Innovation Shortfalls*

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Abstract: There is a common perception that low productivity or low growth is due to what can be called an "innovation shortfall," usually identified as a low rate of investment in R&D. The problem with this analysis is that it fails to see that a low R&D investment rate may be appropriate given the economy's pattern of specialization, or may be just one manifestation of impediments to accumulation more generally. This paper first shows a simple way to estimate the R&D gap that can be explained by a country's specialization pattern, illustrating it for the case of Chile. Second, we show how a calibrated model can be used to determine the R&D gap that should be expected given a country's investment in physical and human capital. If the actual R&D gap is above this expected gap, then one can say that the country suffers from a true innovation shortfall.

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Abbreviations: R&D, OECD, EU, GDP, RDI, LDC, TFP

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1. Introduction

There is a common perception that low productivity or low growth in both developed and underdeveloped countries is due to a lack of innovation. Exhibit number one in favor of this argument is a relatively low R&D investment rate as a share of GDP, a common proxy for innovative activity. Some recent publications, for example, have noted with concern that Latin American countries invest an average of roughly .4% of GDP on R&D, whereas most OECD countries' R&D investment rates hover around 2% of GDP (De Ferranti et. al., 2003; OECD, 2004; World Bank Institute, 2005).

The reaction to this perceived problem is to recommend increasing R&D spending up to some target rate based on the R&D investment rates of "high innovation" countries. Thus, in pursuit of "turning the EU into the most competitive knowledge-based economy in the world" the March 2002 meeting of the European Council in Barcelona announced a goal of increasing the average RDI from 1.9% to 3% by 2010 so as to close the gap with the US (2.7%) and Japan (3.0%) (OECD, 2004). For another example we can cite the recent speech by former President Ricardo Lagos of Chile, a country recognized as offering best practice in developing country economic management and a high growth performer, who stated that his country should reach an R&D investment rate of 1.5% by the year 2010.[1]

The problem with these benchmarking exercises and targets is the failure to recognize that R&D investment is just one more activity whose level is determined by the economy's pattern of specialization as well as by overall economic incentives and distortions. Should we expect the natural-resource abundant economies of South America to invest as much in R&D as the manufacturing oriented countries of East Asia? Should we think of “innovation policies” for countries whose low R&D investment rates may just be one more manifestation of general problems that impede accumulation of all kinds of capital? How can we know when a country suffers from an innovation shortfall above and beyond the ones that should be expected given the country’s specialization and accumulation patterns? These are the questions we tackle in this paper. Because of Chile’s commitment to the innovation agenda, its previous far reaching micro-reforms that are likely to have reduced other impediments to growth, and generally superior data, we have chosen this country to serve as illustration for the analysis that we propose. Thus, the paper can be seen as both as a general exploration of ways to identify innovation shortfalls, and as an analysis of whether Chile suffers from one.

We begin in the next section by exploring the relationship between R&D investment rates and specialization patterns. Clearly, if for exogenous reasons a country is specialized in sectors characterized on average, by low innovation, then one should not be surprised or concerned to find that it spends relatively little on R&D. Ideally, one would directly compare R&D investment rates in the same sector across countries, but unfortunately such data is not available for LDCs. Thus, we perform an indirect analysis, asking how much would R&D investment rates fall in OECD countries if they had the economic structure of a resource rich Latin America country, using Chile as an example. The results suggest that compositional matters are relevant, but do not explain a large part of the country’s innovation shortfall.

Section 3 turns to the question of whether low R&D investment rates should be seen as “innovation shortfalls” caused by environments that adversely affect innovation, or as part of a broader problem of low accumulation in all types of capital. Consider, again, the case of Chile, which had an R&D investment rate of 0.4% of GDP in 1995, a rate that is well below the comparable number for the U.S. (2.5% in 1995). It is tempting to conclude that Chile has an innovation shortfall until one notices that Chile also has low investment rates in human and physical capital, as reflected in a composite capital-output ratio of 50% of the U.S. level.[2] This relationship holds globally. Figure 1 shows that for the 48 countries for which we have the required data for 1995 there is a positive relationship between R&D investment as a share of GDP and the composite capital-output ratio. Again, the conclusion is that – at least for some countries – low R&D investment rates could be just part of a more general accumulation problem.

The challenge that emerges, then, is to find a way to identify true innovation shortfalls and separate them from cases of low overall accumulation (or "accumulation problems"). For this purpose we propose the use of a model developed and calibrated by Klenow and Rodríguez-Clare (2005) that captures the interactions among accumulation of different types of capital, including "knowledge capital," and allows for both barriers to general accumulation and barriers that are specific to the accumulation of knowledge. We explore the model's implications for Latin American countries and find some countries that seem to suffer from true innovation shortfalls. However, we argue that the exercise suffers both from large measurement error intrinsic to the use of international datasets such as those of Barro and Lee (2000) and the Penn World Tables 6.1, as well as model misspecification for some countries. To explore these issues, we consider again the case of Chile and, after showing that some particular adjustments to the model are necessary, we conclude that Chile does indeed suffer from a true innovation shortfall: its R&D investment rate is significantly below what would be expected given its stocks of human and physical capital. Our goal here is not so much to reach a solid conclusion for any particular country, but rather to illustrate how this kind of analysis might be undertaken.

2. R&D and the Pattern of Specialization

As mentioned in the introduction, there is enormous variation in R&D investment rates across sectors. This is a reflection of the fact that, just as with physical and human capital, some sectors are intensive in knowledge capital relative to others. This has important implications for comparisons of R&D investment rates across countries. In a multi-sector economy with international trade, one may have different countries specializing in sectors with differing possibilities for technological change, so that one would observe significant gaps in R&D investment rates that are consistent with factor price equalization and hence similar wage levels (see Grossman and Helpman, 1991). Although income levels would be higher in the economy with higher R&D rates (since it would enjoy a higher stock of "knowledge capital" per worker), under reasonable conditions it would not be appropriate for countries to encourage the growth of high-R&D sectors. We discuss this point by briefly reviewing the relevant theory in the next subsection. The following subsection looks at the R&D data at the sector level to gauge the extent to which differences in specialization patterns may explain a significant part of the R&D insufficiency one observes in LDCs such as Chile.

R&D rates in a multi-sector economy: implications from trade theory

Consider an environment in which there are several goods whose production differs in the extent to which they benefit from R&D. The aggregate R&D investment rate is a weighted average of the sectoral R&D rates with weights given by the shares of each sector in total output. International trade will affect such weights and hence the aggregate R&D investment rate.

To explore this idea, think of R&D as an intermediate good whose production is intensive in human capital. Assuming that the technology is the same across countries (as in the standard Hecksher-Ohlin model of trade), then human capital abundant countries should naturally specialize in R&D-intensive or "high-tech" goods. One could then imagine a situation in which aggregate R&D investment rates differ across countries *entirely* because of differences in specialization patterns that are consistent with international wage equalization (see Grossman and Helpman, 1991). Since technologies are assumed to be the same and wages are equalized through trade, then production techniques used in each sector would be the same across countries. In other words, R&D investment rates in a particular sector would be the same everywhere, but aggregate R&D investment rates would be higher in countries that are specialized in high-tech sectors.

The same outcome would emerge if we think of human capital as an endogenous variable rather than an endowment, and allow for relative (sector-level) productivity differences across countries. Consider for example a case in which rich countries have a Ricardian comparative advantage in high-tech goods. This would lead these countries to specialize in such goods, accumulate more human capital, and exhibit higher R&D investment rates than others. Still, just as in the case in which trade is driven by variation in human-capital endowments, all cross-country R&D differences would emerge from differences in the sectoral composition of output.

Something different would arise if countries differ not only in their endowments of human (and perhaps physical) capital, but also in their policies towards R&D. For example, some countries could have a more favorable tax treatment of R&D or a better functioning National Innovation System. In this case, R&D would become relatively cheap in some countries, which would specialize in high-tech sectors *and also* invest relatively more in R&D in those sectors when compared to countries with less favorable R&D policies. International differences in aggregate R&D investment rates would result from the combination of specialization patterns and cross-country variation in R&D investment rates within each sector.

This analysis reveals that international differences in R&D investment rates are to be expected, and it does not necessarily imply the need for corrective policies. To the extent that they result from international variation in the sectoral composition of output, perhaps because of differences in human capital endowments or Ricardian productivity differences, corrective policies to increase R&D are not called for. Policies to reallocate resources towards high tech-sectors would also be unadvisable. On the other hand, low R&D investments may result from environments that make such investments difficult or expensive. This would result in low R&D investment rates even controlling for the sectoral composition, and the need for corrective policies.

Externalities

Now imagine that there are sector-specific (Marshallian) externalities. As shown in Rodríguez-Clare (2007), the problem that may arise in this case is that the economy may have a comparative advantage in a high-tech good and experience a coordination failure that keeps it specialized in the low-tech good. This is of course the classic analysis of sector-specific externalities and trade, where an economy may be in a bad equilibrium, specialized in a sector where it doesn't have a comparative advantage. If this were the case, then a policy inducing specialization in high-tech would lead to higher accumulation of human capital and a higher TFP arising from specialization in the sector with comparative advantage.

What does this tell us for the case of an LDC? If the LDC has a Ricardian comparative advantage in R&D intensive sectors, but there are sector specific and local spillovers, then it could make sense to think of a policy to induce a reallocation of resources towards the more R&D intensive sectors. This would lead to an increasing R&D investment rate. But does it make sense to think that Chile, for example, has a Ricardian comparative advantage in more R&D sectors? Probably not!

There is a case that can be made for a policy to induce specialization in high R&D sectors. The previous argument applies to the case where externalities or R&D spillovers are entirely within industry. A different result emerges if R&D generates positive economy-wide (i.e., inter-industry) spillovers. In that case, it is easy to show that an economy could be justified in sacrificing efficiency through specialization in sectors where it doesn't have a comparative advantage, to attain higher R&D investment rates and enjoy the associated spillovers. In fact, some of the discussion that took place in the U.S. when it was feared that it was losing its edge in semiconductors can be interpreted in this way, with commentators like Laura Tyson arguing that semiconductors generate strong inter-industry externalities, and that therefore it is important to have a domestic semiconductor industry even if this runs against comparative advantage (Borrus, Tyson and Zysman, 1986).

For this to be a valid argument, however, it would be necessary that knowledge spillovers associated with R&D be stronger across domestic firms than across firms in different countries. Indeed, if spillovers are international, then it would clearly not make sense for a country to intervene, for any market failures would be *international* in scope, and hence *national* economy policy is clearly not the correct type of intervention. Although there is some controversy on this matter, our reading of the evidence leads us to think that domestic spillovers are stronger, since knowledge spillovers are clearly attenuated by distance (Audretsch and Feldman, 2003).

Ultimately, then, this is an empirical matter. If R&D spillovers go beyond sectors but stay mostly within borders, one cannot easily discard policies to push resources towards high R&D sectors. Of course, favoring high-R&D sectors may not be the most standard way to encourage R&D; a more conventional approach would be simply to subsidize R&D. But if for practical reasons the latter approach is not advisable, then perhaps a sectoral approach is relevant. As with any policy option, however, there are significant costs and risks that would have to be carefully considered.

Before going any further with policy discussions, however, it is necessary first to explore whether in fact there are significant systematic differences in R&D intensities across sectors, and whether this can explain a significant part of LDCs' (and Chile's, in particular) shortfalls in R&D.

A look at sector level R&D data

We first examine how R&D investment varies across sectors for the OECD since LDC data do not yet permit this kind of exercise. We combine the industry level R&D expenditures of the OECD Science and Technology and R&D Statistics Database with the value added statistics from the OECD Structural Analysis Data Base to generate investment rates. Table 1 tabulates the results for selected sectors and reveals several important stylized facts. First, there is a wide range of average R&D investment rates by sector from around .1% in Services, apparel or publishing to almost 30% in pharmaceuticals; office, accounting and computing equipment; and air and spacecraft. Second, the standard deviations across countries are very high, suggesting tremendous variation of investment rates within sectors. In manufacturing in the aggregate, for example, Spain holds up the bottom with 2% while Sweden tops the list at close to 12% (not shown). Third, overall, individual sectoral investment rates have tended to rise suggesting an increasing intensity in the use of knowledge in the production of these products.

Taken together, these suggest that both sectoral composition and level of investment within sectors matters in determining R&D efforts. In fact, the declining aggregate R&D investment rates across this period, partially a phenomenon of this particular sample cut, is driven by the fact that OECD countries have moved heavily into services – over 4 percentage points of total non-agricultural value added in many OECD countries (See Maloney 2005. A more careful decomposition of differences in aggregate R&D Investment (RDI) rates within the OECD suggests a combination of both elements with wide variations across countries (see figures 2 and 3). The RDIs in the US and France are higher than the mean largely due to higher investment rates within the mean set of sectors, while Finland and Korea's high RDI, and Canada's, Australia, Netherlands and Norway's lower RDIs are due largely to compositional effects—electronics in the former, perhaps natural resources in the latter. Among the newly emerging eastern European countries, countries, Poland, Spain, Czech Republic, the deficit is due almost entirely to low investment rates within sectors. Within the manufacturing sector (not shown), the story is again mixed. Again, the deficits of the younger countries are due largely to low within-sector investment rates. Among the wealthier countries there is a mix with Germany's superiority and to a lesser extent Japan's due largely to within sector rates while others, again, Finland, Belgium Canada and the US, being driven more prominently by sectoral composition.

To get a feel for what is happening in Chile, for which we lack comparable rates of R&D investment at the sector level, we take an indirect route. The first column of Table 2 applies Chile's industrial structure to the sectoral investment rates in each country in the OECD.[3] Column 3 relates this simulated value to the actual. It is first clear that structure is not everything. Norway's predicted level is within 10% of its actual suggesting that the fact that its RDI is double that of Chile is significantly due to low investment rates within existing sectors. However, it is also clear that structure matters. On average, simulated OECD aggregate investment rates are just under 60% of those observed and Finland and Germany, are roughly 30% of their actual.

Table 3 asks which sectors are most responsible for these very large disparities by applying the average OECD sectoral investment rates to the difference between Chile's and the aggregate OECD sectoral participation rates. Virtually the entire difference can be accounted for by Chile's very low participation in the electronics and transport sectors, both of which show very high average investment rates. The fact that Chile has not added Nokia to its forestry industry the way Finland did explains the vast difference in the two countries simulated rates.

In summary, Chile's low R&D comes in part from its specialization in sectors with low R&D intensity, but this is not the whole explanation as there is also a significant gap that comes from lower R&D investment rates at the sector level. In the next section we explore whether such lower R&D investment rates can be seen as consequences of a specific innovation shortfall or of a broader problem of low accumulation of all kinds of capital.

3. A model of knowledge capital accumulation

There is a long literature that tries to understand the relative contribution of capital accumulation and productivity growth to economic growth. More recently, research has focused on what is sometimes called "development accounting," the goal of which is to understand the determinants of income differences across countries at a particular point in time. In particular, the exercise explores whether a country's low income level is due to low investment in physical capital, human capital, or to a low TFP level. One problem with development accounting is that it is almost never acknowledged that TFP, just as the stock of physical and human capital, is the result of investments in some kind of capital, perhaps "organizational" capital or technology. In other words, TFP is also the result of accumulation of some sort.

To tackle this issue and undertake a more meaningful development accounting exercise, Klenow and Rodríguez-Clare (2005) formulate a model in which TFP is the result of accumulation decisions. The authors used the model to explore the relevance and magnitude of international spillovers, and also to understand whether policies that affect appropriability in general, together with exogenous differences in the relative price of investment goods and investment levels in human capital, can explain the international variance of income levels, or whether one also had to postulate significant differences across countries in their treatment of innovation and technology adoption. The conclusion was that this latter element was important: to explain differences in labor productivity across countries, one has to assume that there are significant cross-country differences in policies or institutions that affect the cost of technology adoption.

In this section we turn our attention to a slightly different matter. We are interested in applying the framework of Klenow and Rodríguez-Clare to understand the different reasons behind an LDC's low income level. Perhaps there are some countries where low income is due to low appropriability, others where low income is due to low human capital, others where it is mainly due to a high relative price of investment, and yet others where low income is due to a high implicit cost of technology adoption. In a sense, we are interested in exploring this framework to conduct a sort of "R&D diagnostics," so that one can see whether a country suffers from low R&D beyond what would be expected given its low investment in other types of capital. We take the case of Chile for an illustration of this methodology, and to discuss its advantages and disadvantages, as well as the way in which it is sensitive to different assumptions.

We first explain briefly the main workings of the model. As customary, we postulate a Cobb-Douglas production function of the form $Y = K^{\alpha}(AhL)^{1-\alpha}$, where Y is total output, K is the physical capital stock, A is a technology index, h is average human capital per worker, and L is the total labor force. We follow the Mincer specification, so that $h = e^{\gamma s}$, where s is years of schooling, assumed constant and exogenous. Output can be used for consumption (C), investment (I), or research (R), $Y = C + pI + R$, where p is the relative price of investment and is assumed constant through time. Physical capital is accumulated according to: $\dot{K} = I - \delta K$.

The only thing left to specify is the way that A evolves. A complete description is beyond the scope of this paper, and the reader is referred to Klenow and Rodríguez-Clare (2005). Here we just provide a brief sketch. First, there is a world technology frontier, denoted by A*, that increases thanks to the R&D performed in all countries. The rate of growth of A* is denoted by g_A.

Second, each country's A relative to the world level – which we denote by $a = A / A^*$ – is determined by the country's efforts in technology adoption, which we equalize to a broad concept of R&D. Thus, R&D in our model has two functions: it contributes to increasing the world's technology level frontier and it allows the country to come closer to the world's frontier (i.e., decrease a). Given that R&D is more effective in increasing the country's A when the country has a lower relative A level (i.e., there are benefits of backwardness), then low R&D does not translate into lower growth, but rather into a lower steady state relative A, with all countries in steady state growing at a common rate. Moreover, there is also a "free flow" of ideas from the rest of the world to any particular country, and this happens at a rate denoted by ε. It is also assumed that the basic productivity in R&D is the same across countries, although the actual labor productivity in R&D may differ due to differences in the amounts of physical and human capital. We denote this basic productivity in R&D by λ. Thus,

$$\dot{A} = \left(\lambda R / L + \varepsilon A\right)\left(1 - A / A^*\right)$$

In steady state we have:

$$a = 1 - \frac{g_A}{\lambda s_R k + \varepsilon} \tag{1}$$

where s_R is R&D as a share of GDP (i.e., $s_R \equiv R/Y$) and $k \equiv h(K/Y)^{\alpha/(1-\alpha)}$ is the "composite" capital-output ratio (incorporating both physical and human capital).

As usual, $y \equiv Y/L = Ak$, so that labor productivity is the product of the technology index and the capital-output ratio. This expression takes into account that – just as in the neoclassical model – an increase in A leads to an increase in the rate of return to capital, so that to bring the economy back to steady state an increase in the capital-labor ratio is called for. The full effect of an increase in A, once one takes into account the indirect effect through the induced capital accumulation, is a proportional increase in labor productivity (see Klenow and Rodríguez-Clare, 1997). But here there is an additional interaction between *A* and *k*, since a is positively affected by k. The reason for this is that R&D uses the same technology as production of output, which relies on human and physical capital, hence a high level of *k* makes R&D more effective in accumulating A. Thus, this model incorporates both the effect of technology on capital accumulation, and the reverse effect from capital accumulation to increased technology adoption.

Third, a country's R&D investment is the sum of R&D performed by firms, who undertake R&D together with accumulation of physical capital to maximize the present value of their future stream of profits, which are equal to total income net of wages paid and net of taxes. Apart from general income taxes, there are also policies and institutions that affect the cost of R&D, which we capture by the parameter ϕ, so that the unit cost of R&D in terms of units of output is $1+\phi$. Apart from this implicit R&D tax, we allow for an R&D externality, so that a firm's A increases not only thanks to its own R&D but also thanks to R&D performed by other firms in the economy. We use a parameter μ

between zero and one to capture this externality, with $\mu = 0$ implying no externalities and $\mu = 1$ implying full externalities, in the sense that A is determined completely by average R&D efforts among all the firms in the economy.

The firm's decision about how much to invest is determined by a dynamic optimization problem, which yields two first order conditions: one for investment in physical capital, and one for R&D. The first order condition for investment in physical capital yields the following steady state restriction:

$$p(K/Y) = \alpha\left(\frac{1-\tau}{r+\delta}\right) \tag{2}$$

where τ is the tax on profits, and *r* is the equilibrium steady state real interest rate, which is assumed equal across countries. Assuming a common interest rate across countries, and using data for each country for *p* and *k*, equation (2) yields an implicit τ for each country. Note that τ and *r* are "interchangeable" – that is, the model cannot differentiate between low accumulation due to high taxes or low finance, since both work through the same channels. As mentioned, however, we assume that r is the same across countries, so that all international differences in the "nominal" capital-output ratio are explained by differences in tax rates.

The second first order condition determines R&D, and hence relative A in steady state. This condition is:

$$\Omega(1-\alpha)\lambda k(1-a) - g_A a/(1-a) + \varepsilon(1-a) = r \tag{3}$$

where $\Omega = (1-\tau)(1-\mu)/(1+\phi)$ is a composite distortion term that captures the effect of taxes and externalities. To see this better, the difference between the social and the private rate of return to R&D can be shown to be equal to:

$$\tilde{r} - r = (1-\Omega)(1-\alpha)\lambda k(1-a) + g_L$$

where g_L is the rate of growth of the labor force. The wedge between the social and private rates of return to R&D is thus composed of two components: the first component is generated by taxes and the domestic R&D externality, as captured by the term Ω, whereas the second term is associated with the rate of growth of firms, which in the model is equal to the rate of growth of the labor force, and arises because of an assumption in the model that new firms are born with a productivity equal to the average productivity of existing firms. Equation (3) determines the relative A level of a country given its measured levels of *k*, and the two tax parameters τ and ϕ.

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.[4]

Initial Results

Table 4 presents the results of this exercise for several Latin American countries plus the U.S. We emphasize that these results are only suggestive, since they are affected by the measurement error intrinsic to international databases such as those of Barro and Lee (2000) and the Penn World Table 6.1. Although useful to generate broad international stylized facts, such databases are too noisy to be reliable in undertaking a country-specific analysis. Moreover, although the calibrated model is a good approximation for broad international patterns, it may be way off for particular countries. A serious analysis about a particular country necessarily entails obtaining better data and adjusting the model for country idiosyncrasies. We illustrate the relevance of this for the case of Chile below.

Columns 1-3 of Table 4 come from Barro-Lee data on human capital and the Penn World Tables, using $\alpha = 1/3$, $\gamma = 0.085$, and a procedure to construct capital stocks as described in Klenow and Rodríguez-Clare (2005). Column 4 calculates the income tax τ implied by equation (2) above assuming that all countries have the same interest rate as in the U.S., calibrated above as $r = 8.6\%$. The country with the lowest implied income tax is Mexico, which has a physical capital-output ratio equal to that of the U.S. in spite of having a relative price of capital that is twice as high. The only way for this to be an equilibrium is to have an income tax much smaller than that of the U.S.

Column 5 presents the composite capital-output ratio $k \equiv h(K/Y)^{\alpha/(1-\alpha)}$ as a ratio of the U.S. level. Column 6 uses equation (3) to calculate the value of a *assuming that all* *countries had the same implicit tax on R&D as the U.S. (i.e.,* $\phi = -0.2$), and presents it also as a ratio of the U.S. level. Column 7 shows the associated R&D investment rate, using equation (1). Column 8 shows the product of relative *k* and relative a, which yields labor productivity relative to the U.S. Thus, for example, if Chile had $\phi = -0.2$, given its levels of human capital, the relative price of investment, and the (real) physical capital-output ratio K/Y, then its labor productivity would be 42% of that of the U.S. Column 9 presents the social rate of return to R&D given $\phi = -0.2$.

The exercise continues in columns 10-13 of Table 4. Columns 10 and 11 show labor productivity and technology level A calculated directly from the data expressed as ratios of corresponding U.S. levels, respectively. (The level of *A* is obtained from *y* and *k* by applying $y = Ak$). Column 12 calculates the R&D investment rate implied by a country's "measured" a using equation (1). Finally, column 13 shows the R&D tax ϕ necessary for the model to be consistent with this R&D investment rate. Comparison of columns 6-8 with columns 10-12 reveals the impact of innovation policies and regulations, and column 13 summarizes this comparison in a single index. Finally, column 14 presents the implied social rate of return to R&D.

As way of illustration, consider the case of Peru. According to the model, with $\phi = -0.2$ Peru's labor productivity would be 62% of the U.S. level, rather than the 18% recorded in the data; the reason for this is that given its (implied) low income tax ($\tau = 3\%$), a 20% R&D subsidy (i.e., $\phi = -0.2$) would lead Peru to an R&D investment rate of 3.2%, implying a steady state technology index equal to 95% of the U.S. level. In contrast, Peru's actual R&D rate is only 0.4%, implying a level of *A* of only 28% of the U.S. level, and hence a labor productivity of only 18% of the U.S. level. For this to be an equilibrium phenomenon, the model requires an R&D tax of 172%, which implies a social rate of return to R&D of 51%. Thus, Peru appears to suffer from a true innovation problem, that is, a case of policies and institutions that negatively affect broad R&D.

Something quite different happens in Chile. In this case the labor productivity that would obtain with a 20% R&D subsidy would be 42% of the U.S. level, which is very similar to what is recorded in the data. In both the hypothetical and "real" cases, the implied R&D investment rate is close to 2% of GDP. In line with this, the model's implied R&D tax for Chile is –11%. Thus, according to this exercise, Chile's problem is almost entirely driven by its low *h* and its high implicit income tax τ. In other words, it is an accumulation rather than an innovation problem.

On the other extreme, we find El Salvador: given its low levels of *h* and K/Y (and hence a very low *k* equal to only 0.3 relative to the U.S.), one would expect El Salvador to have a low relative A level (39% of the U.S. level), yet one observes a high relative A of 72%, implying a high R&D investment rate of 3.3%. Hence, it must have policies and institutions that favor R&D: the model implies that El Salvador enjoys an R&D subsidy of 53%, significantly higher than the one in the U.S.

To summarize the previous results, the exercise suggests (again, remember these results are only suggestive; more elaborate country-specific analysis is required to explore individual countries) very high R&D taxes in Ecuador, Mexico, Panama and Peru, and medium R&D taxes in Argentina, Bolivia, Brazil, Colombia and Venezuela. Chile, El Salvador and Uruguay appear to have favorable R&D institutions and regulations. The first group of countries has an innovation problem, whereas the problem in the later group is one of accumulation. The first group of countries would benefit enormously from adopting policies and regulations more favorable to innovation. For example, Panama's R&D investment rate would increase from 0.6% to 3% of GDP if it could go from $\phi = 1.26$ to $\phi = -0.2$, leading to an increase in its labor productivity relative to the U.S. from 27% to 64%. Of course, this is not to say that this is a simple matter of innovation or tax policy; as we discuss below, the institutions and regulations that determine the effective R&D implicit tax are much more complex. For the group of countries with favorable innovation institutions and regulations, there is little to gain from additional efforts in this dimension.

The next subsection explains columns 15-17 of Table 4. The last column of the table shows the *measured* R&D investment rate. All the implied R&D investment rates of column 12 are higher than the measured ones in column 18. This reveals that measured R&D is significantly lower than the model's implied R&D including technology adoption efforts. This should not be surprising: measured R&D only considers a small portion of overall innovative and technology adoption efforts, since the formal definition of R&D excludes investments that one would normally want to include as technology adoption. Indeed, one advantage of the approach taken here is that the "R&D" measure we back out is really a more general measure of innovative effort that is mapped to the TFP measures plugged into the model. In this way, we avoid some issues complicating innovation diagnostics mentioned earlier. First, as already stated, we include technology adoption efforts that are likely to be left out of the formal measurement of R&D. Second, we implicitly take into account international differences in effectiveness with which R&D is turned into useful knowledge, resulting – among other factors – from differences in the fraction of R&D that is financed by governments across countries.

The role of distortions

The model we have used so far assumes that all TFP differences across countries result from differences in R&D or technology adoption. Thus, it leaves no room for distortions acting through other channels, such as trade barriers that decrease efficiency directly or regulations that lead firms to adopt suboptimal combinations of inputs. We believe that an interesting area for future research is precisely to explore ways to identify the relevance of barriers to technology adoption and direct distortions for international TFP differences. For now, we undertake a simple exercise: we want to know the distortions that would be necessary to account for observed productivity levels if countries had the same R&D policy and institutions as the U.S. (i.e., $\phi = -0.2$).

We model distortions as a factor z that directly reduces output: $Y = K^{\alpha}(zAhL)^{1-\alpha}$. Everything else is as in the model presented above. The analysis of steady state equilibrium is exactly as above as if human capital per worker was zh, instead of h. This implies that now $k \equiv zh(K/Y)^{\alpha/(1-\alpha)}$. For any particular country we can then ask: what is the value of the distortions variable z such that the data and the model are consistent if we also impose $\phi = -0.2$. The result is presented in column 15, whereas columns 16 and 17 present the implied R&D investment rate and the associated social rate of return to R&D.

Consider Peru again. Instead of being a case of failed development due to perverse innovation policies and institutions, it is now seen as an economy plagued by distortions that by themselves explain a labor productivity level of 30% of the U.S. level.[5] More generally, the countries that in the previous exercise (column 13) were classified as having the highest levels of ϕ, are now portrayed as having the lowest levels of z (i.e., highest distortions). The problem with this analysis is that it is hard to know what specific distortions, and through what channels, would generate such enormous static productivity losses. Moreover, it is hard to compare this to the result that – in the opposite extreme, without distortions – a “barriers to technology adoption” explanation of Peru’s low productivity would entail $\phi = 1.72$, which implies firms face a cost of R&D in terms of output that is approximately three times higher than in the U.S. This is because although the distortions analysis only tells us the overall productivity loss resulting from unknown distortions, the barriers to technology adoption analysis tells us the specific “wedge” needed to create the technological backwardness consistent with that productivity loss.

In summary, although the model without distortions used for the analysis of the previous subsection suggests that some Latin American countries suffer true innovation problems, an alternative explanation is that rather than lack of innovation, these economies suffer from severe distortions that directly lower TFP. More research is necessary to understand how to disentangle static distortions from barriers to technology adoption. For now, we proceed (mostly) under the assumption that distortions play no role in explaining low productivity levels.

Potential pitfalls of using international databases and common parameters: the case of Chile

As mentioned above, one limitation of the analysis we have conducted so far is that it relies on international databases and assumed common parameters. Although this is fine for the purpose of establishing stylized facts, it is not satisfactory when analyzing a particular country. We now consider two specific issues. First, some countries may exhibit a high measured TFP as result of their large endowment of natural resources. Ideally, one would correct for this to make the results comparable across countries. Second, although the assumption of a constant Mincer coefficient may be a good approximation when studying broad regularities in the data, this is no longer the case when one is interested in a particular country. In that case, it is much better to use the particular Mincer coefficient for the country in question. In this section, we explore these two issues for the case of Chile, assuming first that there are no distortions (i.e., $z = 1$).

First consider the impact of natural resources. In the case of Chile, it is clear that a significant part of its GDP is not so much the result of using human and physical capital according to the production function above but rather the result of "using" its large endowment of mineral resources. According to the Central Bank, mining contributed 6.7% of GDP in 1999, whereas according to the 1998 Household Survey employment in this sector accounted for 1.6% of total employment. Assuming that the physical and human capital stocks per worker were the same in mining as in the rest of the economy, then this implies that pure natural resources in mining account for approximately 5% of GDP.

Table 5 shows the results of this adjustment. The first row replicates the exercise above, while the second row shows the adjusted results. We see that the implied capital-output ratio increases, implying a drop in the implicit income tax from 26% to 22%. Also, there is a small increase in k, and a small decrease in the relative technology index. For this new relative technology index to be consistent with the model above, it is necessary to have a small R&D tax, calculated to be 7%.

The third row of Table 5 turns to the second adjustment mentioned above. We consider Chile's estimated Mincer coefficient rather than the common coefficient imposed for the exercise in Table 4. The estimated TFP (and hence the estimated technology index A) is quite sensitive to the Mincer coefficient. For example, according to Arellano and Brunner (1999) the Mincer coefficient in Chile is close to 0.12. If we use this coefficient, then h increases from 1.85 to 2.39, which by itself would imply a decline in A of 23%. Together with the mining adjustment above, a falls to 51% of the U.S. level. The R&D investment rate and R&D implicit tax that go with this (according to the model) are 0.8% and 76%, respectively. Chile now appears to have an innovation problem.

Is the upward adjustment to the Mincer parameter driving these results reasonable? Theory offers little advice: on the one hand, educational quality is likely to be lower in Chile than in the OECD; on the other hand, education stock is lower and hence, ceteris paribus, the return should be higher. What we can say is that the finding has empirical precedent. The adjusted rate is the same as the one Bils and Klenow (2000) and borrowed from Psacharopoulos (1994) and substantially below Lam and Schoeni's (1993) estimate for Brazil.

What would be the required distortions to explain Chile's low TFP after the previous adjustments? Row 4 of Table 5 presents an exercise similar to the one performed in the previous section, to determine the distortions that would be necessary to explain Chile's lower TFP level given an R&D subsidy of 20%. The result is that distortions would have to be such as to reduce Chile's labor productivity by 32%. Although we do not have anything rigorous to say about whether this number is reasonable or not, our feeling is that it would be hard to argue that Chile is so much more inefficient than the United States as to generate such a large direct fall in TFP. Still, this clearly remains an open question for research.

In summary, adjusting for the impact of natural-resource abundance and a higher than average return on schooling, the analysis for Chile changes radically: these adjustments lead to a lower TFP, a lower implied R&D investment rate, and a higher “innovation tax.” More broadly, the analysis suggests that Chile’s low labor productivity (37% of the U.S. level after adjustments) is the result of (1) a higher relative price of investment and a lower average mean years of schooling of the adult population that lower k to 72% of the U.S. level, (2) the indirect effect of the lower k on R&D, which results in TFP of 91% of the U.S. level, and either (3) distortions that would cause a decline in labor productivity by 32% or (4) unfavorable policies and institutions for innovation that would lower R&D from 2.6% down to 0.8%, or a combination of (3) and (4).[6]

5. Conclusion

Countries do have innovation shortfalls, but we have argued that their diagnosis requires more than simple unconditional comparisons of R&D or other related indicators. In this paper, we explore the considerations lying behind a potentially reliable diagnostic, using data-rich star reformer Chile as an illustrative guinea pig.

We first ask to what degree measured R&D investment is determined by a country’s comparative advantage and under which conditions policy makers should be working against this. In a dynamic context where accumulation of factors, whether physical or knowledge capital is endogenous, comparative advantage is largely determined by

Ricardian considerations. Hence, if we find that a country's level of R&D investment is dictated by its economic structure, then the question must be asked "Does this country have a Ricardian comparative advantage in more R&D intensive products." If the answer is no, then the low level of aggregate R&D investment is optimal. This last conclusion can be overturned if there are large economy-wide (i.e. inter-industry) spillovers arising from an industry in which the country does not have a Ricardian comparative advantage as long as these spillovers are mostly national in scope.

It may also be the case that a country is not producing goods within its comparative advantage at the global technological frontier: the level of R&D investment in those industries is below that found elsewhere and this is what leads to low aggregate R&D investment. We explore these two possibilities for the case of Chile and find that much of the country's low level of R&D is driven by structure, but much is not. Even if Chile's economic structure is optimally specialized, there appears to be a shortfall in knowledge accumulation in its industries. .

That said, even if we establish conditionally low levels of innovation, it is not immediately clear whether the problem pertains particularly to this factor: whether there are barriers to accumulation of knowledge in particular, or to accumulation in general that need to be addressed. To approach this issue, we follow the modeling approach of Klenow and Rodriguez-Clare and simulate the expected level of TFP given the level of physical and human capital accumulations. Using standard databases, for a variety of Latin American countries, we calculate the shortfall of the actual relative to the predicted TFP value and the implicit "tax" on innovation that would generate it. Focusing more carefully on Chile for which better data is available, we conclude, first, that the results are sensitive to data quality and parameter assumptions but that, in all likelihood, Chile has a TFP shortfall. We further flag that such a shortfall may correspond to the innovation weaknesses highlighted above (the relatively low level of R&D in its industries), but may also correspond to static inefficiencies unrelated to innovation. Though we cannot rule out his possibility, the implied magnitudes of these inefficiencies seem implausibly large and we continue to suspect a true innovation shortfall.

Understanding what causes these shortfalls in Latin America is an agenda in itself that we have not touched here. In the companion background paper, we discuss four tentative candidates- labor market rigidities, poor human resources, lack of access to credit, and absence of policies to internalize externalities- and the readers are referred there. Clearly, we don't have the last word on any of these issues. However, the problem of how diagnose shortfalls to innovation diagnostics we consider a central one and we encourage further refinements both in technique and data.

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Endnote Citations

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[1] Ricardo Lagos, Discourse on the State of the Nation, May 21st, 2005, (see http://www.gobiernodechile.cl/21mayo2004/indice_discursos.asp).

[2] The composite capita-output ratio includes both human and physical capital, and is given by $k \equiv h(K/Y)^{\alpha/(1-\alpha)}$, where h is human capital per worker (measured as $h = e^{\gamma s}$, where γ is the Mincer coefficient and s is the average years of schooling of the adult

population), K is the stock of capital, Y is total output, and α is the share of capital in output (see below for a formal derivation).

[3] Let x(i,j) and s(i,j) be the share of sector i in region j and sector i's R&D investment rate in region j, respectively, where we consider two regions, OECD and Chile. Region j's average R&D investment rate is then the sum of x(i,j)s(i,j) across i. The difference between the aggregate R&D rate in Chile and the OECD comes both from differences in sector shares and in sector R&D rates. The part of this difference that is due to differences in sector shares can be approximated by the sum of [x(i,OECD)-x(i,Chile)]s(i,OECD) across i.

[4] 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 (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.

[5] This effect of distortions takes into account its total effect, both the direct effect through a lower TFP, and the indirect effect through a lower capital stock given a constant capital-output ratio (and constant rate of return to capital).

[6] The total effect of (3) or (4) or their combination is to reduce labor productivity by another 44%, so that in the end Chile's labor productivity is 37% of the U.S. level.

Sector	Median R&D investment rate		Standard Deviation
	1985	2000	2000
Manufacturing, Utilities, Construction and Services	**0.014**	**0.013**	**0.007**
TOTAL MANUFACTURING	**0.060**	**0.067**	**0.035**
Food products, beverages and tobacco	**0.012**	**0.013**	**0.007**
Textiles, textile products, leather and footwear	**0.007**	**0.011**	**0.010**
Wood, paper, printing, publishing	**0.006**	**0.007**	**0.006**
Chemical, rubber, plastics and fuel products	**0.101**	**0.103**	**0.055**
Pharmaceuticals	**0.248**	**0.251**	**0.158**
Other nonmetallic mineral products	**0.016**	**0.015**	**0.014**
Basic metals and fabricated metal products	**0.015**	**0.016**	**0.010**
Machinery and equipment, instruments and transport equipment	**0.119**	**0.145**	**0.062**
Electrical and optical equipment	**0.178**	**0.242**	**0.153**
Office, accounting and computing machinery	**0.243**	**0.274**	**0.783**
Electrical machinery and apparatus, nec	**0.091**	**0.080**	**0.053**
Radio, television and communication equipment	**0.231**	**0.186**	**0.438**
Transport vehicles	**0.103**	**0.085**	**0.067**
Aircraft and spacecraft	**0.289**	**0.212**	**0.079**
Furniture; manufacturing n.e.c.	**0.005**	**0.025**	**0.007**
ELECTRICITY, GAS AND WATER SUPPLY	**0.006**	**0.006**	**0.005**
CONSTRUCTION	**0.001**	**0.002**	**0.002**
TOTAL SERVICES	**0.002**	**0.003**	**0.002**

Source: OECD Science and Technology Data Base; OECD Structural Analysis Data Base

Table 1. OECD R&D investment rates by sector and standard deviation (1985, 2000)

Country	Estimated RDI using Chilean shares	Observed	Estimated/ Observed
Australia	0.007	0.008	0.886
Belgium	0.007	0.014	0.471
Canada	0.007	0.011	0.645
Czech Republic	0.005	0.008	0.550
Germany	0.004	0.017	0.259
Denmark	0.011	0.015	0.750
Spain	0.002	0.005	0.509
Finland	0.008	0.021	0.365
France	0.007	0.015	0.433
United Kingdom	0.010	0.014	0.724
Italy	0.005	0.006	0.846
Japan	0.010	0.020	0.531
Korea	0.006	0.019	0.329
Netherlands	0.006	0.012	0.507
Norway	0.011	0.012	0.929
Poland	0.002	0.003	0.486
Sweden	0.014	0.030	0.475
United States	0.011	0.019	0.567

Note: Applies Chile's sectoral shares in value added to OECD Country's R&D investment rates (RDI).Calculations as follows: Let x(i,j) and s(i,j) be the share of sector i in country j and sector i's R&D investment rate in country j, respectively. Country j's observed average R&D investment rate is then the sum of x(i,j)s(i,j) across i. For each country, we then replace x(i,j) with x(i, Chile) and recalculate the average investment rate. The difference between the aggregate observed R&D rate and the estimated rate using Chilean shares arises purely from the change in industrial structure. The important of industrial structure is then calculated by the estimated/observed aggregate investment rates.

Source: UNCTAD; Central Bank of Chile; OECD Science and Technology Data Base; OECD Structural Analysis Data Base.

Table 2. European R&D investment rates with Chile's economic structure (1995-1990 average)

sector	Shares in Chile (a)	Mean Shares in OECD (b)	Mean RDI in OECD (c)	Mean Shares- Chile's Shares (b-a)	c*(b-a)	Share of difference
Food products and beverages	0.059	0.028	0.009	-0.031	-0.029	-0.06
Tobacco products	0.008	0.002	0.010	-0.006	-0.006	-0.01
Textiles	0.007	0.007	0.013	0.000	-0.001	0.00
Wearing apparel, dressing and dying of fur	0.006	0.005	0.004	-0.001	0.000	0.00
Leather, leather products and footwear	0.005	0.002	0.006	-0.003	-0.002	0.00
Pulp, paper and paper products	0.013	0.008	0.028	-0.005	-0.015	-0.03
Printing and publishing	0.012	0.012	0.002	0.000	0.000	0.00
Wood and products of wood and cork	0.012	0.006	0.004	-0.006	-0.003	-0.01
Chemicals and chemical products	0.019	0.020	0.109	0.001	0.007	0.01
Coke, refined petroleum products and nuclear fuel	0.017	0.006	0.029	-0.010	-0.029	-0.06
Rubber and plastics products	0.007	0.008	0.034	0.002	0.006	0.01
Iron and steel	0.005	0.007	0.022	0.003	0.006	0.01
Nonferrous metals	0.003	0.003	0.025	0.000	0.000	0.00
Other non-metallic mineral products	0.012	0.010	0.015	-0.002	-0.002	0.00
Fabricated metal products, except machinery and equipment	0.013	0.015	0.011	0.002	0.003	0.01
Machinery and equipment, n.e.c.	0.003	0.018	0.052	0.015	0.077	0.16
Electrical machinery and apparatus, n.e.c.	0.002	0.024	0.153	0.022	0.341	0.71
Transport Equipment	0.006	0.018	0.099	0.012	0.118	0.25
Furniture; manufacturing n.e.c.	0.006	0.008	0.014	0.002	0.003	0.01
Recycling	0.000	0.001	0.016	0.001	0.001	0.00
Construction	0.114	0.063	0.002	-0.052	-0.011	-0.02
Utilities	0.035	0.028	0.006	-0.007	-0.004	-0.01
Services	0.636	0.702	0.003	0.066	0.022	0.05
Total	1.000	1.003		0.003	0.481	1.000

Notes: Sectors selection is based on the highest possible level of desegregation for Chile; n.e.c. = not elsewhere classified
Source: UNCTAD; Central Bank of Chile; OECD Science and Technology Data ,Base; OECD Structural Analysis Data Base. Calculations as follows: Let x(i,j) and s(i,j) be the share of sector i in region j and sector i’s R&D investment rate in region j, respectively, where we consider two regions, OECD and Chile. Region j’s average R&D investment rate is then the sum of x(i,j)s(i,j) across i. The difference between the aggregate R&D rate in Chile and the OECD comes both from differences in sector shares and in sector R&D rates. The part of this difference that is due to differences in sector shares can be approximated by the sum of [x(i,OECD)-x(i,Chile)]s(i,OECD) across i.

Table 3. Sectors responsible for difference in aggregate R&D investment in Chile vs. OECD (1995-1990 average)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Country	**h**	**P**	**K/Y**	**tau**	**k**	**A (1)**	**sR (1)**	**y (1)**	**SRR (1)**	**y (D)**	**A (D)**	**sR (2)**	**Phi (2)**	**SRR (2)**	**z**	**Imp. sR (z)**	**SRR (z)**	**sR (D)**
Argentina	2.1	1.1	1.5	16%	0.7	92%	2.8%	65%	22%	44%	63%	1.2%	53%	37%	0.5	2.3%	20%	0.4%
Bolivia	1.6	1.7	0.8	29%	0.4	56%	1.8%	22%	23%	12%	30%	0.7%	15%	30%	0.7	1.1%	22%	0.4%
Brazil	1.5	1.2	1.7	-1%	0.5	88%	3.3%	46%	18%	33%	64%	1.7%	34%	27%	0.6	2.8%	17%	0.9%
Chile	1.9	1.3	1.1	26%	0.5	77%	2.3%	42%	23%	39%	72%	2.0%	-11%	26%	0.9	2.2%	23%	0.6%
Colombia	1.5	1.8	0.9	14%	0.4	70%	2.5%	28%	20%	22%	53%	1.5%	7%	25%	0.7	2.1%	19%	0.3%
Ecuador	1.7	1.3	1.6	0%	0.6	92%	3.3%	54%	18%	23%	39%	0.7%	118%	41%	0.4	1.9%	16%	0.1%
Mexico	1.8	1.3	1.7	-9%	0.7	99%	3.6%	65%	17%	37%	57%	1.1%	104%	38%	0.4	2.8%	15%	0.3%
Panama	2.0	1.2	1.5	11%	0.7	94%	3.0%	64%	21%	27%	39%	0.6%	126%	47%	0.4	1.7%	18%	0.4%
Peru	1.9	1.2	1.6	3%	0.7	95%	3.2%	62%	19%	18%	28%	0.4%	172%	51%	0.3	1.3%	16%	0.1%
El Salvador	1.5	2.0	0.7	35%	0.3	39%	1.2%	13%	24%	24%	72%	3.3%	-53%	16%	1.7	1.9%	26%	0.3%
Uruguay	1.9	1.2	1.1	33%	0.5	71%	2.0%	38%	25%	35%	65%	1.7%	-10%	28%	0.9	1.9%	25%	0.3%
Venezuela	1.8	1.4	1.5	-1%	0.6	93%	3.4%	56%	18%	36%	61%	1.3%	61%	32%	0.5	2.7%	17%	0.5%
USA	2.7	0.9	1.7	25%	1.0	100%	2.5%	100%	26%	100%	100%	2.5%	-20%	26%	1.0	2.5%	26%	2.5%

All the data is for 1995, except **p** which is an average over the 1986-1995 period. The reader can consult Klenow and Rodríguez-Clare (2005) for more details

(1) These are calculations assuming that all countries have the same R&D subsidy as the U.S.

(2) These are calculations using the data and the model to obtain the implied R&D investment rate, the implied R&D tax and the associated social rate of return to R&D.

(z) These are calculations where all countries have the same R&D subsidy as the U.S. but have distortions that yield their measured income and TFP levels.

(D) These are calculations based directly on the data.

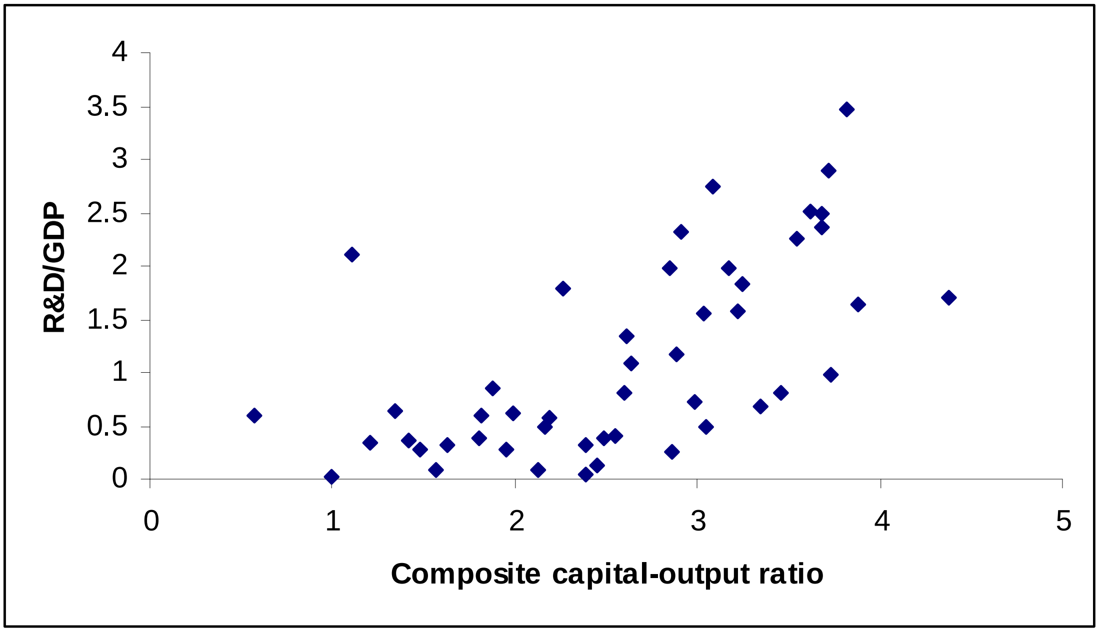
Source: Klenow and Rodríguez-Clare (2005) and own calculations

Table 4. A new growth accounting exercise

	1	2	3	3	4	5	6	7	8	9
	K/Y	τ	***z***	***k***	**Rel. *k***	**Data rel. Y/L**	**Data rel.** a	**Implied** s_R	ϕ	SRR
Chile (1)	1.15	26%	1	1.98	0.55	39%	72%	2%	-11%	26%
Chile (2)	1.21	22%	1	2.04	0.56	37%	66%	1.7%	7%	28%
Chile (3)	1.21	22%	1	2.62	0.72	37%	51%	0.8%	76%	44%
Chile (4)	1.21	22%	0.68	1.80	0.50	37%	75%	12.4%	-20%	22%

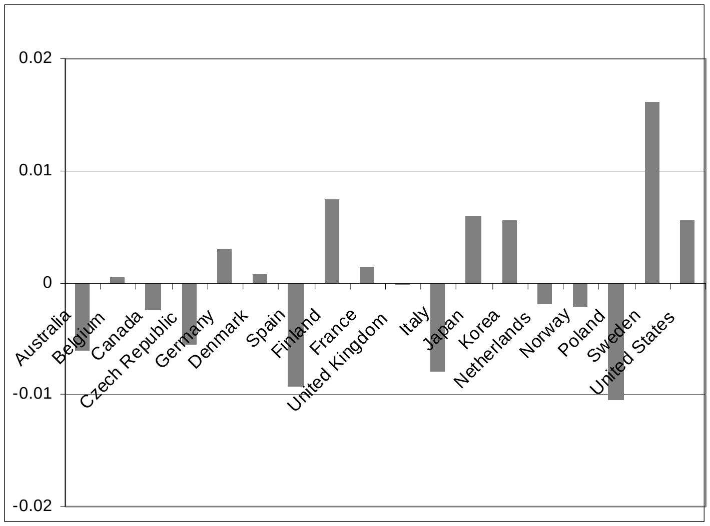
Source: Klenow and Rodríguez-Clare (2005) and authors calculations

Table 5. Exploring limitations of international databases and common parameters, the case of Chile



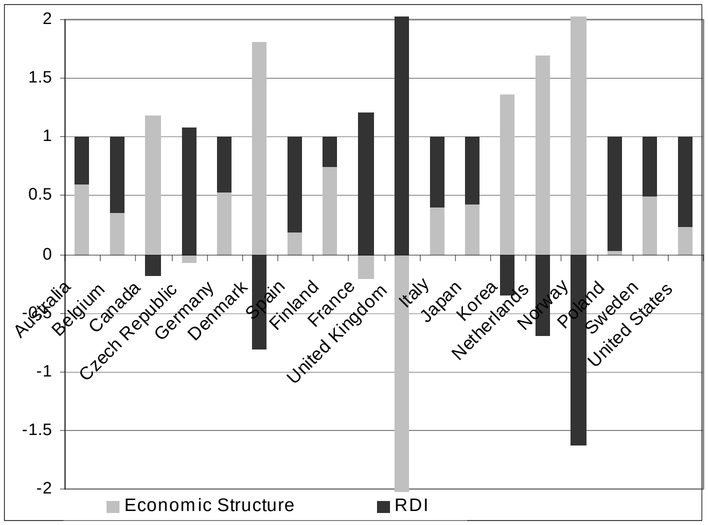
Source: Barro and Lee (2000), Lederman and Saez (2002) and authors' calculations.

Figure 1. R&D investment rates versus capital-output ratios, 1995



Source: Authors’ calculations based on OECD Science, Technology and R&D Database (2005); OECD Structural Analysis Data Base (2005)

Figure 2. Differences in aggregate R&D investment rates (RDI) from OECD mean



Source: Authors' calculations based on OECD Science, Technology and R&D Database (2005); OECD Structural Analysis Data Base (2005)

Figure 3. Contribution of economic structure vs sectoral RDI to deviations from OECD mean aggregate RDI