology system, adapts existing or generates new knowledge of use to the firms generally from the stock of A found in the international innovation system. As the NIS literature stresses, many of these institutions are often non-market (government research institutes, universities) and we can nest weaknesses in the linkages among them as raising the cost of innovation.

By nature, investments in physical capital and innovation are expected to affect profits and be repaid over a long period and hence the model assumes forward looking behavior. While perfect foresight is perhaps unrealistic, the conclusions derived from the model are reasonably intuitive. For both physical and knowledge capital, the firm is going to relate the contribution of the last dollar devoted to accumulation of the factor to the cost of borrowing that dollar, the interest rate, r . In the case of physical capital, the firm will invest until the capital/output ratio equals the right hand side.

$$p(K/Y) = \alpha \left(\frac{1-\tau}{r} \right) \quad (3a)$$

That is, the amount of physical capital accumulated (K) will fall with the overall level of “taxes” on all accumulation, τ (which lowers the profitability of the investment), and the cost of borrowing, the interest rate, r .

For knowledge capital (A), the firm will choose its optimal distance from the frontier (and hence investment in knowledge capital) by setting the contribution of the last dollar invested in innovation to the interest rate, r ¹⁶

$$\frac{(1-\tau)(1-\mu)}{(1+\phi)} \lambda k(1 - A_i / A^*)(1-\alpha) = r \quad (3b)$$

Several insights emerge immediately.

First, again, the further from the frontier, A/A^* , the higher the return to investments in innovation, capturing standard Schumpeterian catch up. This is consistent with Griffith et al.’s finding that returns to R&D rise with distance from the frontier in the OECD. Poorer countries should, all else held equal, have higher rates of return to innovative effort.

Second, all else is not equal and the lower the efficiency of R&D effort, λ , the lower the return. This result can be thought to capture concern with firm capabilities central to the NIS literature. That is, a firm with a short planning horizon or poor human resource strategy to staff innovative activity will be characterized by a low λ and hence see fewer benefits to engaging in innovation. Government policies to increase R&D spending in firms based on offsetting the standard appropriation externality may manage to raise the nominal aggregate statistic for the country as firms re-classify activities as R&D, but may have no impact on aggregate productivity. Hence, as stressed by the NIS literature, resolving the market failures preventing firms from upgrading becomes a central focus of innovation policy.

Third, the return is also a function of investment in physical capital and, more generally, *all* factors of production including those we are not modeling. Put differently, we cannot treat innovative activity

¹⁶ To simplify the exposition, we assume that the frontier is fixed, that is $g_{A=0}$, and this eliminates one term.

or R&D in a vacuum, but must be aware of the *complementarities* with a variety of other factors. That is, it is not the case that a country that, due to business climate variables, invests very little in physical capital should still assume high returns to investing in innovation. A lack of physical or human capital, or firms to take ideas to market will keep returns to innovation low. Viewed differently, as countries get farther from the frontier, the lack of complementary factors- firm capabilities, functioning NIS, human and physical capital- offsets the Schumpeterian effect. And, in fact, Goñi and Maloney find an inverted U in returns where Griffith et al.'s (2000) relationship eventually turns over and returns start to fall and become negative for very poor countries.

Fourth, the specific tax on innovation, ϕ and general barriers to *all types of accumulation*, τ , lower the return and hence investment in knowledge. This is, again, reflected in the center panel of figure 2a/b. That is, if a firm is thinking of adopting a new technology, it will not only be affected by innovation issues, but it will be affected by access to credit markets to finance the related necessary machinery, ability to import that machinery, the overall predictability of the investment climate, the reliability of the contracting environment, the ability to diversify risk,¹⁷ etc. An innovative startup will care as much about bankruptcy laws and barriers to entry and exit as any other firm. That is, a low rate of innovation, e.g., measured by R&D/GDP, would not provide any information as to whether the linkages among universities, firms, etc. are healthy or reflect garden variety accumulation (investment) barriers as are commonly discussed in World Bank Doing Business-type analyses. Aghion (2016), for example, has made the case for the necessity of complementing innovation and structural reforms with reference to Europe, arguing the Netherlands, Canada, Australia, and Sweden that invest in knowledge economy *and* structural reforms have performed best. Hence, though we cannot say *ex ante* which factors are most binding, the circle around the NIS needs to err on the ample side and incorporate all the elements grouped together in figure 2b as τ .

Fifth, standard appropriability market failures impinge on knowledge capital accumulation as well. If a firm's knowledge investments can be costlessly appropriated by others, $\mu=1$, the return to that investment will fall considerably.

Implications for our conception of the NIS

¹⁷ See Michelacci, C., & Schivardi, F. (2013), Krishna et al. 2016).

The analysis has important implications for how broadly we should conceive of the NIS. As Soete et al. (2010) note, there are many definitions of the NIS and where the circle should be drawn around the relevant policies and institutions included. One of the earliest definitions by Freeman (1987) stressed "The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" and Nelson & Rosenberg (1993) are similarly narrow with "a set of institutions whose interactions determine the innovative performance of national firms," especially those supporting R&D efforts (see also Patel and Pavitt 1994, Metcalf 1995). Lundvall (1992) suggests a broader view that includes national education systems, labor markets, financial markets, intellectual property rights, competition in product markets and welfare regimes. Edquist's (1997) view includes "all important economic social, political organizational institutional and other factors that influence the development, diffusion and use of innovations."¹⁸ (see also Soete et al. 2010).

Broadly speaking, the light blue areas of Figure 2b comprise elements that have priority in the National Innovation System literature, including human capital, firm support and S&T institutions, innovation specific credit and subsidy policies, and the capabilities of the entrepreneurs (see Dahlman and Nelson 1995 for example). Not only do we have the usual concerns with externalities captured by μ , but we have the direct efficiency of converting effort into knowledge λ approximating firm capabilities, and the particular "taxes" that raise the cost of innovation per se, ϕ . Everything that may make growth and accumulation in general less profitable, captured by the parameter τ , should be seen as part of the challenge to increasing innovation, particularly in developing countries where business climates are more challenging. These elements, hence, are included in the "Greater NIS" sketched in figure 2a and b.

¹⁸ Benavente, J.M. & G. Crespi, (1995) distinguish between "narrow" and "broad" conceptions of the NIS and, taking a broader view, seek to introduce the market into the NIS.

Figure 2a:

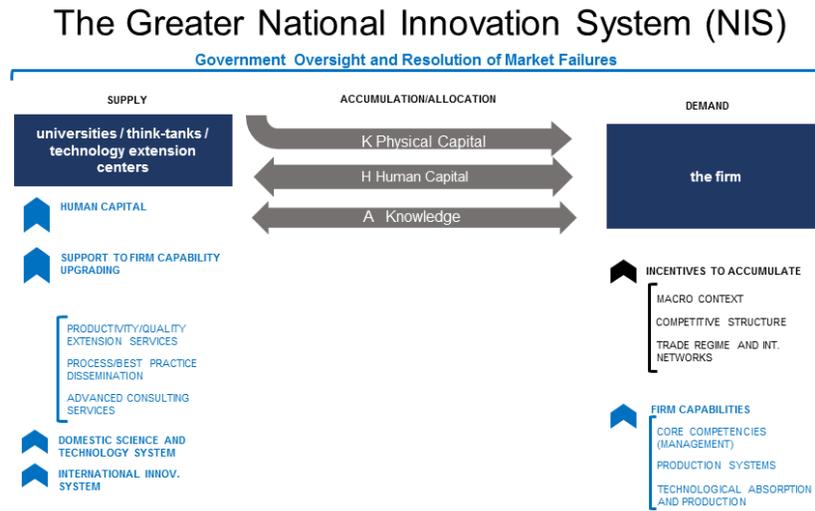
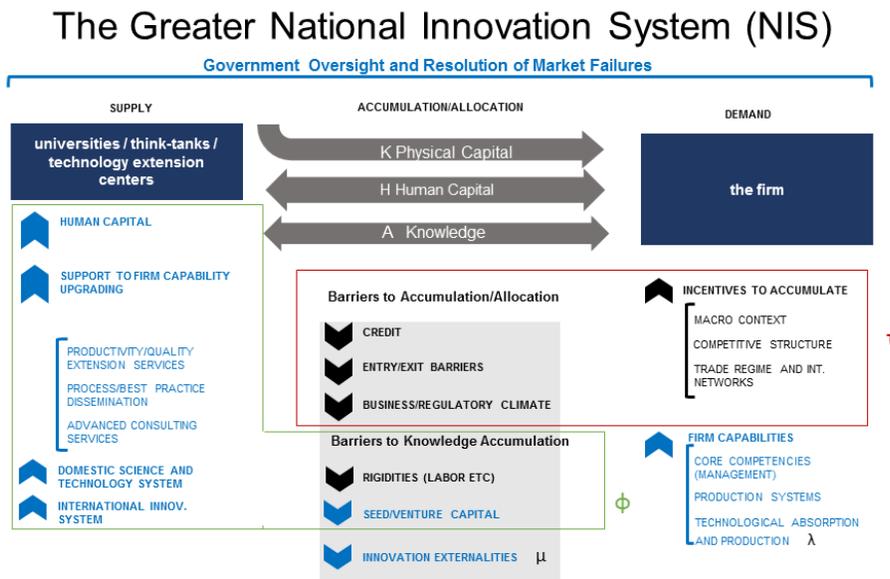


Figure 2b:



To complete figure 2, overseeing the functioning of the system should be a coherent, time consistent government policy that monitors what is working and what is not. It also clearly engages in resolution of the various market failures discussed earlier which, in the end, could imply a quite active role, for instance, in programs to upgrade firms and develop technological capabilities.

C. Benchmarking Innovation Performance

The previous discussion also has implications for how we benchmark the performance of the NIS. The level of R&D/GDP, to take one commonly used but by no means adequate measure, is illustrative.¹⁹ Ideally, we would be able to observe the social rate of return of R&D and countries would invest up to the point where it fell to the long-term interest rate. Such estimates are hard to come by and it is common to use levels of R&D expenditure, for example, as a barometer of performance with the assumption that more is better. For instance, the Lisbon declaration in Europe set a goal of raising the R&D target from 1.9% to 3% of GDP by 2010 to close the gap with the US (2.7%) and Japan (3.0%). Given Chile's comparatively low investment rate, Former President Lagos proposed a goal of 1.5% by the same date for Chile.²⁰ The World Bank will often offer recommendations based on simple comparisons of R&D investment with frontier investors. Colombia, Senegal, and Tunisia, ideally, should invest as much as the Republic of Korea. Policy tends to be focused on underwriting innovation related expenditures.

However, this assumes that the only relevant argument in equation 3 is that relating to Schumpeterian catch up (i.e., and that none of the others impinge). That is, as long as there is a gap with the knowledge frontier, more investment in R&D is better. But as we have seen, low investment in R&D could arise from a specific problem with the innovation system or market failure, or it could reflect general problems of accumulation. Vietnam may have low R&D for exactly the same reasons it has low physical or human capital accumulation. And we would not expect that its private sector, given its lower level of physical and human capital (including managerial capabilities) could use the same

¹⁹ See Lee (2013) for a recent discussion of several more sophisticated measures, p 45-50.

²⁰ <http://www.scidev.net/global/innovation/news/chiles-president-pledges-boost-for-rd-funding.html>

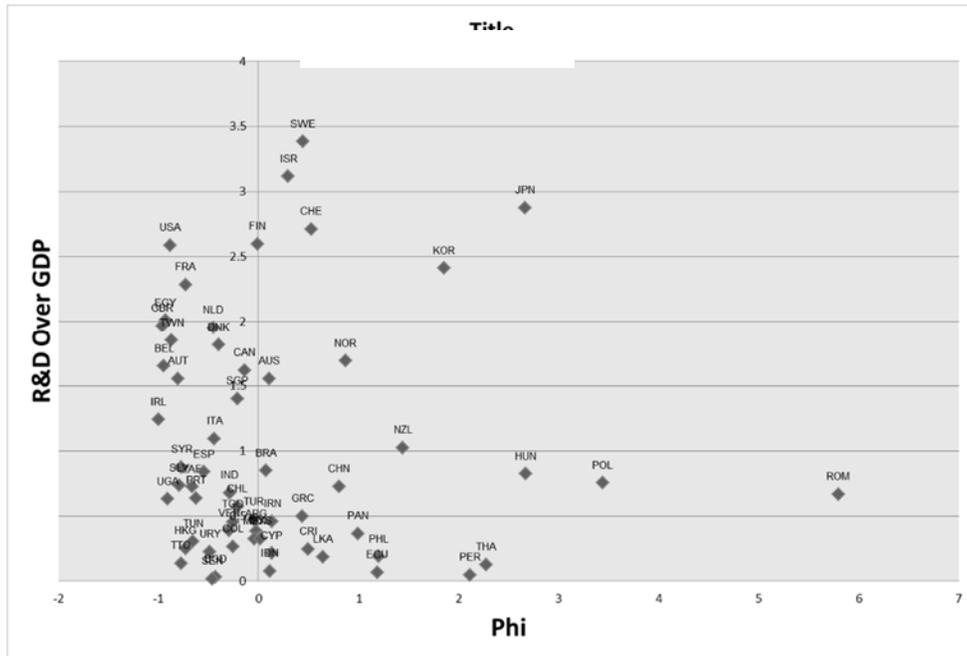
amount of newly produced or adopted knowledge as, for instance, Korea. Hence finding that developing countries invest less in R&D than frontier countries does not necessarily imply that they should do more *relative to their investments in other complementary factors*.

Aggregating up our firm decision problem illustrates the problem. From the above it can be shown that a country's relative distance from the technology frontier as proxied by relative TFP is determined by:

$$A / A^* = 1 - \frac{g_A}{\lambda s_R k} \quad (4)$$

where s_R is the share of innovation spending in GDP (i.e., $s_R \equiv R/Y$), and g_A is the rate of growth of the technological frontier. If we assume that all countries face the same rate of growth of the frontier, g_A the overall innovative performance of the country depends on efficiency of R&D effort, the magnitude of the effort, the capital (and human capital stock), and, through them, the underlying factors that we discuss above.

Figure 3: Estimated barriers to innovation against R&D/GDP.



Innovation Tax ϕ

To make this point Figure 3 calibrates (4) and extracts a measure of the derived “tax” on innovation ϕ against the standard GERD. This was previously done in more detail for several Latin American countries in Maloney and Rodríguez-Clare (2007) but here we seek to make a general point focusing on a global sample of countries.

Details on data and the calibration are in the annex. In practice, to simplify we set μ equal to the US value and λ we assume constant across all countries so effectively all of our distortions of the NIS-unresolved externalities, firm capabilities and specific barriers to innovation are captured in our simulation of ϕ .

How does this measure of innovation/NIS shortfalls correlate with common measures of performance such as R&D which do not take this into account? Figure 3 suggests essentially no relationship between the two. Korea shapes up, despite high R&D, as having relatively low R&D relative to its human and physical capital and Colombia, Senegal and Tunisia have low R&D, but seemingly more than might be expected given their other factors of production. Though the methodology is overly simple, it makes a fundamental point: The fact that Colombia, Senegal and Tunisia have low R&D/GDP does not necessarily imply that the problem is necessarily particular to innovation, or even less to S&T institutions, and could, for instance, be a problem of other types of accumulation.²¹ This exercise is meant only to be suggestive (and should not take the heat off of Colombia, Senegal and Tunisia to improve their innovation systems per se given that reforms of educational systems and firm upgrading is a process of decades). There are numerous issues of calibration discussed by Maloney and Rodríguez-Clare, including the fundamental problem of exclusively treating TFP differences as reflecting innovation performance as opposed to, for instance, allocation inefficiencies. However, it does suggest that a narrow focus on stimulating R&D, or regulating the problem to a particular Science and Technology or Innovation ministry is likely mistaken. Consistent with a substantial current of the NIS literature, a broader view of the overall accumulation problem of the country is in order.

²¹ This method has several drawbacks. For one thing, the TFP measure used to calculate ψ depends on the rate of return to education, implicitly, in how we divide up the unaccounted for part of output between technological progress and returns to human capital. Further, these are crude estimates assuming the same rate of return to education, same overall structure of the economy. However, the bottom line is a low R&D rate does not necessarily imply suboptimal R&D. That is, simply comparing Vietnam’s rate of R&D against that of Korea is not an adequate diagnosis of the NSI. Further, our measure of innovation is TFP, which could include any number of barriers to reallocation of factors of production or other inefficiencies.

Conclusions

This paper has attempted to reconcile, in the context of a very simple neoclassical economic model, very basic mainstream economic insights and the longstanding critiques of the NIS literature. It begins arguing that the gaps between the two literatures may have been overstated and are narrowing as neoclassical models expand to account for institutional considerations. Each tradition brings elements which are critical to better characterize our understanding of the innovation process. In particular, there is broad consensus on the role of the market as the primary allocator of resources and on the importance of market failures that innovation policy needs to address. The NIS literature's concern with the essential task of raising the level of capabilities of firms is gaining more attention in the mainstream through the management quality literature. However, arguably even this can be framed as a market failure that, while potentially requiring extensive and multidimensional interventions to overcome, fits comfortably within a standard market framework.

In line with both literatures, the focus of the model is the behavior of the firm and its demand for knowledge. Mapping it to a schematic of the NIS, it also highlights the importance of the set of complementarities to that knowledge, which are often not on the radar screen of innovation policy makers. In particular, for developing countries, this will lead us away from a very R&D promotion centric view to one stressing the need to incorporate a wide range of policy areas such as firm capability upgrading. But it also suggests that the circle around what we consider as encompassed in the NIS needs to be drawn amply, incorporating not only barriers to knowledge capital accumulation, but also those impeding the accumulation of all types of capital- business climate, bankruptcy laws, poor product and factor regulation, etc. Put differently, a low level of innovation may not reflect problems in the innovation system narrowly construed, but rather very general problems in the business environment. This highlights the importance of keeping in mind all the complementary factors required for successful innovation both in policy and benchmarking: asking whether a country has an innovation problem cannot be answered by unconditionally comparing GERD, but requires knowledge of a broader set of factor endowments. Hence, the analysis leads to a questioning of the validity of some popular measures of the performance of the NIS.

This heuristic analysis, while highlighting their centrality and creating a “placeholder” for them, cannot fully integrate institutions or capture the non-economic dynamics that the NIS literature has stressed as critical. The hope is that at least putting the various arguments on the same page in a structured fashion will help clarify our thinking on making effective innovation policy.

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Annex I: Calibration

For the calibration, we follow Klenow and Rodríguez-Clare in having $\alpha = 1/3$, $\gamma = 0.085$, $\delta = 0.08$, $r = 0.086$, $g = \varepsilon = 0.015$, $\lambda = 0.38$, and $\mu = 0.55$. The interested reader can consult that paper to understand the details of this calibration. Here we just provide a brief explanation. The values used for the parameters α , γ , and δ are standard in the literature. The interest rate is obtained by noting that with a tax rate of 25% in the U.S. (i.e., $\tau = 0.25$) and given data for the capital-output ratio and the relative price of investment in the U.S., then equation (2) implies $r = 0.086$. The steady state growth rate of A^* , g , is obtained from the average growth of TFP in the OECD for the period 1960-2000. We assume that $\varepsilon = g$ to generate reasonable steady state properties. Finally, parameters λ and μ are calibrated to U.S. data. In particular, these parameters are set so as to have that the social rate of return to R&D in the U.S. be three times the net private rate of return given an R&D subsidy of 20% (i.e., $\phi = -0.2$), and given an R&D investment rate in the U.S. of 2.5% of GDP.²²

²² Assuming that the U.S. has a 20% subsidy on R&D may be questioned for two reasons. First, because although this is the statutory rate (see Hall and Van Reenen, 2000), the effective rate is much lower. Second, because since we are considering a broad concept of R&D, then the actual rate would be even lower. It turns out, however, that this is not too relevant for our main conclusions. We recalibrated the model with a U.S. R&D tax of 0%, and the results do not change in any significant way.