Importing Technology

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Abstract

We look at disaggregated imports of various types of equipment to make inferences on cross-country differences in the composition of equipment investment. We make three contributions. First, we document large differences in investment composition. Second, we explain these differences as being based on each equipment type's intrinsic efficiency, as well as on its degree of complementarity with other factors whose abundance differs across countries. Third, we examine the implications of investment composition for development accounting, i.e., explaining the cross-country variation in income per capita.

1 Introduction

$Y = F(K, L)$ is equation (1) in virtually all papers that attempt to explain income differences across countries. That is how it should be: differences in capital and labor explain a large fraction of the dispersion in income.[1] It has also long been recognized that factor "L" can usefully be disaggregated in order to enhance the explanatory power of F for Y. Hence, distinctions between "raw labor" and "human capital"; or between "skilled labor" and "unskilled labor," have been successfully introduced in attempts to understand differences in income. In this paper, we propose to begin exploring an analogous disaggregation of factor "K". Specifically, we break down overall capital in nine equipment categories (from computers to motor vehicles).

Direct measurements of the quantity of equipment installed in a country by type is, of course, not available. However, recent research by Eaton and Kortum (2001) has shown that most of the world's capital is produced in a small number of R&D-intensive countries, while the rest of the world generally imports its equipment. This suggests that, for most countries, imports of capital of a certain type are an adequate proxy for overall investment in that type of equipment. This stylized fact partly motivates our empirical approach and, for the most part, this is a maintained assumption throughout our paper (though we do verify that our results are robust to it).

We make three contributions. First, we show that there is enormous cross-country variance in the *composition* of K: different types of equipment constitute widely varying fractions of the overall capital stock across countries. Second, we shed a good deal of light on the determinants of these differences in composition. In particular, we estimate a simple model of investment in heterogenous types of capital, where a capital-type share in total investment depends on its intrinsic efficiency (reflecting embodied technology), as well as on the degree to which it is complementary with other inputs. For example, computers may be more complementary with human capital than other types of capital, leading to the prediction that human-capital abundant countries will devote a larger share of their investment to computers.

Our results indicate that, indeed, the intrinsic efficiency of equipment differs across equipment types: holding the supply of complementary factors constant, a dollar spent on one type of capital delivers more efficiency units than a dollar spent on another. Furthermore, we uncover clear patterns of differential complementarity between equipment types and other country characteristics (including, among many others, the human-capital–computers

[1] See, e.g., Mankiw, Romer, and Weil (1992), Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Hendricks (2002), and Caselli and Coleman (2002). This line of research has come to be known as "development accounting."

complementarity conjectured above): cross-country differences in human capital, institutions, sectorial composition, financial development, etc. have considerable explanatory power for differences in the composition of K. In addition, both the intrinsic efficiency, and the patterns of complementarity of different equipment types, can be rationalized with data on the R&D intensity of the industries that produce them: equipment types coming out of high R&D industries embody more efficiency units, and are generally more complementary with factors that one would expect to be more relevant for the adoption of new technology.

Our third contribution is to begin examining the implications of differences in the composition of K for cross-country income differences. In particular, we perform variants of the development–accounting exercise where – consistent with our results in the first part of the paper – different types of capital contribute differently to output in different countries. At one level, one can interpret this exercise as trying to decompose the well-documented explanatory power of K for Y into "quantity" vs. "quality" components: is K higher in high Y countries because rich countries sacrifice a greater portion of their income to investment, or is it because they direct this investment towards more productive (and/or more complementary with their characteristics) types of capital? Based on our simple model, however, we also argue that K as conventionally measured may fail to fully reflect quality differences. In this case, when performed on equipment data disaggregated by type, the development accounting exercise may even have more explanatory power (in the R^2 sense) than when performed using aggregate capital. Our preliminary results so far seem to indicate that composition effects are very significant (quality matters!), but we have not determined yet whether the overall explanatory power of the development accounting exercise increases.

Besides contributing to the development-accounting research agenda, this paper is at the cross-roads of several other literatures. Since it tells a story where most countries acquire embodied technologies through capital imports from the world technological leaders, it directly adds to a series of contributions on cross-country technology diffusion.[2] In this line of research, the paper is especially closely related to Caselli and Coleman (2001), who study the determinants of computer diffusion across countries. As in that paper, the main idea here is to look at equipment imports as measures of technology adoption by "follower" countries. This paper, however, generalizes the analysis to a larger number of equipment types – adding up to the total stock of equipment. Furthermore, in this paper we ground the empirical work into a theoretical model of investment in heterogeneous equipment types, and this allows us to more neatly map some of the empirical results into parameters describing

[2] E.g. Grossman and Helpman (1991), Barro and Sala-i-Martin (1995), and Aghion and Howitt (1998) on the theory side, and Coe and Helpman (1995), Coe, Helpman and Hoffmeister (1997), Keller (1998), Eaton and Kortum (1999), and Caselli and Coleman (2001) on the empirical side – see Keller (2001) for additional references and a survey of this literature.

the intrinsic efficiency of various types of capital, and to relate these parameters to the R&D intensity of the industries where that capital is produced.[3]

By relating the R&D content of imported capital goods to the country-specific efficiency of capital and, in turn, to GDP per capita (i.e., labor productivity), we can also contribute to the closely-related literature of "R&D Spillovers." As emphasized in Terleckyi (1974), Griliches (1979) and Scherer (1982), R&D from one firm or industry can have both knowledge and rent spillovers to other firms or industries.[4] Wilson (2002) argues that the R&D directed at particular capital types positions these types in *embodied technology space*. He then shows, using U.S. data, that an industry's TFP is increasing in its capital composition across this space. Our paper builds on this approach first by applying it to the international environment and second by laying out *the* (or at least *a*) theoretical and empirical link between capital-directed R&D and productivity: R&D determines the intrinsic quality of a capital type and its appropriateness for a given country, which in turn determines that country's choice of capital composition, which in turn contributes to GDP per capita.

The paper is also clearly related to the tradition on embodied technical change, which emphasizes differences in the efficiency units delivered by different vintages of capital.[5] Particularly close here are those papers that, a la Jovanovic and Rob (1996), attempt to improve the success of the development-accounting exercise through vintage effects. Effectively, this is equivalent to breaking down K by vintage, while maintaining the assumption that within a vintage capital is homogeneous. The difference here, of course, is that we do not break down K by vintage but by type, i.e. we relax the within-vintage homogeneity assumption. While this has not been previously done in the development-accounting literature, this *is* best practice in the growth accounting literature.[6]

We emphasize differences in the patterns of complementarity between different types of equipment and various other factors that differ by country. Since we think of different types of equipment as embodying different technologies, this implies that we also provide direct evidence in support of theories of appropriate technology.[7] In these theories, countries with different factor endowments optimally choose different technologies. In our setting this shows up in the composition of the capital stock by equipment type.

[3] Our results on computers are consistent with the results in Caselli and Coleman (2001).

[4] This idea has since been extended to spillovers from foreign countries' R&D (e.g., Coe & Helpman (1995); Coe, Helpman, and Hoffmaister (1997); and Keller (1998)). Recent work in this area has found that the strongest channel for spillovers from foreign R&D is international trade, with capital goods trade providing a stronger channel than non-capital trade (see Xu and Wang, 1999).

[5] Solow (1960), Greenwood, Hercowitz, and Krusell (1997), and Jovanovic and Rob (1996), inter many alia.

[6] E.g. Jorgenson, Gollop, and Fraumeni, 1987; Young, 1993.

[7] Examples: Atkinson and Stiglitz (1969), Diwan and Rodrick (1991), Basu and Weil (1998), Acemoglu and Zilibotti (2001), and Caselli and Coleman (2002).

We start the rest of the paper with a simple model of investment in heterogeneous types of capital (Section 2). This model delivers predictions on the share of each type of capital in total investment, and in Section 3 we show how these predictions can be turned into an empirical model. Section 4 describes the data, and Section 5 presents empirical results on the composition of a country's investment. Our model also generates predictions on the relationship between the composition of investment and per-capita income: Section 6 investigates this relationship and assess the role of quality vs. quantity in delivering the high explanatory power of real capital in development-accounting exercises. Section 7 summarizes the results.

2 Basic Theory

Imagine that in country i final output Y^i is produced combining various intermediate inputs, x_p^i, according to the CES production function[8]

$$Y^i = B^i \left[\sum_{p=1}^{P} \left(x_p^i \right)^{\gamma} \right]^{\frac{1}{\gamma}} \qquad \gamma < 1,$$

where B is a disembodied total factor productivity term. Intermediate-good p is produced combining equipment and labor:

$$x_p^i = A_p^i \left(L_p^i \right)^{1-\alpha} \left(K_p^i \right)^{\alpha} \qquad 0 < \alpha < 1,$$

where K_p^i (L_p^i) measures the quantity of equipment (labor) used to produce intermediate-input p, and A_p^i is the productivity of sector p.

Our key assumption is that capital is heterogeneous: there are P distinct types of capital, and each type is product specific, in the sense that intermediate p can only be produced with capital of type p. In other words, an intermediate in our model is identified by the type of equipment that is used in its production. For example, for equipment-type "trucks," the corresponding intermediate good x (say, "road transportation") is the one obtained by combining workers with trucks. For equipment-type "computers," the corresponding intermediate good is "computing services," etc. Hence, our intermediates do not easily map into industries or sectors (computers are used in most industries), but rather into the various types of activities (transport, computing, etc.) required to generate output within each sector. The assumption that $\gamma < 1$ implies that – in producing aggregate output – all these activities are imperfect substitutes.

[8]Production functions such as this one have been the staple of recent developments in growth theory.

In contrast, for simplicity and in order to focus on the novel contribution of the paper, we assume that labor is homogeneous within a country, though its quality can vary across countries, as we detail below. The x production function allows for capital-labor substitutability. This feature is not very important but it facilitates linking up our model with the development-accounting literature.

It is absolutely critical in order to correctly interpret both the model and the empirical results to be very clear about the units in which K_p^i is measured. In our data equipment of different types is measured in US dollars. We need, therefore, to be concerned that one dollar spent on equipment p in country i may deliver more or less efficiency units than in country i'. For example, equipment of type p may be more complementary with the endowments of country i. Furthermore, we need to be concerned that one dollar spent in country i on equipment of type p may deliver different amounts of efficiency units if instead spent on type p'. For example, the embodied-technology content of good p may be greater, say because the industry producing equipment of type p is more R&D intensive. The term A_p^i, which varies both by country and by equipment type, is meant to capture such differences. Our empirical work will allow us to learn about how A_p^i varies systematically with i and with p, and what this implies for furthering our understanding of cross-country differences in Y.[9]

Since K_p^i is measured in units of the final good, we can write:

$$\sum_p K_p^i = K^i,$$

where K^i is the total amount of dollars devoted to investment, which we take as given.[10] We assume that labor is fully mobile across types of capital, and denote by $L^i = \sum_p L_p^i$ the aggregate labor supply. Note that in equilibrium this economy will feature aggregate constant returns to scale in K^i and L^i (see below).

Since labor is perfectly mobile across the production processes p, producers in all sectors face a horizontal labor supply schedule with wage w^i. Furthermore, if investors allocate their dollars so as to arbitrage away differences in the rental rate of capital, producers face a common user cost r^i. Define $\xi_p^i = K_p^i/K^i$ the share of capital-type p in the aggregate

[9] Our formulation is reminiscent of a popular version of the vintage-capital model, in that each type (vintage) of capital is combined with a certain amount of labor to produce some input into (or, in vintage models: some portion of) final output. As in those models, we could have written the producton function in a more specifically "capital augmenting" way, such as $x_p^i = \left(L_p^i\right)^{1-\alpha}\left(A_p^i K_p^i\right)^{\alpha}$, but of course with Cobb-Douglas technologies the two formulations are equivalent.

[10] Since differences in disembodied productivity affect all sectors equally, and the model is symmetric in all other respects, endogenizing the investment rate would not change any of the formulas we use in the empirical analysis.

capital stock. Under our assumptions, in equilibrium we have

$$\xi_p^i = \frac{\left(A_p^i\right)^{\frac{\gamma}{1-\gamma}}}{\sum_j \left(A_j^i\right)^{\frac{\gamma}{1-\gamma}}}. \tag{1}$$

This expression (derived in the appendix) simply states that investment tends to concentrate on the equipment types that feature the highest embodied efficiencies, but this is counterbalanced to some extent by the diminishing returns to each intermediate input produced with those equipment types (because $\gamma < 1$).

This result should also clarify why in equilibrium different equipment types can deliver different amounts of efficiency units per dollar. If $\gamma = 1$ (perfect substitutability among capital types), then in each country all the investment will be concentrated on the highest-efficiency type of capital. However, with imperfect substitutability, investors will be willing to hold a diversified portfolio of types, even if the intrinsic efficiency of different types differ. However, more efficient types will be held in larger proportions. While we do not model the conditions under which the capital is produced (in some foreign country) it is easy to imagine situations where the price of efficiency unit would vary across types. For example, this will arise if capital is produced under perfect competition, so that price equals marginal cost, and the cost of producing one unit of efficiency differs across types. Alternatively, the degree of monopoly power could vary across equipment producing sectors (in the equipment-producing country).[11]

We can also look at the implications of our assumptions for aggregate income. Using results in the appendix it is possible to write aggregate output as

$$Y^i = B^i \left(K^i\right)^{\alpha} \left(L^i\right)^{1-\alpha} \left[\sum_p \left(A_p^i\right)^{\gamma} \left(\xi_p^i\right)^{\gamma}\right]^{\frac{1}{\gamma}},$$

where the last term is an index of the quality of the capital stock.[12] We can think of this representation as breaking down the contribution of investment to output as a *quantity* (K) vs. *quality* (the expression in square brackets) decomposition. Substituting from (1) this decomposition can be alternatively stated as :

$$Y^i = B^i \left(K^i\right)^{\alpha} \left(L^i\right)^{1-\alpha} \left[\sum_p \left(A_p^i\right)^{\frac{\gamma}{1-\gamma}}\right]^{\frac{1-\gamma}{\gamma}}. \tag{2}$$

[11] Below we further comment on the implications of cross-type differences in the price of one efficiency unit for existing work in development accounting and empirical growth.

[12] It is very tempting to identify the last term in the equation (perhaps multipied by B) with TFP, but this would not be consistent with the conventional interpretation of TFP. In conventional measures of TFP the capital stock is evaluated – at least in principle – in terms of efficiency units, and not in units of the consumption good, as here. Hence, in the model we have written down conventional TFP is just B.

The last section of the paper will presents the results of this decomposition and discuss their implications.

The model presented here implicitly assumes complete depreciation of capital within one period. The next draft will contain a discussion of the implications of relaxing this assumption.[13]

3 Empirical Specification

The main focus of the empirical analysis is equation (1), where investment of capital of type p in country i is related to the efficiency level of type p in country i relative to the efficiency of total capital in country i. The P (nine in our case) equations share a common denominator representing the efficiency of total capital. Solving for the common term and substituting it into the other equations allows us to reduce this P-equation system to the following $P-1$ equations:

$$\frac{\xi_p^i}{\xi_1^i} = \frac{\left(A_p^i\right)^{\frac{\gamma}{1-\gamma}}}{\left(A_1^i\right)^{\frac{\gamma}{1-\gamma}}}, \qquad \text{for } p = 2, ..., P. \tag{3}$$

For the purposes of obtaining an empirical specification, we conjecture that A_p^i depends on a series of country and product characteristics as follows:

$$A_p^i = A_p \prod_c \left(z_c^i\right)^{\delta_{c,p}}. \tag{4}$$

In this equation, A_p is a product-specific productivity term that applies in all countries (the intrinsic efficiency of this type of capital). z_c^i is the value of characteristic c in country i, and $\delta_{c,p}$ measures the degree of complementarity between equipment of type p and characteristic c. For example, c could be human capital. If $\delta_{c,p} = 0$ there is no complementarity between human capital and physical capital of type p: brute force is all that is needed to operate this capital. Instead, if $\delta_{c,p}$ is large, p is a highly skill-complementary type of capital.[14]

Besides human capital, other possible characteristics c are:

Inward (external liabilities) foreign direct investment (FDI), where a high δ denotes a comparative-advantage by foreign corporations in importing and installing this type of capital.

[13] At this point we believe our results in the next section should be robust to multi-period depreciation for two reasons. First, we estimate our model on panel data where the cross-sections at five-year intervals. So the implicit time period in our model is five years, which should be long enough so that full depreciation is a reasonable approximation. Secondly, as long as depreciation rates are not country-specific, differences in depreciation by type should be picked up in the type fixed effects we include in our regressions.

[14] This discussion assumes that there is a representative worker with the average level of human capital.

Outward FDI (external assets): As pointed out by Feenstra (1998), outward FDI (as well as inward FDI in the reverse) may be a mechanism for acquiring intangible assets such as technical knowledge. Thus, a high δ here may indicate that having outward FDI may bring in knowledge which is complementary to this type of capital.

Degree of protection of intellectual property rights (IPR), where a high δ implies that investing in this type of capital is profitable only if intellectual property rights are well protected.

Share of government in GDP (GOVCONS), where a high δ signals that the government has a comparative advantage in operating this type of capital, or a unique demand for this capital.

The shares of private GDP accounted for by industry (INDSHR; includes mining, manufacturing, construction, electricity, water, and gas) and services (SERVSHR) (the residual category, which is omitted in the regressions, is agriculture). This allows for sector-specificity of the capital types p.

Overall property rights (PROPERT), where a high δ implies that enforcement of personal property rights is important to the demand for this capital type.

The lack of very high marginal tax rates (TAXRATE), where a high δ indicates that high marginal tax rates serve as a deterrent to demand for the capital type.

Effective monetary policy and price stability (MONPRI), where a high δ signals that price stability is an important element in attracting this capital type.

Freedom to engage in international trade (TRADE), where a high δ implies that barriers to trade have a relatively stronger effect on reducing the imports of this type of capital.

Freedom to engage in capital and financial markets (CAPFIN), where a high δ may mean that financing is comparatively more important for investing in this capital type.

Without loss of generality, we can normalize $A_1 = 1$ and $\delta_{c,1} = 0$ for all c. We can then redefine A_p as the quality of type p capital relative to the quality of type 1 capital, and $\delta_{c,p}$ as the complementarity between type p and characteristic c, above and beyond the complementarity between type 1 and c. That is, the quality of any type of capital is only meaningful as a *relative* concept – it must be defined relative to some benchmark type. The choice of numeraire is arbitrary, though it obviously affects the interpretation of A_p and $\delta_{c,p}$. In our empirical analysis, we choose "Fabricated Metal Products" (ISIC 381, Rev. 2) based on our *a priori* belief that this type of capital would embody the least technology.[15]

[15] "Fabricated Metal Products" contains cutlery, hand tools, general hardware, metal furniture and fixtures, structural metal products, etc..

Substituting (4) and the above normalizations into (3), and taking logs we get:

$$\log(\xi_p^i/\xi_1^i) = \frac{\gamma}{1-\gamma}\log(A_p) + \sum_c \left(\frac{\gamma}{1-\gamma}\right)\delta_{c,p}\log\left(z_c^i\right). \tag{5}$$

One possible reduced-form implementation of this equation is

$$\log(\xi_p^i/\xi_1^i) = \beta_p + \sum_c \beta_{c,p}\log\left(z_c^i\right). \tag{6}$$

where β_p and $\beta_{c,p}$ are parameters to be estimated. β_p is a capital-type fixed effect, while $\beta_{c,p}$ represents the interaction between the type fixed effect and characteristic c. Adding an i.i.d. error term ϵ_{ip} to this equation yields an estimable specification. In this specification, the interpretation of β_p is as $\gamma/(1-\gamma)\log(A_p)$, and the interpretation of $\beta_{c,p}$ is as $\gamma/(1-\gamma)\delta_{c,p}$.

A more informative implementation may be to model the terms A_p and $\gamma_{c,p}$ as functions of capital type $p's$ characteristics. In particular, both A_p and $\delta_{c,p}$ may depend on the amount (or the intensity) of global research and development spending (R) that is embodied in capital-type p (relative to type 1). This suggests modeling $A_p = f(R_p/R_1)$ and $\delta_{c,p} = g_c(R_p/R_1)$ where $f()$ and $g_c()$ are functions to be determined. In other words, the inherent efficiency of capital type p relative to type 1 is a function of the R&D embodied in each type; likewise for the relative complementarity of type p with characteristic c.

The substantive issue regarding $f()$ and $g_c()$ are not necessarily their functional forms – assuming $f(R_p/R_1)$ is of the form $(R_p/R_1)^\sigma$ and $g(R_p/R_1)$ is of the form $b\log(R_p/R_1)$ seems a general and reasonable starting point (where σ and b should be positive).[16] The more substantive question is how R_p should be measured in order to best proxy for the level of embodied technology in capital type p. We will defer that discussion for the data section below. Substituting in our assumptions regarding $f()$ and $g()$, equation (5) reduces to:

$$\log(\xi_p^i/\xi_1^i) = \phi\,\log\left(\frac{R_p}{R_1}\right) + \sum_c \phi_c\left[\log(z_c^i)\cdot\log\left(\frac{R_p}{R_1}\right)\right] \tag{7}$$

where the parameter ϕ represents $\sigma\gamma/(1-\gamma)$ and ϕ_c represents $b\gamma/(1-\gamma)$.

There are several advantages of this specification over the previous one containing capital-type dummy variables. First, there are far fewer coefficients that need to be estimated ($1/(P$-$1)$ as many as before), which should allow for more precise coefficient estimates. Second and most importantly, the coefficients now specifically identify the determinants of import shares over the *embodied technology space*, whereas the dummy coefficients in the previous specification could be identifying effects on import shares coming from both technology and non-technology causes. The disadvantage of this second specification, though, is

[16]These functional form choices ensure that $A_1 \equiv f(R_1/R_1) = f(1) = 1$ and $\delta_{c,1} = g_c(1) = 0$, as was assumed in making type 1 the numeraire good.

that in the R&D regression we may be omitting determinants that are not captured-by R&D intensity. Furthermore, if the omitted factors are correlated with R&D, we may be assigning the contributions of these omitted factors to R&D.

4 Data and Measurement

The data on imports and exports (needed for our 'adoption' measure described below) from 1970 to 1997 come from the United Nations Trade Data as assembled by Statistic Canada (see Feenstra (2000)). These data provide bilateral imports and exports from over 100 countries at a very disaggregated level (generally the 4-digit SITC, Revision 2, level). First, we aggregate the bilateral imports and exports data across partner countries to get total imports by importing country and total exports by exporting country, both at the 4-digit commodity level. We then identify the SITC 4-digit commodities that correspond to capital goods. Capital goods imports and exports at the 4-digit level are aggregated (if necessary – it depends on the capital-type category) to the classification level (9 capital-type categories) that the R&D data is available. The nine capital-type categories are listed and described in Table 1.

Import shares are calculated as $\xi_p^i = \frac{M_p^i}{\sum_p M_p^i}$, where M_p^i is imports, in current domestic currency, of capital-type p into country i. Note that the denominator is *capital* imports, not *total* imports, as is consistent with our model.

For some of our robustness checks, we attempt to measure the total adoption of a capital-type. We define adoption as total imports minus total exports plus domestic production: $Adoption_p^i = M_p^i - X_p^i + Y_p^i$. We then construct adoption shares as:

$$\xi_p^i = \frac{M_p^i - X_p^i + Y_p^i}{\sum_p \left(M_p^i - X_p^i + Y_p^i\right)} \tag{8}$$

The data on exports come from the UN Trade Data as described above. Domestic production data by capital-type are available for a much smaller set of countries from the UNIDO Industrial Statistics Database.

Data on R&D by industry from 1973 to 1997, for the 15 primary R&D-performing countries in the world, are provided in the ANBERD database maintained by the OECD. A subset, nine, of these industries correspond to capital goods production. To construct "world" R&D flows by capital-type (p), we aggregate R&D (in constant U.S. dollars) across all countries by capital-good-producing industry (p). We construct world R&D stocks by capital-type using a perpetual inventory accumulation of past flows and a depreciation rate of 15%.[17]

[17] We initialize the R&D stock in 1973 as the 1973 R&D flow divided by the depreciation rate, 0.15.

In our empirical work, we use 2 alternative measures of R&D intensity by capital-type. The first, which we call the "R&D flow intensity" is the R&D flow of a type (in constant U.S. dollars) divided by the total sales of the type (in constant U.S. dollars) summed over the same 15 R&D-performing countries. The second measure, "R&D stock intensity," is the R&D stock divided by total sales.

Data on country characteristics came from the following sources:

IPR – Ginarte & Park (1997)

Human capital – Barro & Lee (2001)

Foreign direct investment – Lane & Milesi-Ferretti (2001)

GDP per capita, investment's share of GDP (i.e., savings rate), real investment – Penn World Tables, Mark 6.0, Summers & Heston (2002).

Sectorial composition (Industry's, services', government's, and agriculture's shares of GDP) – World Development Indicators (World Bank).

Institutional variables PROPERT, TAXRATE, TRADE, CAPFIN, and MONPRI – Various past editions of the Fraser Institute's "Economic Freedom of the World."

In the end we have an three-dimensional panel data set. The panel is balanced in the capital-type dimension (8 types – not 9 since one type is the numeraire) but unbalanced in the year and country dimensions. The range of the year dimension is the 5-year intervals 1970-1995. We restrict our panel to 5-year intervals because many of the country characteristics are relatively slow moving over time, therefore we wanted to rely most heavily on the cross-country variation to identify our parameters. There are between 49 and 66 countries in the panel depending on which variables are to be included. Note that though the observations have three dimensions, the only variables that vary by type are R&D (which varies by type and year, but not country) and the capital import shares (which vary by all three dimensions).

Table 2 shows the means and standard deviations, for 1980 and 1995, of the independent variables we use in our empirical section. The means and standard deviations, by capital-type, of the import shares, the adoption shares, and the three measures of embodied R&D are shown in Table 3.

Table 3 documents a number of interesting facts. First, note that the standard deviations on the import shares are quite large relative to the means. The coefficients of variation (std. deviation divided by mean) are especially large for aircraft, other transportation equipment, and computers. These large coefficients of variation document that there is a great deal of cross-country variation in capital composition.

Second, notice that the three measures of embodied R&D roughly agree on the ordering of capital types across the embodied technology space in 1980. This ordering has changed somewhat over time. But in general, the capital types which tend to embody the most R&D

are aircraft, communications equipment, computers, and professional goods, while fabricated metal products and non-electrical machinery seem to embody the least.

5 Estimation Results

5.1 Capital-Type Fixed Effects Specification

We estimate equation (6) via OLS using our unbalanced panel data set described above. The country and year coverage varies according to what country characteristics are included in the regression. We first estimate a parsimonious specification which allows for a large number of observations but a somewhat limited set of country characteristics. We then build on this specification by including additional country characteristics at the cost of lowering the number of observations. In the parsimonious specification, we include intellectual property rights (IPR), human capital (HC), inward FDI, outward FDI (both FDI variables are relative to total investment), and GDP per capita (RGDPCH). GDP per capita is included both because a nation's wealth itself may directly affect the types of products and therefore capital that it demands, and also because GDP per capita may pick up variation in country-specific disembodied technological change (or, equivalently, TFP) over time.

The results of estimating this parsimonious regression are shown in Panel A of Table 4. The sample consists of 58 countries and 2632 observations. The main limiting factors in terms of observations are the FDI variables.[18]

As for the coefficient estimates, first consider the estimated capital-type fixed effects, $\widehat{\beta}_p$. Recall that according to our model, $\beta_p = \gamma/(1-\gamma)\log(A_p)$. So a negative estimated fixed effect implies an A_p less than one, i.e., an inherent (non-country-specific) efficiency level for capital-type p below that of type 1, "Fabricated Metal Products." Interestingly, the capital types yielding significant negative fixed-effect estimates are "Computers" and "Professional Goods." While this result may appear puzzling at first sight, it can easily be rationalized in the context of our model. In particular, these capital goods may actually be less productive than metal products when one pulls out their complementarities with human capital, FDI, IPR, etc.. In other words, a country with the minimum levels of human capital, FDI, IPR, etc. may get more productive use out of hand tools, general hardware, and the other kinds of basic capital goods contained within the "Metal Products" type than out of these other types which may require substantial complementary investments and/or endowments.[19]

[18] Excluding the FDI variables would result in a little over 4,000 observations.

[19] An alternative interpretation is that there is a high degree of homogeneity of capital goods within these categories relative to that of metal products. Our model is predicated on the assumption that each capital type is a homogenous good and is used in the production of a homogenous input into the production of final output. Therefore each capital type has diminishing returns to scale, dictated by the parameter γ. If in fact

We can next look at the estimated coefficients on the interactions of capital-type fixed effects and country characteristics ($\widehat{\beta}_{c,p}$), which estimate $\gamma/(1-\gamma)$ times $\delta_{c,p}$, the degree of complementarity between capital-type p and characteristic c. Since $\gamma/(1-\gamma) > 1$, a positive coefficient implies complementarity between p and c, whereas a negative coefficient implies substitutability.[20]

It turns out that a number of capital types show a statistically significant complementarity with human capital. Computers, communications equipment, and aircraft have coefficients that are significant at the 5% level, while professional goods have a complementarity significant at the 10% level. There is no significant evidence that intellectual property rights (IPR) lead to greater demand of any particular capital type. There is some evidence of a negative relationship with non-electronic machinery but it is only significant at the 10% level. Inward FDI appears to foster greater demand for computers, electronic equipment, communications equipment, and other transportation equipment while fostering lower demand for aircraft and non-electronic machinery. Outward FDI shows significant complementarity with computers and aircraft. Lastly, wealth, as measured by income per capita, seems to generate relatively greater demand for the products produced with computers (or perhaps for computers as consumption goods) and relatively lower demand for motor vehicles and aircraft, holding all else equal. It could also be that wealthy countries are more likely to satisfy demand for motor vehicles and aircraft with domestic production as opposed to imports. We will explore a couple of ways of controlling for domestic production of capital goods in the subsection below.

One important country characteristic that is not controlled for in this parsimonious specification is the sectorial composition of the economy. We can control for this by including measures of the share of the economy accounted for by various sectors. The most disaggregate sectors for which data exists for a large number of countries are government (GOVCONS), industry (INDSHR, which includes manufacturing, mining, construction, electricity, water, and gas), services (SERVSHR), and agriculture. Because these sector shares add up to 1, we must omit one category (we choose agriculture) – so the coefficients of one of the included sector shares capture whether the sector demands more or less of that capital type than the agricultural sector.

The results of this expanded regression are shown in Panel B (Table 4). The in-

a type category contains many varieties of capital goods, as is likely for metal products, it will not suffer the same degree of diminishing returns and will therefore be demanded in larger quantities. One could think of the degree of heterogeneity, or variety, in a capital-type as a feature of its intrinsic quality.

[20]Throughout this section, we refer to "complementarity" or "substitutability" between country characteristics c and capital-types p. It should be kept in mind that, strictly speaking, the degree of complementarity in our model, $\delta_{c,p}$, between a given characteristic and capital-type p is always *relative* to the degree of complementarity between that characteristic and capital-type 1.

clusion of these shares costs us about 600 observations. The estimated coefficients on the previously included variables are broadly similar to the estimates in Panel A. Notable deviations from the previous results are as follows. The negative relationship estimated between aircraft imports and IPR now becomes significant, while a negative relationship between non-electrical machinery and IPR is no longer significant. The statistical significance of the positive relationship found previously between computers and GDP per capita and the negative relationship between motor vehicles and GDP per capita goes away once sectorial composition is accounted for. The negative relationship between aircraft and wealth is now the only type with a significant relationship with wealth. The estimated coefficients on the two FDI variables are roughly similar, though some become no longer significant at the 10% level, to their corresponding estimates in Panel A.

The estimates on the new interaction variables show a number of significant effects from sectorial composition. It appears that the government sector tends to demand relatively less computers, electronic equipment, and non-electronic machinery than other sectors. The government also seems to demand more motor vehicles and aircraft, which could be related to defense spending, though the relevant coefficients have p-values (not shown) just barely over 10%. The services sector is estimated to have a relatively greater demand for computers and professional goods, which seems quite intuitive, as well as aircraft. The industrial sector's share also has a significant coefficient for aircraft. These positive relationships that each of the three sectors, services, industry, and government, seem to have with aircraft may reflect that the agricultural sector (or more generally, an agrarian economy) has an especially low demand for aircraft, which is plausible. The industrial sector is also found to have a relatively greater demand for non-electronic equipment and lower demand for communications equipment.

We next focus on a series of subjective measures of the institutional strength of a country. These variables come from past editions of the Fraser Institute's "Economic Freedom of the World" reports. The first variable, PROPERT, is an assessment of the degree to which personal property rights are enforced. The next variable, MONPRI, assesses the quality of monetary policy and the degree of price stability. TAXRATE is an assessment of the top marginal tax rate and the income level for which it applies. A *high* value for TAXRATE corresponds to a *low* top marginal tax rate. The TRADE variable is meant to capture the freedom with which economic agents can engage in international trade. Lastly, CAPFIN assesses the freedom agents have to engage in financial capital markets.

As mentioned above, the country as well as time coverage for the FDI variables is somewhat limited. Since the Fraser Institute data is also rather limited, adding both the FDI variables and the Fraser variables to the previous regression cuts the number of observations by almost a half. Therefore, we first look at the estimated effects of the institutional variables without the FDI variables in the regression, and then subsequently add the FDI variables to see how the results change.

Panels C and D of Table 4 present the results of these two regressions. Panel C gives the results for a specification that includes the institutional variables but excludes FDI; Panel D includes all variables. Even with the inclusion of the institutional variables, the exclusion of the FDI variable causes the country coverage to the unbalanced panel to increase to 66. Nonetheless, since the Fraser Institute data has rather limited time coverage, the total number of observations actually falls by about 25% relative to the regression in Panel B. The estimated coefficients in Panel C on the capital-type dummies, IPR, HC, RGDPCH, and the three sectorial composition variables are qualitatively similar to those of Panel B. A number of coefficients lose their statistical significance, however, perhaps owing to the decline in the number of observations. One difference worth noting is that the significant negative relationship between computers and government's share of GDP found in Panel B becomes a non-relationship in the new regression, while the positive estimated relationship between "Other Transportation Equipment" and government now becomes significant.

The coefficients on the interactions of the institutional variables with the capital-type fixed effects point to no effect from the tax rate but a number of significant effects from the other variables. Personal property rights appear to be complementary with the importation and use of computers, non-electronic machinery, and especially aircraft (the coefficients on the first two interactions are significant at the 10% level while the coefficient on the aircraft interaction is significant at the 5% level). This complementarity may be because these capital-types tend to be high price-per-unit ("big-ticket") items, therefore effective enforcement of property rights are critical to the decision of whether to purchase these items. Price stability and effective monetary policy are also found to increase the demand for aircraft. The freedom to engage in international trade, as assessed by the Fraser Institute, is found to increase the demand for communications equipment and electronic equipment (and possibly computers and professional goods, whose p-values are just above 10%) while decreasing the demand for non-electronic equipment. Lastly, we find the freedom to engage in capital and financial markets has a strong positive effect on the demand for computers.

Adding outward and inward FDI to the regression cuts observations by about a quarter and reduces the number of countries covered from 66 to 49. Again, the estimated coefficients on the type fixed effects, HC, IPR, RGDPCH, and sector shares are qualitatively similar to the earlier regressions. The most robust (in terms of significance over all specifications) findings are the positive complementarity between computers and human capital, the negative relationship between GDP per capita and aircraft, the positive relationship between the industrial sector and non-electrical machinery, and the negative relationship between that sector and communications equipment.

The estimates related to the institutional variables do not change substantially with the inclusion of the FDI variables, though some lose statistical significance (see Panel D). In particular, now only aircraft show a significant complementarity with property rights. Also, the positive estimated relationship between computers and the freedom to engage in capital and financial markets is no longer significant.

5.2 Embodied R&D Specifications

Table 5 presents the results of estimating the regression equation given in (7). Recall the advantage of this specification is it identifies the determinants of import shares (or more generally, capital composition) over the *embodied technology space*, whereas the dummy coefficients in the capital-type fixed effects specifications could be identifying effects on import shares coming from both technology and non-technology sources.

We estimate (via OLS) four specifications exactly analogous to the four capital-type fixed effects specifications discussed above. The embodied R&D measure used in these regressions is the R&D flow intensity. It turned out that the results were not at all sensitive to the choice of the R&D variable.[21] All of the R&D regressions utilize a fewer number of observations than their fixed effect analogs because the data on output by capital-type industry, the denominator in R&D intensity, begins in 1980.

Column 1 of Table 5 shows the results of regressing the (log of) capital-type import shares, relative to metal products, on (log of) the R&D embodied in the capital-type and interactions of R&D and the following characteristics: IPR, human capital, inward FDI, outward FDI, and GDP per capita. The coefficient on embodied R&D is positive and significant. This suggests that, holding country characteristics constant, capital goods which embody more technology (as measured by R&D) tend to account for a greater share of capital imports.

The coefficients on IPR, HC, inward and outward FDI, and GDP per capita are quite consistent with the results from the analogous type fixed effects regression (see Panel A of Table 4). As in those results, there is no evidence here of any effect of intellectual property rights on the demand for higher technology capital. There is a very strong positive effect, though, of human capital on such demand. This is perfectly consistent with the type fixed effect results. Recall from section 4 that the R&D flow intensity variable implied the following ordering of the capital types in terms of quality (in 1980, though the ordering is stable over time): aircraft, computers, communications equipment, professional goods, elec-

[21] Results using the R&D stock or the R&D stock intensity are availble from the authors upon request.

trical equipment, motor vehicles, non-electrical equipment, other transportation equipment, and fabricated metal products. And recall that type fixed effect regression indicated a significant complementarity between human capital and computers, aircraft, communications equipment, and professional goods. Thus, the positive complementarity between embodied R&D and human capital is to be expected.

Inward FDI is estimated to have a significant negative relationship (i.e., substitutability) with embodied technology, while outward FDI has significant complementarity with embodied technology. Lastly, once these other characteristics are accounted for, GDP per capita actually seems to lead to lower demand for high-tech capital.

Column 2 shows the results of adding the three sectorial composition variables. With this inclusion, the direct effect of embodied R&D on import shares is negative and significant. There remains no effect from IPR. The coefficient on human capital's interaction with embodied R&D remains positive and significant and that on inward FDI remains negative and significant. Both outward FDI and GDP per capita become insignificantly different from zero.

The estimated coefficients on the added variables show that the industrial and service sectors, relative to the agricultural sector, have a greater demand for high-technology capital, while the government sector has a comparatively lower demand for such capital. All of these results are consistent with the results from the corresponding capital-type fixed effects regression (Panel B, Table 4).

We next add the Fraser Institute's institutional variables, first without the FDI variables in order to retain a large number of observations (Column 3), then with the FDI variables (Column 4). With the institutional variables included and FDI excluded, embodied R&D appears to have a negative direct effect on import shares. As in the previous two regressions, the IPR interaction has no significant effect. The coefficient on the human capital interaction decreases some and the coefficient is now significant at the 10% level but not the 5% level. GDP per capita has no effect. Industry's share of GDP remains significantly complementary with embodied R&D and government's share remains significantly negatively related to the demand for high-R&D capital. The effect of services share of GDP now becomes negative but is no longer significant.

Consistent with the lack of any effect of the tax rate in the type fixed effect regressions, the tax rate interaction has no effect here either. Overall property rights and the freedom to engage in capital and financial markets are both found to be complementary with embodied R&D. The assessment of monetary policy and price stability seems to be negatively related to the demand for high-R&D capital imports, while the freedom to engage in international trade appears to have no effect.

Adding the FDI variables causes the estimate of the direct effect of R&D intensity to turn positive and significant, as it is in base specification (Column 1). IPR's interaction becomes positive and significant (at the 10% level) in this full specification, while human capital loses it's statistical significance. All other effects are statistically significant at the 5% level. Complementarity with embodied R&D is found for the following characteristics: outward FDI, industry's share of GDP, services share of GDP, low marginal tax rates, overall property rights, and the freedom to engage in capital and financial markets. Substitutability is found for inward FDI, GDP per capita, government's share of GDP, monetary policy effectiveness and price stability, and the freedom to engage in international trade.

5.3 Robustness Checks Relating to Domestic Production

Our model in Section 2 laid out the relationship between, on the one hand, capital composition, i.e., the shares of each capital type in total capital, and on the other hand, the intrinsic efficiency of each type and the degrees of complementarity each type has with various country-specific factors. This model is indifferent to whether the capital is imported or produced domestically. However, our empirical approach thus far has assumed that all capital is imported, or at least that the composition of total capital is the same as the composition of capital imports, both of which are probably not true. How does domestic production of capital bias our results, if at all? It is well established that a small set of highly developed countries perform nearly all of the world's R&D. Furthermore, these R&D-performing countries tend to produce much of the world's equipment, while most less developed countries import much of their equipment from these R&D-performing countries (see Eaton & Kortum, 2001, for evidence of these stylized facts).

These stylized facts have two implications for our empirical approach: (1) high R&D-performing countries may produce much of their capital domestically and thus their imports composition may not be representative of total capital composition; and (2) what little capital LDCs produce at home is likely to embody very low R&D/technology. This first implication suggests that our estimates may be biased *against* finding positive direct and indirect effects of embodied technology on capital composition if R&D-performing countries tend to specialize in producing high-tech capital. This is because these countries, which are likely to be abundant in complementary characteristics, will tend to import low-tech capital while specializing at producing high-tech capital at home. This argument implies that in the capital-type fixed effects regressions, the fixed effects and interaction terms on high-tech capital types will be biased downward; and the coefficients on embodied R&D and the interaction terms in the R&D regressions will also be biased downward. On the other hand, the first implication might suggest a bias *in favor* of finding positive effects of embodied technology if domestic R&D itself is complementary with high-tech capital. The second implication suggests that the import composition of non-R&D-performing countries may be more tilted towards high-tech capital than their total capital composition. Because there are many more non-R&D-performing countries than R&D-performing countries in our data, this suggests a bias in favor of finding positive direct and indirect effects of embodied technology.

We explore whether and in what direction our previous estimates are biased due to domestic production of capital via two methods, following Caselli and Coleman (2001). First, we simply restrict our sample to non-R&D-performing countries and re-estimate each of the previous regressions. In reality, all countries probably perform some research and development to a limited extent. What we call "non-R&D-performing" are those countries that are not included in the 15 OECD countries for which the OECD collects R&D data. As mentioned earlier, it has been shown that these countries account for the vast majority of the world's R&D.

Estimating the four capital-type fixed-effect regressions discussed in section 5.1 above on this restricted sample yields results that are qualitatively quite similar to the results from the full sample. Because of the large number of coefficients, we will not discuss the individual estimates, which are shown in Table B1 in Appendix B. Suffice it to say that, though the statistical significance of many variables decrease somewhat thanks to fewer observations, most of the significant effects found in the full sample are still present in the non-R&D-performing sample.

The similarity between the full sample and restricted sample results is also the case for the R&D regressions. The restricted sample results are shown in Table 6. Comparing these results to those in Table 5, one can see that the point estimates are remarkably similar across the two samples. The only substantial changes from moving from the full sample to the restricted sample are that IPR, which was negative and insignificant in the first two regressions and significantly positive in the fourth regression, becomes significantly negative in the first two regressions with the restricted sample (see Columns 1 and 2) while losing its significance in the fourth regression.

The second method we use to account for domestic production of capital is to attempt to measure each country's total adoption of each capital type. We measure the adoption of a capital type as its imports minus its exports plus its domestic production. We then compute the share of each type's adoption in total capital adoption (defined as total capital imports minus total capital exports plus total capital production at home). This then becomes the ξ_p^i in the dependent variable of the regression equation shown in (6).

Unfortunately, the data on domestic production by capital type are quite limited in country and time coverage (e.g., the data do not begin until 1980). Estimating the parsimonious type fixed effects regression, containing the interactions of IPR, HC, inward FDI, outward FDI, and GDP per capita, using adoption shares results in only 723 observations and 36 countries. This compares to 2632 observations and 58 countries for the same regression using import shares. The coefficient estimates are shown in Table 7. The coefficients are estimated much less precisely than before and thus far fewer coefficients are statistically significant. Nonetheless, this regression's results do provide support for many of the findings in the import shares regressions. First, human capital is once again found to be significantly complementary with computers. Second, inward FDI appears to have a significantly negative effect on the adoption of non-electrical machinery and a positive effect (though not significant) on the adoption of other capital types (relative to metal products); and outward FDI is again found to have a positive relationship with the demand for aircraft. More generally, the signs of most estimates from this regression are the same as they were in import shares regression.

The results of using the adoption measure of our dependent variable for the R&D specification (containing the same interactions as those discussed above) are shown in Column 5 of Table 5. The results are generally similar to those from using import shares. Again, embodied R&D has a positive and significant direct effect, outward FDI has a positive estimated complementarity, and inward FDI and GDP per capita have negative estimated complementarities. The main difference between this regression and the one using import shares is that here human capital is no longer found to have a significant complementarity with embodied R&D.

6 Implications for Development Accounting

Until now we have endeavored to identify the cross-country determinants of imports of capital-embodied technology. We have found that there are a number of country-specific factors that have a significant effect on the demand for capital of different types. In this section we try to address the obvious question: does it matter for explaining productivity differences across countries?

The simple model we laid out in Section 2 suggests that the answer should be yes. In that section, we derived the equation

$$Y^i = B^i \left(K^i\right)^{\alpha} \left(L^i\right)^{1-\alpha} \left[\sum_p \left(A_p^i\right)^{\gamma} \left(\xi_p^i\right)^{\gamma}\right]^{\frac{1}{\gamma}}, \tag{9}$$

which suggests that differences in the composition of the stock of equipment, i.e. in the vector of the ξs, could have explanatory power for cross-country differences in output – unless, that is, equipment of different types embody identical amounts of technology. The main goal of this section is to present two empirical implementations of equation (9), aimed at assessing the role of imported embodied technology in explaining cross-country variation in output per worker. Before taking this up, it is useful to consider the implications of our model and our results so far for existing development accounting exercises.

6.1 Heterogeneous Capital and Development Accounting

Following standard practice we can rewrite (9) as

$$y^i = B^i \left(\frac{K^i}{Y^i}\right)^{\frac{\alpha}{1-\alpha}} \left[\sum_p \left(A_p^i\right)^\gamma \left(\xi_p^i\right)^\gamma\right]^{\frac{1}{\gamma(1-\alpha)}}, \tag{10}$$

where y^i is real per-worker GDP in country i (i.e. $y_i = Y_i/L_i$). The typical growth-accounting exercise starts by positing the relationship

$$y^i = B^i \left(\frac{\tilde{K}^i}{Y^i}\right)^{\frac{\alpha}{1-\alpha}}, \tag{11}$$

where $\tilde{K}$ is a measure of the *real* (read quality-adjusted) capital stock. Recall that, instead, in (10) K^i is the dollar value of the capital stock. Given a measure of $\tilde{K}^i$, in development accounting one proceeds to estimate or calibrate α, and to then make inferences on the relative importance of capital and disembodied TFP (the term B) in causing cross-country income differences.

One first implication – which is immediately obvious by comparing the two equations – is that for those inferences to be correct it has to be the case that $\tilde{K}^i = K^i \left[\sum_p \left(A_p^i\right)^\gamma \left(\xi_p^i\right)^\gamma\right]^{\frac{1}{\alpha\gamma}}$. Now the particular way $\tilde{K}^i$ is usually measured in this literature is as the *price-weighted* sum of investments in various types of equipment, or

$$\tilde{K}^i = K^i \sum_p \xi_p^i / P_p^i,$$

where P_p^i is the price of equipment of type p. Clearly, then, there is a underlying implicit assumption that (i) $\gamma = 1$, i.e. different types of capital are perfect substitutes, and (ii) $P_p^i = 1/A_p^i$, i.e. country-specific prices for capital of type p fully reflect the country-specific efficiencies of this type.[22] Clearly assumption (i) is not appealing (computers and trucks

[22] It may seem that even if the two assumptions hold, there is still a problem with the term $1/\alpha$ in the exponent. This is true but we don't emphasize this because this term is somewhat model specific. For example, had our model been

$$Y^i = B\left(L^i\right)^{1-\alpha} \left[\sum_{p=1}^{P} \left(x_p^i\right)^\gamma\right]^{\frac{\alpha}{\gamma}}, \qquad x_p^i = A_p^i K_p^i,$$

are probably not perfect substitutes).[23] Assumption (ii) is also unappealing: as discussed in Section (2), if $\gamma < 1$ there is no reason to believe that prices per unit of efficiency will be equalized across equipment types. Furthermore, even if P_p^i is measured using techniques designed to capture quality (e.g., hedonics), it is very unlikely to capture country-specific differences in efficiency of type p. For instances, many countries simply adopt the U.S.'s hedonic computer deflator for their own. Thus, given the inappropriateness of (i) and (ii) above, inferences on the relative contribution of capital and disembodied TFP based on $\tilde{K}^i$ are likely to be misleading.

Even if one believed the bias introduced by the mis-measurement of $\tilde{K}^i$ to be small or second order, though, there would still be reason to implement a more disaggregated view of capital. This makes it possible to investigate the sources of the explanatory power of real capital for development levels. Do high Y^i countries have high $\tilde{K}^i$ because they save a lot, or because they invest in types of capital with particularly high levels of embodied technology? Or is it that they invest in those types of capital that are especially complementary with their factor endowments? It is easy to imagine that answers to questions like these – that can really be fully explored by disaggregating the capital stock – can have profound implications for development policy.[24]

In conclusion, implementing equation (10) instead of equation (11) may provide a set of insights that are both more accurate and richer about the sources of cross-country differences in development.

6.2 Implementation 1

Equation (10), in logs, becomes

$$\log(y^i) = \log(B^i) + \frac{\alpha}{1-\alpha}\log\left(\frac{K^i}{Y^i}\right) + \frac{1}{\gamma(1-\alpha)}\log\left[\sum_p \left(A_p^i \xi_p^i\right)^\gamma\right]. \quad (12)$$

Suppose, first, that there is no country-specificity in the degree to which the quality of capital differs. Then this equation could be estimated as a non-linear regression of per-capita GDP

the condition for the standard exercise to deliver correct inferences would simply be $\tilde{K}^i = K^i\left[\sum_p \left(A_p^i\right)^\gamma \left(\xi_p^i\right)^\gamma\right]^{\frac{1}{\gamma}}$, which only requires (i) and (ii).

[23] That measuring a capital aggregate from a set of subaggregates, all in terms of efficiency units, requires perfect substitutability was proven in Fisher (1983): "[t]he use of subaggregates like 'equipment' and 'plant' together with an aggregate 'capital' thus implies that 'plant' and 'equipment' are perfect substitutes and is highly questionable." Fisher showed that this result holds for any continuous, twice-differentiable production function.

[24] On some of these questions it is actually possible to make some progress without disaggregating the capital stock. For example, Hsieh and Klenow (2002) decompose $\tilde{K}$ into a component due to savings and one due to price levels of investment goods, and find that most of the variation in $\tilde{K}$ comes from prices.

on a proxy for the capital-output ratio, and the vector of import shares ξ_p^i. The parameters to be estimated are α, γ, and the vector of embodied-technology parameters A_p. Statistically significant differences among these $A_p^i s$ would signal that differences in quality exist. And a large R^2 from this regression – relative to the R^2 from a regression that only involves the capital-output ratio – would signal that differences in the composition of the stock of equipment are potentially important sources of productivity differences across countries.

To implement this exercise, we need a proxy for the capital/output ratio, K/Y and an assumption on the disembodied technology term, B. We proxy the capital-output ratio by a country's saving rate. This has the advantage of being in units of output, as in the theory. Furthermore, in the Solow model (the log of) the steady-state capital-output ratio is linear in (the log of) the savings rate, so this proxy may be justified on theoretical grounds.[25] In order to account for disembodied technology we include in the regression year fixed effects. Hence, the assumption is that disembodied technology flows freely across countries, and that cross-country differences in productivity are attributable to the composition of investment.

We estimate equation (12) using non-linear least squares. The results are shown in Table 8. The point estimates are generally quite reasonable: α, the elasticity of output with respect to capital is 0.33 (with a s.e. of 0.03) which is exactly in line with capital's average share of income. The estimate of γ, which governs the returns to variety in product space, is 0.44 (s.e. of 0.19) which is statistically significantly different from 0 or 1. The capital-type-specific efficiencies relative to fabricated metal products, for which $A_1 = 1$ by definition, are estimated with great imprecision. Nonetheless, their point estimates suggest an efficiency ordering across types that is reasonable. Computers are estimated to be seven times as efficient as metal products and more than twice as efficient as any other type. The next most efficient capital type, according to these estimates, is other transportation equipment, followed by professional goods, electrical equipment, non-electrical equipment, communications equipment, aircraft, metal products, and motor vehicles.

The R^2 from this regression is negative. This is a frequent occurrence in non-linear regressions and we are still investigating what to make of this. Regressing $\log(y^i)$ on $\log\left(K^i/Y^i\right)$ (using the same observations) results in an R^2 of 0.19 and an estimate of the coefficient on $\log\left(K^i/Y^i\right)$ of 0.97 (s.e. of 0.08), which implies an $\alpha = 0.49$.

Overall, the non-linear estimation performed in this subsection seems to yield reason-

[25] It should be clear from the discussion in the previous sub-section that using the investment series in Summers and Heston to construct estimates of the capital stock, and then using such estimates in the numerator of K/Y, would be inappropriate, as such estimates already try (though they may very well fail) to put the capital stock in quality-adjusted terms. If the Summers and Heston measures successfully control for quality, then the ξ^is should have no additional explanatory power *even by our model's standards.* On the other hand, if the measure fails at controlling for quality, then the regression is mis-specified and the results uninterpretable.

able point estimates of α, γ, and the type-specific efficiencies but the efficiencies' estimates are very imprecise and the R^2 is negative; therefore, it is difficult to assess from this exercise whether accounting for the composition of imported capital helps explain much of the variation in income per capita across countries.

6.3 Implementation 2

As is obvious from the previous section, we think of the composition of a country's equipment stock (the vector ξ) as endogenous, and indeed most of the effort in this paper was devoted to empirically explaining cross-country differences in it. One obvious question is whether the amount of variation in ξ that we managed to explain (as opposed to the actually observed variation in ξ) is an important source of variation in output per worker. As we have already seen in deriving equation (2) we can express the quality of capital exclusively in terms of the A_p^is, so that equation (12) can also be expressed as

$$\log(y^i) = \frac{\alpha}{1-\alpha}\log\left(\frac{K^i}{Y^i}\right) + \frac{1-\gamma}{\gamma(1-\alpha)}\log\left\{\sum_p \left[A_p \prod_c \left(z_c^i\right)^{\delta_{c,p}}\right]^{\frac{\gamma}{1-\gamma}}\right\}. \qquad (13)$$

Notice that the term upon which the summation operator operates is the exponential of the right-hand side of equation (5), which express the determinants of $\log\left(\xi_p^i/\xi_1^i\right)$. Thus, taking the exponential of the predicted value from a regression based on (5), and summing over capital types within each country-year pair provides a measure of the quality of capital, i.e., the term in brackets to the right of the second log operator above. With this term measured and K/Y measured, we have a linear equation in logs that can be estimated via OLS. The two coefficient estimates on the two log terms can be rearranged to provide estimates of α and γ. As in the first implementation, the R^2 from the regression above compared to the R^2 from a regression of $\log(y^i)$ on $\log\left(K^i/Y^i\right)$ should tell us how much additional variation in income per worker can be explained by capital quality.

So far in this section we have treated the product-specific parameters A_p and the complementarity parameters $\delta_{c,p}$ as just that: parameters. However, as in the previous sections, we can also assume that the A_ps and the $\delta_{c,p}$s are functions of the R&D content of the corresponding equipment types. Hence, we can repeat the exercise above under this assumption, and see how much of the variation in income per worker is attributable to differences in the R&D content of various types of equipment.

Table 9 shows the coefficient estimates and R^2 from regressing $\log(y^i)$ on $\log\left(K^i/Y^i\right)$ and (the log of) capital quality as measured from the predicted values of the import share regressions. The values of α and γ implied by the coefficient estimates are also shown as well as the estimates and R^2 from the same regression (using the same observations) excluding the capital quality term. The standard errors on the coefficient estimates are adjusted for heteroskedasticity and correlation of the residuals within-country (using a robust VC estimator with country clusters). These regressions also include year fixed effects which are not shown in order to save space.

The first column of results in the table uses a measure of capital quality based on the predicted values from our "parsimonious" or "base" capital-type fixed effects specification (Panel A of Table 4). This includes interactions of IPR, human capital, outward FDI, inward FDI, and GDP per capita. The second column gives results based on predicted values from the analogous specification using R&D intensity in place of fixed effects. The third column is based on the type fixed effects regression with the full set of interactions (see Panel D of Table 4), while the fourth has the same interactions but uses R&D intensity in place of fixed effects.

Regardless of which import shares regression we use to form the capital quality measure, including quality substantially increases the amount of variation in income per capita that can be explained by capital (quantity plus quality). In the first case, for instance, capital quantity alone (plus year fixed effects) can only explain 5.5% of the variation, while adding in capital quality allows one to explain 35.6%. The additional variation explained by quality is lower when the quality measure is based on the R&D specifications, but it is still substantial.[26]

The coefficient estimates from these regressions seem to suggest an α near 0.15 (except the fourth regression where α is about 0.05) and a γ somewhere between 0.34 and 0.62. These point estimates seem quite reasonable, though F-tests show that while the estimates of γ are statistically significantly different from 0 or 1, the estimates of α are not significantly different from 0.

7 Conclusions

The development accounting exercise above shows that, analogous to disaggregating labor into "skilled" and "unskilled," disaggregating capital into separate quantity and quality terms is important for development accounting. When capital types differ in terms of quality (embodied technology), attempting to measure a single capital aggregate that incorporates quality requires the implausible assumptions that (i) all capital goods are perfectly substitutable; and (ii) measured prices of capital types reflect country-specific efficiencies.

This first result was established many years ago by Fisher (1983). Yet, development accounting has proceeded under the implicit assumptions that (i) capital goods are near

[26]That variation in saving rate has very little explanatory power for cross-country income differences is a point recently forcefully made by Hsieh and Klenow (2002).

enough to being perfectly substitutable that the specification bias due to a single capital aggregate is small; and (ii) cross-country differences in capital efficiency are negligible. The results in this paper counter both of these assumptions.

First, the perfect substitutability between capital types is inconsistent with the tremendous variation in capital composition both within and across countries for a given year. Moreover, estimating a simple development accounting model with capital disaggregated into quantity and quality, we find that the elasticity of substitution between capital types is actually fairly low. We also find that capital quality, measured by composition alone or by the fitted values from our regressions explaining composition, has a large and significant effect on income per capita.

Secondly, when we estimate our empirical model of capital import shares, we find not only that capital types differ greatly in terms of intrinsic efficiency (casting doubt on (i)), but also that country-specific factors substantially affect the efficiency, and therefore the demand, of capital types (casting doubt on (ii)). In particular, human capital, outward FDI relative to investment, property rights, low marginal tax rates, industry's share of GDP, and services share of GDP are found to be complementary with high-technology capital types (as measured by R&D), while the size of the government and inward FDI are complementary with low-technology capital types.

Overall, our results indicate that countries do seem to allocate their investment dollars across capital goods in a manner that is most appropriate for their country given its particular characteristics. More importantly, we show that this allocation is quantitatively important in determining a country's wealth.

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Appendix: Derivation of Equation (1)

Here for notational convenience we drop the country superscripts i. In each intermediate process p the marginal product of labor is equal to the wage rate w, or

$$(1-\alpha)\left(\sum_j x_j\right)^{\frac{1}{\gamma}-1} A_p^{\gamma} L_p^{(1-\alpha)\gamma-1} K_p^{\alpha\gamma} = w.$$

Solving for L_p, summing over all sectors, and imposing the market-clearing condition $\sum_p L_p = L$, we can solve for the wage w. Substituting back into the above equation we get

$$\lambda_p \equiv \frac{L_p}{L} = \frac{A_p^{\frac{\gamma}{1-(1-\alpha)\gamma}} K_p^{\frac{\gamma}{1-(1-\alpha)\gamma}}}{\sum_j A_j^{\frac{\gamma}{1-(1-\alpha)\gamma}} K_j^{\frac{\gamma}{1-(1-\alpha)\gamma}}} = \frac{A_p^{\frac{\gamma}{1-(1-\alpha)\gamma}} \xi_p^{\frac{\gamma}{1-(1-\alpha)\gamma}}}{\sum_j A_j^{\frac{\gamma}{1-(1-\alpha)\gamma}} \xi_j^{\frac{\gamma}{1-(1-\alpha)\gamma}}}.$$

We also have the condition that the marginal product of capital is equalized across sectors, or

$$\alpha \left(\sum_j x_j \right)^{\frac{1}{\gamma}-1} A_p^{\gamma} L_p^{(1-\alpha)\gamma} K_p^{\alpha\gamma-1} = w.$$

Dividing this by the pricing equation for labor we find the conventional result that the capital labor ratio is equalized across sectors:

$$\frac{K_p}{L_p} = \frac{K}{L},$$

which implies

$$\xi_p = \lambda_p.$$

Hence we must solve the system of equations

$$\xi_p = \frac{A_p^{\frac{\gamma}{1-(1-\alpha)\gamma}} \xi_p^{\frac{\gamma}{1-(1-\alpha)\gamma}}}{\sum_j A_j^{\frac{\gamma}{1-(1-\alpha)\gamma}} \xi_j^{\frac{\gamma}{1-(1-\alpha)\gamma}}}.$$

Conjecturing that the solution takes the form $\xi_p = A_p^a / \left(\sum_p A_p^a \right)$ and substituting in the last equation one finds $a = \gamma/(1-\gamma)$, and hence the solution in the text.

Table 1

Capital-Type	ISIC code (Rev. 2)	Description
Fabricated Metal Products	381	Cutlery, hand tools, general hardware, metal furniture and fixtures, structural metal products, etc..
Non-electrical equipment	382-3825	Engines & turbines, agricultural machinery (including tractors, excluding metal tools), metal & wood-working machinery, industrial trucks, military ordinance (including tanks), etc..
Office, Computing, and Accounting Machinery	3825	Computers, calculators, typewriters, and other office equipment (excluding photo-copiers)
Electrical Equipment (excluding communications equipment)	383-3832	Electrical industrial machinery, electrical appliances, and other electrical apparatus
Communications equipment	3832	Semiconductors, wire & wireless telephone equipment, radio & TV sets, audio recording equipment, signalling equipment, radar equipment, etc..
Motor Vehicles	3843	Automobiles and related parts (excludes industrial trucks and tractors)
Other Transportation Equipment	3842+3844+3849	Railroad equipment, motorcycles & bicycles, wagons & carts, etc..
Aircraft	3845	Aircraft and related parts
Professional Goods	385	Measuring & controlling equipment, photographic & optical goods, and watches & clocks

Table 2. Summary Statistics

Variable	1980 # of countries	1980 Mean	1980 Std. Dev.	1995 # of countries	1995 Mean	1995 Std. Dev.
Intellectual Property Rights, ranges from 0 to 5 (IPR)	103	2.402	0.931	110	2.740	0.945
Average years of education for population 25 and over (HC)	103	4.734	2.914	100	5.824	2.941
Real GDP per capita (RGDPCH)	108	6666.065	6377.264	118	8226.864	9177.571
Industrial sector's share of GDP (INDUSSHR)	98	0.341	0.159	117	0.289	0.100
Service sector's share of GDP (SERVSHR)	98	0.458	0.135	117	0.514	0.140
Government's share of GDP (GOVCONS)	112	0.155	0.069	122	0.149	0.063
Inward FDI	60	0.00029	0.00041	62	0.00058	0.00059
Outward FDI	59	0.00009	0.00023	61	0.00030	0.00057
Freedom to engage in international trade, on scale of 0 to 10 (TRADE)	99	5.472	2.458	117	6.194	1.878
Assessment of monetary policy and price stability, on scale of 0 to 10 (MONPRI)	105	6.897	2.183	122	6.861	2.589
Freedom to engage in capital and financial markets, on scale of 0 to 10 (CAPFIN)	98	4.561	2.380	123	5.601	2.453
Assessment of top marginal tax rate and income at which it applies -- low value means high tax rate, on scale of 0 to 10 (TAXRATE)	73	2.616	2.870	86	5.593	2.758
Overall property rights, on scale of 0 to 10 (PROPERT)	84	5.027	2.374	0	N/A	N/A

Table 3

1980

Capital Type →	Fabricated Metal Products	Non-electrical equipment	Office, Computing, and Accounting Machinery	Electrical Equipment	Communi-cations equipment	Motor Vehicles	Other Transportation Equipment	Aircraft	Professional Goods
ISIC (Rev. 2)	381	382-3825	3825	383-3832	3832	3843	3842+3844+3849	3845	385
Import Share Mean	0.095	0.240	0.025	0.123	0.096	0.247	0.056	0.048	0.071
Std. Deviation	0.043	0.096	0.023	0.049	0.053	0.091	0.065	0.068	0.036
# of countries	155	155	155	155	155	155	155	157	155
Adoption Share Mean	0.302	0.164	0.018	0.152	0.141	0.187	0.028	0.017	0.027
Std. Deviation	0.192	0.119	0.024	0.076	0.143	0.110	0.038	0.028	0.047
# of countries	34	34	25	34	29	32	31	29	26
R&D Stock (billions of US $)	112	484	519	688	1220	923	30	1370	321
ranking:	*8*	*6*	*5*	*4*	*2*	*3*	*9*	*1*	*7*
R&D flow intensity	0.011	0.031	0.204	0.080	0.200	0.072	0.026	0.230	0.119
ranking:	*9*	*7*	*2*	*5*	*3*	*6*	*8*	*1*	*4*
R&D stock intensity	0.060	0.164	1.113	0.515	1.044	0.400	0.143	1.426	0.561
ranking:	*9*	*7*	*2*	*5*	*3*	*6*	*8*	*1*	*4*
1995									
Import Share Mean	0.083	0.209	0.060	0.144	0.114	0.238	0.034	0.047	0.071
Std. Deviation	0.062	0.079	0.052	0.070	0.052	0.100	0.039	0.092	0.028
# of countries	165	165	165	165	165	165	165	165	165
Adoption Share Mean	0.336	0.152	0.031	0.153	0.136	0.186	0.029	0.010	0.037
Std. Deviation	0.241	0.100	0.070	0.098	0.172	0.154	0.043	0.018	0.053
# of countries	48	47	49		44	47	45	43	37
R&D Stock (billions of US $)	202	887	1170	848	2280	1810	57	1880	801
ranking:	*8*	*5*	*4*	*6*	*1*	*3*	*9*	*2*	*7*
R&D flow intensity (%)	0.007	0.024	0.074	0.035	0.077	0.034	0.036	0.178	0.096
ranking:	*9*	*8*	*4*	*6*	*3*	*7*	*5*	*1*	*2*
R&D stock intensity (%)	0.043	0.130	0.521	0.211	0.448	0.185	0.212	1.304	0.455
ranking:	*9*	*8*	*2*	*6*	*4*	*7*	*5*	*1*	*3*

TABLE 4. Full Sample

	2	3	4	5	6	7	8	9
Variable[a]	Non-elec eqp	Computers	Elec Eqp	Comm Eqp	Motor Vehicles	Other Transport Eqp	Aircraft	Professional goods
Panel A -- Dependent Variable = Import Shares								
TYPE DUMMY	0.709	**-4.229** **	-0.658	-1.117	0.712	-0.499	1.821	**-2.799** **
IPR	**-0.198** *	0.042	0.211	0.042	0.055	0.011	-0.260	0.161
HC	0.120	**0.772** **	0.191	**0.404** **	-0.103	0.074	**0.898** **	**0.305** *
Inward FDI	**-0.136** **	**0.089** **	**0.079** *	**0.134** **	0.062	**0.146** **	**-0.103** **	0.026
Outward FDI	0.020	**0.062** *	-0.002	-0.011	0.032	-0.003	**0.200** **	-0.003
RGDPC	-0.036	**0.288** **	0.009	0.043	**-0.227** *	0.155	**-0.458** **	0.128
Adj. R2	0.6379							
N	2632							
# countries	58							
Panel B -- Dependent Variable = Import Shares								
TYPE DUMMY	2.218	**-4.978** **	-2.881	-2.360	1.010	-0.008	**6.912** **	-3.637
IPR	-0.179	0.044	0.279	0.055	0.002	-0.057	**-0.330** **	0.152
HC	0.117	**0.732** **	0.202	**0.418** **	-0.163	0.102	**0.892** **	0.288
RGDPC	-0.106	0.300	0.121	0.061	-0.285	0.070	**-0.800** **	0.136
INDUSSHR	**0.743** **	-0.186	-0.382	**-0.586** **	-0.506	-0.475	**0.617** **	-0.301
SERVSHR	0.198	**1.108** *	0.057	0.823	0.718	0.784	**1.649** **	**1.026** *
GOVCONS	**-0.260** *	**-0.529** **	**-0.354** *	-0.217	0.257	0.228	0.253	-0.244
Inward FDI	**-0.131** **	0.028	0.060	**0.090** *	0.029	**0.125** **	**-0.172** **	-0.025
Outward FDI	**0.053** *	**0.088** **	0.004	-0.022	-0.007	-0.044	**0.225** **	-0.020
Adj. R2	0.6677							
N	2040							
# countries	52							
Panel C -- Dependent Variable = Import Shares								
TYPE DUMMY	0.845	-2.707	-2.950	0.050	0.007	0.608	0.052	-1.978
IPR	0.063	-0.042	0.001	0.013	0.025	-0.025	**-0.162** **	0.008
HC	-0.104	**0.516** *	0.112	0.315	-0.166	0.116	**0.475** *	0.214
RGDPC	0.142	-0.090	0.017	-0.307	**-0.346** *	-0.131	**-0.438** **	-0.077
INDUSSHR	**0.643** **	-0.188	-0.343	-0.524	**-0.704** **	**-0.744** **	0.282	-0.271
SERVSHR	-0.441	0.878	-0.039	**1.121** *	0.194	0.274	-0.234	0.731
GOVCONS	-0.098	0.010	**-0.348** *	-0.190	0.010	**0.349** *	0.205	-0.246
TAXRATE	0.004	0.022	0.025	0.042	-0.015	0.005	-0.015	0.014
PROPERT	**0.051** *	**0.078** *	-0.004	0.008	0.016	-0.033	**0.147** **	0.002
MONPRI	-0.027	-0.049	0.017	-0.007	0.006	-0.036	**0.059** *	0.008
TRADE	**-0.067** **	0.065	**0.079** *	**0.096** **	0.053	0.061	0.035	0.068
CAPFIN	-0.009	**0.118** **	0.030	0.031	-0.003	0.042	0.035	0.053
Adj. R2	0.636							
N	1490							
# countries	66							
Panel D -- Dependent Variable = Import Shares								
TYPE DUMMY	2.638	-4.806	-5.253	-2.687	0.207	-0.618	4.681	-3.605
IPR	0.122	0.133	0.294	0.163	-0.168	-0.249	0.142	0.237
HC	-0.134	**0.521** *	-0.018	0.196	-0.379	0.117	0.336	0.120
Inward FDI	**-0.142** **	-0.011	0.086	0.095	0.049	0.100	**-0.130** **	-0.007
Outward FDI	0.045	0.065	-0.061	-0.059	-0.038	-0.050	**0.131** **	-0.034
RGDPC	-0.078	0.199	0.176	-0.055	-0.191	0.124	**-0.832** **	0.053
INDUSSHR	**0.827** **	-0.318	-0.597	**-0.956** *	-0.535	-0.466	0.360	-0.401
SERVSHR	0.205	0.805	-0.893	0.359	0.402	0.508	1.276	0.657
GOVCONS	-0.113	-0.363	-0.362	-0.157	0.324	0.361	-0.121	-0.256
TAX	0.035	0.027	-0.005	0.030	-0.055	-0.029	0.044	0.010
PROP	0.050	0.013	0.031	0.023	0.021	-0.043	**0.146** **	0.014
MONPRI	-0.044	-0.047	0.001	-0.014	-0.001	-0.030	**0.088** **	0.003
TRADE	**-0.075** **	0.045	**0.094** **	**0.107** **	0.021	0.036	-0.013	0.042
CAPFIN	0.011	0.055	0.024	-0.010	0.026	0.068	-0.044	0.036
Adj. R2	0.6764							
N	1152							
# countries	49							

[a] The listed variable names represent *interactions* of (log of) that variable with the capital type fixed effects

TABLE 5

FULL SAMPLE

	1	2	3	4	5
Dependent Variable → / **Independent Variable[a] ↓**	Import Share	Import Share	Import Share	Import Share	Adoption Share
LOG(R_P/R_1)	**0.693** **	**-1.492** **	**-0.953** **	**0.709** **	**0.786** **
IPR	-0.039	-0.026	0.009	**0.051** *	0.022
HC	**0.267** **	**0.239** **	**0.092** *	0.037	-0.058
Inward FDI	**-0.036** **	**-0.084** **		**-0.072** **	**-0.103** **
Outward FDI	**0.048** **	0.003		**0.024** **	**0.156** **
RGDPC	**-0.139** **	0.018	-0.002	**-0.123** **	**-0.136** **
INDUSSHR		**0.188** **	**0.160** **	**0.381** **	
SERVSHR		**0.281** **	-0.118	**0.495** **	
GOVCONS		**-0.134** **	**-0.058** *	**-0.079** **	
TAX			0.006	**0.014** **	
PROP			**0.037** **	**0.033** **	
MONPRI			**-0.011** **	**-0.021** **	
TRADE			0.000	**-0.015** **	
CAPFIN			**0.018** *	**0.025** **	
Adj. R2	0.532	0.534	0.226	0.576	0.345
N	1792	1496	1290	984	723
# countries	58	52	66	49	36

[a] The listed variable names represent *interactions* of (log of) that variable with the (log of) the R&D variable

TABLE 6

NON-R&D-PERFORMING SAMPLE

Dependent Variable → / Independent Variable[a] ↓	1 Import Share	2 Import Share	3 Import Share	4 Import Share
LOG(R_P/R_1)	**0.689** **	**-1.634** **	**-0.703** *	**0.713** **
IPR	**-0.067** **	**-0.047** *	0.005	0.046
HC	**0.304** **	**0.278** **	**0.114** **	0.043
Inward FDI	**-0.035** **	**-0.091** **		**-0.070** **
Outward FDI	**0.049** **	0.007		**0.017** *
RGDPC	**-0.145** **	0.023	-0.035	**-0.148** **
INDUSSHR		**0.228** **	**0.158** **	**0.377** **
SERVSHR		**0.167** **	-0.075	**0.453** **
GOVCONS		**-0.111** **	-0.039	-0.069
TAX			0.007	**0.017** **
PROP			**0.039** **	**0.038** **
MONPRI			**-0.014** **	**-0.023** **
TRADE			-0.003	**-0.015** *
CAPFIN			**0.022** *	**0.029** **
Adj. R2	0.522	0.529	0.248	0.571
N	1344	1160	1050	744
# countries	44	40	55	38

TABLE 7

Dependent Variable = Adoption Shares

Variable[a]	2 Non-elec eqp	3 Computers	4 Elec Eqp	5 Comm Eqp	6 Motor Vehicles	7 Other Transport Eqp	8 Aircraft	9 Professional goods
TYPE DUMMY	2.197	-3.547	1.134	1.578	8.024	5.681	3.112	-2.028
IPR	0.420	-0.143	-0.025	0.720	-0.102	-0.450	**-2.298** **	0.256
HC	-0.588	**1.943** *	-0.136	-0.675	0.064	1.432	1.192	0.083
Inward FDI	**-0.363** **	0.062	0.123	0.203	0.110	0.184	0.188	0.163
Outward FDI	**0.284** **	0.121	-0.153	-0.080	0.051	-0.073	**0.561** **	-0.095
RGDPC	-0.206	-0.128	-0.184	-0.066	-0.957	-0.783	-0.004	0.010
Adj. R2	0.4717							
N	723							
# countries	36							

[a] The listed variable names represent *interactions* of (log of) that variable with the capital type fixed effects

Table 8

Variable	Coefficient Estimate	Std. Error
1970 Fixed Effect	-0.179	-3.982
1975 Fixed Effect	0.026	0.099
1980 Fixed Effect	0.030	0.103
1985 Fixed Effect	-0.044	0.103
1990 Fixed Effect	-0.080	0.107
1995 Fixed Effect	-0.126	0.110
alpha	0.335	0.028
gamma	0.444	0.185
A2	2.035	3.205
A3	7.328	9.491
A4	2.389	4.215
A5	1.786	2.926
A6	0.000	0.000
A7	2.710	4.462
A8	1.195	1.639
A9	2.495	4.215
R^2	-28.150	
N	635	
1970 Fixed Effect	10.664	0.159
1975 Fixed Effect	0.007	0.132
1980 Fixed Effect	0.040	0.130
1985 Fixed Effect	0.179	0.129
1990 Fixed Effect	0.150	0.128
1995 Fixed Effect	0.161	0.128
log(K/Y)	0.974	0.081
R^2	0.191	
N	635	

Table 9

	Base Spec.				Full Spec.			
	Type FE		R&D		Type FE		R&D	
	coeff.	SE	coeff.	SE	coeff.	SE	coeff.	SE
log(K/Y)	0.181	0.193	0.149	0.244	0.225	0.218	0.050	0.216
log(quality)	2.257	0.313	1.842	0.220	0.740	0.228	1.239	0.248
→ implied α	0.153		0.130		0.184		0.048	
→ implied γ	0.344		0.384		0.623		0.459	
R^2	0.356		0.400		0.111		0.239	
Omitting capital quality								
log(K/Y)	0.417	0.250	0.313	0.287	0.324	0.233	0.321	0.233
R^2	0.055		0.028		0.041		0.041	
N	323		273		144		142	
# countries	57		57		49		49	

Appendix B. Non-R&D-performing sample

Panel A -- Dependent Variable = Import Shares

Variable[a]	2 **Non-elec eqp**	3 **Computers**	4 **Elec Eqp**	5 **Comm Eqp**	6 **Motor Vehicles**	7 **Other Transport Eqp**	8 **Aircraft**	9 **Professional goods**
TYPE DUMMY	0.477	**-3.759** **	-0.484	-1.366	-0.153	-1.113	1.565	**-2.602** *
IPR	**-0.223** *	-0.073	0.194	0.009	0.092	0.040	**-0.382** **	0.116
HC	0.186	**0.821** **	0.203	**0.428** **	-0.208	0.035	0.963	0.350
Inward FDI	**-0.170** **	**0.104** *	**0.093** *	**0.132** **	0.030	**0.124** **	**-0.155** **	0.056
Outward FDI	0.033	0.054	-0.004	-0.018	0.001	-0.035	**0.218** **	-0.015
RGDPC	-0.029	0.235	0.000	0.062	-0.186	0.162	**-0.449** **	**0.111** *

Adj. R2 0.638
N 1960
countries 44

Panel B -- Dependent Variable = Import Shares

Variable[a]	2 **Non-elec eqp**	3 **Computers**	4 **Elec Eqp**	5 **Comm Eqp**	6 **Motor Vehicles**	7 **Other Transport Eqp**	8 **Aircraft**	9 **Professional goods**
TYPE DUMMY	1.030	**-5.119** **	-3.069	-3.226	0.834	-0.010	**5.794** **	-3.641
IPR	-0.179	-0.054	0.240	-0.012	0.042	-0.033	**-0.488** **	0.087
HC	0.136	**0.814** **	0.252	**0.508** **	-0.215	0.124	**1.042** **	**0.357** *
RGDPC	-0.025	0.321	0.159	0.181	-0.304	0.037	**-0.663** **	0.157
INDUSSHR	**0.760** **	-0.269	-0.489	**-0.832** **	-0.339	-0.514	0.347	-0.484
SERVSHR	0.188	**1.043** *	-0.044	0.624	0.816	0.790	**1.377** **	0.896
GOVCONS	**-0.327** **	-0.349	-0.233	-0.012	0.141	0.245	**0.605** **	-0.066
Inward FDI	**-0.187** **	0.030	0.066	0.079	0.011	**0.124** **	**-0.205** **	-0.001
Outward FDI	**0.061** *	0.073	0.008	-0.002	-0.025	-0.060	**0.234** **	-0.024

Adj. R2 0.674
N 1624
countries 40

Panel C -- Dependent Variable = Import Shares

Variable[a]	2 **Non-elec eqp**	3 **Computers**	4 **Elec Eqp**	5 **Comm Eqp**	6 **Motor Vehicles**	7 **Other Transport Eqp**	8 **Aircraft**	9 **Professional goods**
TYPE DUMMY	1.039	-0.987	-3.226	-0.747	-0.136	0.810	0.312	-1.523
IPR	0.061	-0.063	-0.003	0.008	0.033	-0.026	**-0.180** **	-0.004
HC	-0.107	**0.603** **	0.164	0.408	-0.218	0.161	**0.587** **	0.294
RGDPC	0.118	-0.268	0.042	-0.228	-0.336	-0.161	**-0.450** **	-0.119
INDUSSHR	**0.666** **	-0.134	-0.383	**-0.654** *	**-0.617** *	**-0.781** **	0.204	-0.367
SERVSHR	-0.433	1.128	-0.109	0.999	0.153	0.338	-0.240	0.833
GOVCONS	-0.102	0.057	-0.312	-0.096	-0.104	0.320	0.337	-0.128
TAXRATE	0.003	0.045	0.019	0.024	-0.003	0.013	-0.021	0.013
PROPERT	**0.057** *	0.066	-0.009	0.006	0.006	-0.047	**0.122** **	0.007
MONPRI	-0.031	-0.056	0.017	-0.005	0.013	-0.033	0.056	0.001
TRADE	**-0.070** **	0.049	**0.078** *	**0.095** **	0.068	0.073	0.040	0.055
CAPFIN	-0.001	0.129 **	0.040	0.045	-0.036	0.015	0.038	0.071

Adj. R2 0.622
N 1202
countries 55

Panel D -- Dependent Variable = Import Shares

Variable[a]	2 **Non-elec eqp**	3 **Computers**	4 **Elec Eqp**	5 **Comm Eqp**	6 **Motor Vehicles**	7 **Other Transport Eqp**	8 **Aircraft**	9 **Professional goods**
TYPE DUMMY	2.367	-4.589	-5.260	-3.279	-0.618	-1.074	3.991	-2.972
IPR	0.171	-0.014	0.224	0.035	-0.118	-0.267	0.026	0.120
HC	-0.174	**0.668** **	0.042	0.344	-0.440	0.172	0.411	0.212
Inward FDI	**-0.166** **	0.000	0.102	0.104	0.033	0.083	**-0.141** *	0.025
Outward FDI	0.040	0.049	-0.058	-0.040	-0.052	-0.067	0.107	-0.041
RGDPC	-0.100	0.192	0.205	0.061	-0.134	0.130	**-0.764** **	0.026
INDUSSHR	**0.953** **	-0.356	-0.665	**-1.208** **	-0.533	-0.677	0.254	-0.617
SERVSHR	0.242	0.757	-0.979	0.201	0.373	0.444	1.059	0.571
GOVCONS	-0.251	-0.168	-0.268	0.037	0.260	0.471	0.069	0.009
TAX	0.041	0.021	-0.020	0.011	-0.045	-0.027	0.041	-0.001
PROP	0.052	-0.002	0.031	0.008	0.009	-0.051	**0.115** **	0.030
MONPRI	-0.042	-0.050	-0.002	-0.014	0.004	-0.039	**0.084** *	-0.012
TRADE	**-0.071** *	0.036	**0.091** *	**0.105** **	0.037	0.046	0.006	0.029
CAPFIN	0.014	0.074	0.037	-0.009	-0.003	0.058	-0.061	0.055

Adj. R2 0.653
N 864
countries 38

[a] The listed variable names represen*interactions* of (log of) that variable with the capital type fixed effec