Mark-Ups, Economies of Scale and the Role of Knowledge Spillovers in OECD Industries

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Abstract

Using R&D-based models of economic growth as a foundation, it is argued that market-driven knowledge creation as an engine of productivity growth is necessarily linked to economies of scale and market-power. A cost function and factor demand model is applied to a new cross-country industry dataset to study market-power, economies of scale and the role of knowledge in an integrated approach. Empirical results reveal the presence of market-power and economies of scale in all of the investigated industries. R&D and spillovers explains some of the observed productivity growth. Spillovers are identified as an external source o economies of scale.

JEL Classification C31, C33, O32, O47; Economic Growth, Technological Change, Market Power, Knowledge Spillovers, OECD Industries, Error Correction Models

1 Introduction

Most empirical researchers choose a Hall/Solow residual approach to study the impact of knowledge and spillovers on productivity growth (Coe & Helpman 1995, Keller 2001). This framework, however, relies on the assumptions of constant returns to scale and perfect competition, while increasing returns and market power are essential features of R&D based models of economic growth (Romer 1990, Grossman & Helpman 1991, Aghion & Howitt 1992). In contrast, the cost function and factor demand system, employed in this study encompasses all of these interrelated features of R&D-based growth models, thus providing a framework to study links between them, while avoiding biases inherent in the Solow residual.

As emphasized by Romer (1990), recognizing the non-rivalrous nature of knowledge necessarily links it with economies of scale and imperfect competition The development of an idea, such as the design of a new car or a patent for a new medicine, may require huge initial costs. Yet, once it has been created, the idea can be used over and over again with zero or trivial additional costs. In this sense, knowledge creation is analogous to incurring a fixed cost. Knowledge is a non-rivalrous good, because on a technological level, nothing precludes the simultaneous use of an idea in many different production processes. While returns to scale in rival factors should be constant by a standard replication argument, this does not hold for non-rival knowledge, precisely because it does not have to be replicated. Thus, returns to scale in all factors including knowledge should be increasing. Euler's theorem implies that with increasing returns not all factors can be paid their marginal product. So if knowledge creation is assumed to depend on economic decisions, as in R&D based models of economic growth, than there must be at least some market power so that resources devoted to it can be recompensed.

A few researchers "correct" the Solow residual to account at least for the presence of imperfect competition (Keller 2001). Beyond concerns regarding biases of the Solow residual, however, theory suggests that it may be very revealing to study the role of knowledge and the presence market power and economies of scale explicitly in an integrated approach.

A new version of the OECD Stan dataset including industry data from Canada, France, Germany, Italy, Japan and the US is employed to investigate economies of scale, market-power, the role of knowledge creation and spillovers for productivity growth, as well as links between these features. While earlier versions of this data set have been used before to investigate the impact of R&D on productivity growth (Keller 2001, Verspagen 1997), the attractive feature of the new version is that it includes constant price data of material inputs for the first time. Since the omission of material inputs is bound to distort results when the material inputs sector is not competitive (Basu & Fernald 1995, Basu & Fernald 1997), the close link between market-power and knowledge creation in R&D-based models of growth implies that gross output rather than value added data should be used in empirical work investigating this theory.

The study is organized as follows. Part 2 outlines the theoretical framework of the investigation, while the modelling strategy for spillovers is presented in part 3. Part 4 discusses the empirical model. The data is discussed in part 5. Estimation results are presented in part 6. Part 7 concludes.

2 R&D-Based Models of Growth

Essential features of R&D based models à la Romer (1990), and Aghion & Howitt (1992), which are important from an empirical perspective, can be summmarized in a few equations. A reduced form aggregate production function can be written as

$$Y = C + I^K + I^R = K^{1-\alpha}(AL)^{1-a} \tag{1}$$

where Y is output, A is productivity, or the economy's stock of knowledge, and L is labor input. Because the production function in equation (1) is homogenous of degree one in the firms' choice variables, the non-rivalrous factors labor and capital, output can be described in terms of the actions of a single price-taking firm. Overall returns to scale in all factor inputs including knowledge are increasing. The aggregate output of the economy, Y, consist of consumption goods, C, investments in physical capital, I^K and investments in R&D capital, I^R.

The stock of knowledge evolves according to

$$\frac{\dot{A}}{A} = \zeta i^r \tag{2}$$

where ζ is a constant parameter. $i^r = \frac{I^R}{A}$ is the productivity-adjusted level of R&D spending which can be shown to be constant in the steady state. Consumption, the capital stock and the flows of investment in physical and R&D capital grow at the constant rate of technological progress $\gamma_A = \zeta i^R$ on a balanced growth path. This one-sector set up, where all goods are produced with the same production function using labor and capital is closest to Rivera-Batiz & Romer's (1991) and Aghion & Howitt's (1998) model formulations.

The economy's physical capital stock, K, is proportional to the different varieties of intermediate capital goods services, x_i, each of which is produced at the same quantity in equilibrium.

$$K = Ax \tag{3}$$

Two alternative metaphors are used in R&D-based models of growth to illustrate technological change. In Romer's (1990) and Rivera-Batiz & Romer's (1991) models A is the number of varieties of intermediate inputs. Conducting research, innovators are able to develop new varieties of the intermediate good, as described in (2). In these models, ongoing specialization associated with an increasing number of varieties of intermediate inputs is the metaphor for technological change.

In Aghion & Howitt's (1998) model version, the number of varieties is constant. A represents the average quality of intermediate inputs. Each intermediate good embodies a different productivity or quality, A_i. Research is conducted in each intermediate good sector and a successful innovation consists in the development of a new, higher quality generation of the intermediate capital good in that sector.

In each of the two model versions, intermediate goods producers incur a fixed costs associated with the invention of their new or improved variety of the intermediate input, before they can start production. Once they have invented a new good, or purchased a patent from the R&D-sector, they act as monopolists in this market and charge a mark-up of price over marginal costs. Market-power is necessary to cover the costs of inventing a new or improved product.

Since the increase in knowledge is proportional to R&D-spending, $\dot{A} = \zeta I^R$, the stock of knowledge A is proportional to its sum

$$A = \zeta \int_0^\infty I^R = \zeta R \tag{4}$$

where R is the economy's R&D capital stock. This R&D capital stock enters the production function (1) as an additional input variable.

Both the increasing varieties and the increasing quality metaphor of technological change can equally well be applied to non-durable intermediate goods (Barro & Sala-i-Martin (1999), chapters 6-7). It is also possible to formulate an R&D-based growth model which is based on increasing varieties of consumption goods (Grossman & Helpman (1991)). The basic features are the same as in the model with an increasing variety of capital goods. There is imperfect competition in the markets of those goods, which are subject to technical change, because somehow firms have to recover the fixed costs of knowledge creation. R&D capital stocks enter the aggregate production function as an additional production factor, because knowledge is embodied in intermediate inputs.

In reality technological change may very well be associated with capital inputs, non-durable material inputs and/or consumption goods at the same time. As technological change embodied in intermediate inputs will always be associated with market-power, value-added is not the ideal output concept for empirical work that investigates R&D-based models of economic growth. Basu & Fernald (1995) and Basu & Fernald (1997) have shown that using value added data is very likely to bias results concerning estimates of economies of scale and externalities, if the material inputs are not produced in competitive markets.

When thinking about industry data, it seems reasonable to assume that each industry engages in several if not all of the activities, described in R&D-based growth models. Each industry will typically produce consumption goods, capital goods and material inputs, as well as perform R&D to develop new or improved products or more efficient production processes.

R&D based models of economic growth imply several forms of knowledge spillovers. Purchasing material inputs or capital goods from other industries, each industry may take advantage of embodied technological advancements developed elsewhere. Industries can thus enjoy knowledge spillovers through trade, because they do not have to develop this new or improved variety themselves. A second, disembodied spillover associated with the knowledge production process is described in the increasing qualities version of R&D-based growth models. Innovators can take advantage of technological advancements made before, because they have free access to the existing technological knowledge of the economy represented by the leading edge technology.

For empirical purposes, it is preferable to choose a more general production function than the Cobb-Douglas functional form. A general production technology for industry i, which encompasses some of the more relevant features of R&D-based growth models, could be represented as

$$Y_i = F(K_i, L_i, M_i, R_1, ..R_i, ..R_j, ..t) \tag{5}$$

Industry i produces its output, Y_i, using labor, L_i, material inputs, M_i, and its physical capital stock, K_i. Technological progress due to innovations developed in industry i are captured by its R&D capital stock, R_i. Other industries' knowledge capital stocks may enter the production function, because they are embodied in intermediate capital or non-durable inputs that are used in the production process. The time trend t captures any technological progress due to factors that are exogenous to the model, such as better organization or a change in government regulations.

Each industry that actually conducts research and development, should be expected to charge a mark-up of price over marginal cost to cover the fixed cost associated with knowledge creation. Mark-ups may be expected to be higher in industries where the R&D-intensity, as measured by the ratio of R&D expenditures to output, is relatively high. However, market-power and the size of mark-ups can be related to many other things than a patent or technological knowledge that can effectively be hidden from other producers. Market-power may be due to monopoly rights granted by the government or the level of protection from international trade. Moreover, the size of the mark-up also depends on the price elasticity of market demand, which is unrelated to market-power.

Economies of scale may be observed in industries conducting research and development because of the fixed cost associated with knowledge creation. As argued above, the production technology should be expected to exhibit constant returns to scale in the rival factors, capital, labor and material inputs by a replication argument. However, theory suggests that there should be economies of scale in rival factors and R&D together. R&D from other industries, which is embodied in intermediate goods, may constitute an external source of economies of scale.

3 Modelling Spillovers

Ideally, the impact of each different source of productivity growth should be estimated separately to assess its relative importance. The cost or production function of an industry i would than include its own R&D capital stock and that of all other industries. Especially when working with many cross-sections, though, degrees of freedom may not be the only limit to the inclusion of all potential spillover sources as a separate variable. Since R&D capital stocks are typically trended, these variables are more often than not highly collinear. Due to this multicollinearity problem, it will be more than difficult to pin down the magnitude of the individual impacts of different R&D capital stocks and the time trend on costs or productivity.

To reduce the number of collinear variables to be included in the estimation, this study will focus on three different spillover sources: Each industry may benefit from spillovers of other industries in the same country, from international intra-industry spillovers and from inter-industry spillovers.

The weighting schemes used for aggregating the R&D capital stocks focuses on capturing trade as a spillover channel. They draw heavily on Keller

(2001).

To capture spillovers from other industries in the same country, input-output coefficients are used to weight their R&D capital stocks. Hence, the domestic spillover variable for industry i in country k is constructed as

$$S_d^{ki} = \sum_{j \neq i} \omega_{ij} R_j \tag{6}$$

where ω_{ij} denotes the input-output coefficients of intermediate goods flowing from industry i to industry j. More specifically, ω_{ij} is industry j's sales to industry i as a percentage of industry j's total sales to the entire economy. The weights for the domestic spillover variable, ω_{ij} are measured with input-output coefficients.

Input-output tables measuring domestic intermediate goods flows for each of the countries in the sample are provided by the OECD (OECD 1995). Qualitatively, matrices are quite similar across countries. Quantitatively, however, there are important differences between the input-output coefficients of different countries. This indicates that accuracy is gained, when using input-output data from each individual country rather than assuming that input-output structures can be approximated well with data from the US only, as in Keller (2001)

Stressing trade as a transmission channel on an international level involves using import shares as weights. These are conceptually equivalent to the input-output coefficients that capture domestic trade relations. Let m_{kvi} be the bilateral import share of country k from country v for goods from industry i. For a given country k and sector i the effect of R&D conducted in the same sector in foreign countries is then:

$$S_{fs}^{ki} = \sum_{v \neq k} m_{kvi} R_{vi} \tag{7}$$

Using (7) to calculate the intra-industry spillover variable, it is implicitly assumed that country k's import share of goods from country v, that can be assigned to industry i, captures the channel of intra-industry spillovers appropriately, although, of course, not all imports from industry i abroad will go to that same industry. However, assigning imports to industries according to the type of good that is traded is the best that one can do with the available data. To the best of my knowledge, international trade data that contains information about buying and selling industries does not exist.

Industry i can also benefit from R&D that is conducted in foreign sectors $m \neq i$. This is referred to as inter-industry spillovers. To construct weights, input-output matrices for imports are used. For each industry the matrices display the use of intermediate inputs which are produced in foreign countries.

For a specific country k, let v_{mi} denote the share of industry $i's$ imports of intermediates from the m industry. S^{ki}_{fo} may then be defined as:

$$S^{ki}_{fo} = \sum_{m \neq i} v_{mi} S^{km}_{fs} \tag{8}$$

This aggregation scheme reduces the number of spillover effects to be estimated to three. It thus preserves degrees of freedom and alleviates multicollinearity problems.

Import input-output matrices provided by the OECD are used to construct weights for the inter-industry spillover variable. The coefficients are calculated in a manner completely analogous to the input-output coefficients for the domestic spillover variable. Again, there are some similar patterns across countries, but significant quantitative differences remain, so constructing weights individually for each country is advantageous. A more detailed description of the construction of spillover weights is provided in the data appendix, which is available from the author upon request.

4 Empirical Framework

4.1 The McFadden Cost Function

The symmetric generalized McFadden functional form originally introduced into the literature by Diewert & Wales (1987) is used as the empirical framework. The cost function including R&D capital stocks and spillovers takes the following form:

$$\begin{aligned} C &= g(P)Y + \sum_i b_{ii}P_iY + \sum_i b_iP_i + \sum_i b_{it}P_itY \\ &\quad + b_t(\sum_i \theta_iP_i)t + b_{yy}(\sum_i \theta_iP_i)Y^2 + b_{tt}(\sum_i \theta_iP_i)t^2Y \\ &\quad + b_{ry}(\sum_i \theta_iP_i)R * Y + \sum_j b_{sj}(\sum \theta_iP_i)S_j \end{aligned} \tag{9}$$

where $g(P) = \frac{1}{2}(\frac{P^{\theta}sP}{\theta P})$. P is a n-dimensional vector containing the prices, s a symmetric matrix with elements (s_{ij}), and θ a n-dimensional vector of constants, θ_i, selected by the researcher. In this study, the cost function includes three different prices, namely the wage rate, P_L, the price of material inputs, P_M, and the user cost of physical capital, P_K, so $i = L, K, M$.

Although equation (9) looks like a variable cost function with R&D as a quasi-fix factor, the interpretation in the empirical investigation presented here is different due to the specifics of the data construction. The "traditional" input factors, labor, capital and material inputs, are not corrected for the inclusion of R&D costs. Therefore, b_{ry} measures the impact on total costs including R&D. It can be interpreted as an excess return to R&D, an argument which will be made more precisely below. Because of this, the R&D capital stock does not have to comply with the usual regularity conditions for quasi-fix factors.

There may be spillovers from other domestic industries, S_d, spillovers from the same industry in other countries, S_{fs} and spillovers from the other industry in foreign countries, S_{fo}, so $j = d, fs, fo$.

The choice of θ is completely arbitrary. Different researchers have experimented with many different values, including a value of one for all elements of θ. In this study, the elements of θ are set equal to the sample midpoint of the ratio of the corresponding input to costs.

For identification purposes, n additional restrictions have to be imposed on s : $\sum_j s_{ij} = 0$. Note, that the cost function is homogeneous in prices by construction.

Factor demand equations can again be derived using Shephard's lemma.

$$\begin{aligned} x_i \;=\; & \frac{\sum_k s_{ik} P_i}{\sum_k \theta_k P_k} * Y - \theta_i \frac{\sum_j \sum_k s_{kj} P_k P_j}{(\sum_k \theta_k P_k)^2} * Y \\ & + b_{ii} * Y + b_i + b_{it} t * Y + b_t \theta_i t + b_{yy} \theta_i Y^2 + b_{tt} \theta_i t^2 * Y \\ & + b_{ry} \theta_i R * Y + \sum_j b_{sj} \theta_i S_j \end{aligned} \qquad (10)$$

for $i = L, K, M$, $j = L, K, M$ and $k = L, K, M$. Profit maximization implies $P_Y = \mu \frac{\partial C}{\partial Y}$, where μ is the mark-up of price over marginal cost. In the case of the McFadden cost function the exact specification for this equation is:

$$\begin{aligned} P_Y \;=\; & \mu \{ g(P) + \sum_i b_{ii} P_i + \sum_i b_{it} P_i t \\ & + 2 b_{yy} (\sum_i \theta_i P_i) Y + b_{tt} (\sum_i \theta_i P_i) t^2 + b_{ry} (\sum_i \theta_i P_i) R \} \end{aligned} \qquad (11)$$

The mark-up μ is then a parameter to be estimated. The cost function approach readily encompasses non-competitive behavior and the possibility to estimate the size of mark-ups.

The primal rate of returns to scale is defined as the increase in output due to a proportional increase in all inputs. Considering a production function

$Y = F(X,t)$, where Y is output, $X = (X_1, ..., X_i, ..., X_n)$ is a vector of inputs and t denotes time, it can be measured as $\lambda = \frac{\sum \frac{\partial F(X,t)}{\partial X_i} X_i}{F(X,t)}$. Using duality theory, it can be shown that

$$\lambda = \frac{1}{\varepsilon_{CY}} \tag{12}$$

where $\varepsilon_{CY} = \frac{\partial \ln C}{\partial \ln Y}$. This measure of economies of scale can easily be derived from the estimated cost function by calculating the ratio of average to marginal costs.

The dual measure of productivity growth is

$$-\varepsilon_{Ct} = -\frac{\partial C}{\partial t}\frac{1}{C} \tag{13}$$

The primal measure of productivity growth, $\frac{\partial F}{\partial t}\frac{1}{F}$, is related to the dual as $\frac{\partial F}{\partial t}\frac{1}{F} = -\frac{\varepsilon_{Ct}}{\varepsilon_{CY}}$. Thus, primal and dual measure of productivity coincide only when returns to scale are constant.

When external factors, such as knowledge spillovers, enter the production function, it is interesting to derive the rate of returns to scale in internal and external factors. The overall rate of returns to scale of a production function, $F(X,S,t)$, with external spillover factors, $S = (S_1, ..., S_m, ...S_M)$, is defined as $\eta = \frac{\sum_i \frac{\partial F(X,S,t)}{\partial X_i} X_i + \sum_m \frac{\partial F(X,S,t)}{\partial S_m} S_m}{F(X,S,t)}$. This can be derived from the cost function as

$$\eta = \frac{1 - \sum_k \varepsilon_{CX_k} - \sum_m \varepsilon_{CS_m}}{\varepsilon_{CY}} \tag{14}$$

where ε_{CX_k} is the elasticity of the cost function with respect to the *kth* quasi-fix factor of production and ε_{CS_m} is the elasticity of costs with respect to the *mth* external factor. This shows that the cost function framework readily lends itself to the investigation of economies of scale both in internal production factors and due to spillovers.

Many studies that use the factor demand framework exploit the possibility to model some factors as quasi-fix. Adjustment costs are often modeled explicitly. In this study an error correction form is chosen instead to accommodate short-run deviations from equilibrium. This framework allows for temporary deviations from optimal adjustment of all factors of production, even those which are not modelled as being quasi-fix. At the same time, there is no need to model adjustment costs explicitly.

4.2 Error Correction Form

The motivation for the use of an error correction form is the observation, that actual factor demand may not be optimal in each period, because for some reason adjustment to optimum may be costly.

Let X_t denote the vector of actual factor inputs at time t. X_t^* is the vector of equilibrium factor inputs when all variable factors are optimally adjusted. A general error correction framework can then be represented as

$$\Delta X_t = \sum_j A_j \Delta X_{t-j}^* + \Gamma(X_{t-1} - X_{t-1}^*) + \sum_j E_j \Delta X_{t-j} + w_{xt} \tag{15}$$

where w_{xt} is a vector of error terms.Note that the elements in X_t^* are linear combinations of equilibrium parameters and independent variables as apparent in (10).

While there is no economic theory underlying the short-run off-equilibrium dynamics in (15), the equilibrium factor inputs X_t^* can be derived from a cost function applying Shephard's lemma. It is assumed that the cost function can also be represented in an error correction form

$$\Delta C_t = \sum_j \delta_{cj}^e \Delta C_{t-j}^* + \gamma_c(C_{t-1} - C_{t-1}^*) + \sum_j \delta_{cj} \Delta C_{t-j} + w_{ct} \tag{16}$$

C_t denotes actual or observed cost at time period t and C_t^* denotes equilibrium costs as specified in (9). γ_c is the error correction parameter and w_{ct} is an error term. The $\delta_{cj}^e s$ are the parameters for the lagged differences of equilibrium costs and the $\delta_{cj} s$ for the lagged differences of actual costs. Accordingly, the error correction representation for the price equation can be represented as:

$$\Delta P_{Yt} = \sum_j \delta_{Yj}^e \Delta P_{Yt-j}^* + \gamma_Y(P_{Y(t-1)} - P_{Y(t-1)}^*) + \sum_j \delta_{Yj} \Delta P_{Yt-j} + w_{Yt} \tag{17}$$

The system (15)-(17) can then be estimated imposing cross-equation restrictions on equilibrium factor shares X_{t-1}^*, lagged equilibrium prices, $P_{Y(t-1)}^*$, and lagged equilibrium costs, C_{t-1}^*, as well as cross equation restrictions among lagged differences of these variables. Measures for rate of returns to scale, the rate of technological progress and cost elasticities for the R&D variables can be derived from the estimated equilibrium function

5 The Data

The data used to estimate the cost function includes manufacturing industries of six major OECD countries: USA, Canada, Japan, Germany, France and Italy. An industry list is provided in the appendix A.

Output is gross output in 1995 prices. Table I shows the relative size of each country in terms of its share in the aggregate gross output of the manufacturing sector. The US is the biggest economy followed by Japan and Germany, while Canada is the smallest.

Table I: Relative Size of Manufacturing Sectors with respect to R&D Capital, Gross Output and Growth of the Manufacturing Sector's R&D Capital Stock

Country	Share in R&D	Share in Output	R&D capital growth
Canada	1.51	4.00	5.88
France	6.96	7.43	3.66
Germany	12.94	11.22	3.65
Italy	2.95	8.50	5.09
Japan	20.32	21.77	6.72
US	55.30	39.62	3.11

(Average Percentage over 1982-1998)

Prices for gross output and value-added are calculated as the ratio of the nominal output series to its constant price counterpart. 1995 is the baseyear. Material inputs are measured as the difference between gross output and value added. The material inputs price is the ratio of nominal material inputs to the same series in 1995 prices.

The labor input variable is measured as total employment, and the wage rate is the ratio of labor compensation to the number of employees. This assumes implicitly that the self-employed receive the same wage rate as the employees. All prices are normalized to 1 in 1995. Consequently, the labor input variable is multiplied by the wage rate of the baseyear, so that the product of labor input and the wage rate still equals labor compensation.

Net capital stocks are available for the US, Italy and France. For Canada, Germany and Japan, they are calculated with the perpetual inventory method. The user cost of capital is calculated as $p_K = \omega_K(\rho + \delta_K)$, where ω_K is the investment price deflator, ρ is the real interest rate and δ_K is the depreciation rate of physical capital. All constant price variables are converted to US dollars using 1995 purchasing power parities.

The sample period is 1980-1998. However, the data is not always complete. For Italian industries, no data is available for the time before 1982.

Canadian data is complete only up until 1996. Japanese data is available only for a few relatively aggregate industries. A detailed description of data sources and variable construction is provided in a data appendix, which is available from the author upon request.

Due to data limitations it is not possible to correct labor, material inputs and capital for R&D expenditures and thus avoid double counting. To understand what this implies for the interpretation of the estimated effect of R&D, consider a simple Cobb-Douglas production function $Y = AL^{\alpha}K^{\beta}M^{\gamma}R^{\xi}$. The labor variable may include R&D expenditures, because some of the staff works in research and development. Likewise, some of the material inputs just as well as machinery and equipment are used in the process of acquiring new knowledge. In that case, ξ will be positive, only if knowledge is indeed different from the traditional production factors, in that for example the work of R&D personnel has a stronger and/or longer lasting effect on output than simple production labor. ξ can thus be interpreted as an excess return to R&D capital.

An analogous argument can be raised for a cost function. A negative effect of R&D on costs means that R&D reduces costs including R&D expenditures. If this is the case, it is certainly safe to conclude that investment in knowledge-creation enhances productivity. With double-counting related to R&D ε_{CX_k} is the cost elasticity with respect excess returns to R&D.

Table II presents average productivity growth for each industry in the sample as measured by the Solow residual. It is measured as:

$$SR_t = d(\log(Y_t)) - \frac{1}{2}\bar{a}_{Lt}d(\log(L_t)) - \frac{1}{2}\bar{a}_{Kt}d(\log(K_t)) - \frac{1}{2}\bar{a}_{Mt}d(\log(M_t)) \tag{18}$$

where t is a time index, $d(\cdot)$, is the first difference operator, $d(X_t) = X_t - X_{t-1}$. $\bar{a}_{it}$ is the average of the factor share in income over two consecutive years: $\bar{a}_{it} = \frac{1}{2}(a_{it} + a_{i(t-1)})$ for $i = K, L, M$ and $a_i = \frac{P_i X_i}{P_Y Y}$. The factor share of capital is measured as the residual $a_K = 1 - a_L - a_{M.}$ The total factor productivity is constructed as a Divisia index, which is a correct approximation to a translog cost function. This encompasses more flexibility than calculating the weights as the average over the sample period, which implicitly implies a Cobb-Douglas cost function.

Equation (18) is a discrete-time version of the primal measure of technological change, $\frac{\partial F}{\partial t}\frac{1}{F} = \frac{\dot{Y}}{Y} - \sum_{i=M,K,L}\frac{\partial F X_i}{\partial X_i F}\frac{\dot{X}_i}{X_i}$. Factor shares will measure the production elasticities of input factors correctly, when the assumptions of perfect competition and constant returns to scale hold. Profit maximization

Table II: Average Growth of Total Factor Productivity; 1982-1996

Country *Industry*	Canada	France	Germany	Italy	Japan	US
15-16	-0.05	-0.07	0.34	0.30	-0.014	-0.09
17-19	0.81	0.28	0.22	0.85	-	0.011
20	0.71	-	0.84	1.57	-	-
21-22	-0.36	0.16	0.47	0.74	-	-
23-25	1.02	0.70	-	0.23	0.27	0.92
23	0.32	-	0.18	-0.21	-	0.92
24	1.41	-	0.89	1.49	-	1.20
25	1.05	-	0.34	0.17	-	1.32
26	0.88	1.01	0.43	0.88	-	1.41
27	-	-	0.81	-	-	0.71
28	-	-	0.67	-	-	1.07
27-28	0.90	0.65	0.81	1.13	0.49	0.95
29	1.04	0.83	0.66	0.76	0.01	-
29-33	0.33	1.20	0.74	1.03	1.50	3.08
30-33	1.82	1.46	0.72	1.41	2.40	-
34-35	0.65	0.14	0.16	0.73	0.24	0.21
36-37	-	0.07	0.42	0.38	-	-

then requires $\frac{P_i}{P_Y} = \frac{\partial F}{\partial X_i}$, so $a_i = \frac{\partial F X_i}{\partial X_i F}$. Note that it will overestimate technological change when economies of scale are present. Since partial production elasticities sum to the rate of returns to scale which is larger than one, in that case, the weight for the growth of the capital stock will be too small. Likewise, the weights for factor input growth are underestimated when mark-ups are present. In this case, optimization conditions require $\mu \frac{P_i}{P_Y} = \frac{\partial F}{\partial X_i}$, for each factor i, where $\mu > 1$ is the mark-up of price over marginal cost. So to be accurate, the weights would have to be multiplied by μ. Thus in the presence of market power as well as with economies of scale the Solow residual overestimates technological growth.

Overall, productivity growth measured with the Solow residual is rather small. In general, the Solow residual is highest in the chemical industry and in electrical and optical equipment. It is lowest in the food and tobacco industry, where the average over the sample period is negative for France, Japan and the US. In many industries, productivity growth as measured by the Solow residual has been slowest in Germany.

R&D investment data provided in the OECD's Anberd database (OECD 1999) is used to construct R&D capital stocks. They are compiled applying the perpetual inventory method to the R&D investment data. The investment series are deflated with the respective country's GDP-deflator. All R&D capital stocks are converted into US Dollars using 1995 purchasing power parities.

Table III: Average Ratio of R&D to Output over 1982-1998; in per cent

Country *Industry*	Canada	France	Germany	Italy	Japan	US
15-16	0.16	0.23	0.18	0.07	0.58	0.33
17-19	0.31	0.21	0.33	0.01	0.56	0.20
20	0.13	-	0.19	0.03	-	0.311
21-22	0.29	0.11	0.18	0.02	0.33	0.384
23-25	1.1	2.59	2.75	0.03	3.84	2.97
23	-	-	2.02	0.32	0.61	1.34
24	1.7	3.74	4.69	1.32	5.09	4.68
25	0.30	1.66	1.01	0.55	6.34	1.03
26	0.21	0.71	0.87	0.08	2.00	1.06
27	0.60	0.91	0.65	0.31	1.16	0.56
28	0.27	0.36	1.08	0.23	0.79	0.61
27-28	0.47	0.59	0.87	0.26	1.03	0.59
29	1.04	1.45	2.23	0.50	1.92	1.6
30	8.1	6.16	6.79	-	6.08	15.11
31	0.97	2.29	3.72	-	6.42	3.87
32	13.78	12.43	16.12	-	5.63	11.77
33	-	8.41	2.60	-	6.41	6.20
29-33	5.56	4.66	4.24	1.72	1.92	6.33
30-33	7.92	6.97	6.40	3.28	5.98	8.97
34-35	1.15	5.06	4.70	3.84	2.83	8.28
36-37	0.53	0.26	0.52	0.03	0.36	0.66

Table III displays R&D-intensity by industry as measured by the ratio of R&D expenditures to gross output over the period 1982-1998. In most industries, either the US or Japan displays the highest R&D-intensity. Germany also ranks relatively high in terms of R&D-intensity in most industries. R&D-intensity is remarkably low in Italy and in some Canadian industries. Overall, the same industry groups tend to be the most R&D capital intensive across countries, namely chemicals, electrical and optical equipments and transport equipment. Only the Canadian chemical industry is not very R&D intensive.

To explore the empirical relevance of mark-ups and economies of scale, the next section presents estimation results obtained without R&D capital stocks included in the cost function first, before estimates of the impact of knowledge are presented.

6 Estimation Results

6.1 Estimation Method

It is sensible to suspect that there may be important differences between, say, the food industry and the chemical industry in each country. At the same time, the production structure of the same industry is very likely to be similar in different industrialized countries. Therefore, data for each industry is pooled across countries. The cost function is then estimated industry by industry. This opens the possibility to identify and analyze differences between industries. Unfortunately, complete data for all of the six countries is available only for a few rather aggregate industries. The cost functions for the more disaggregate industries are estimated each with only a subset of the countries.

The size of the industries sometimes differs significantly across countries. To make the assumption of homoscedasticity more plausible, the factors of production and output are normalized by dividing them with the industry's sample average of output.

Appendix B reports parameter estimates for the cost function in the error correction form, where the R&D capital stocks have not been included as a separate variable. It is encouraging that results obtained when estimating the system (9)-(11) directly (results not reported) are very similar, although they are subject to severe autocorrelation in the residuals,.

Since output is very likely to be endogenous, it may seem preferable to estimate the system with three-stage least squares using lagged cost function arguments as instruments. However, while output, inputs and prices in levels are autocorrelated quite strongly, this is not true for the first differences of these variables. As research on the properties of instrumental variable estimators in small sample shows (Nelson & Startz 1990), the instrumental variable bias may in fact be worse than the OLS bias when the instruments are only weakly correlated with the instrumented variables. As no valid instruments are available for the differenced variables, SUR is the preferred estimation method.

It is assumed for simplicity that the matrices A_j, E_j and Γ in the factor demand system (15) are diagonal. However, including off-diagonal elements in the estimation usually results in insignificant estimates, so this simplifying assumption seems appropriate. The length of the lag structure is decided by the data in the sense that additional lags are included until Ljung-Box

Q-Statistics (not reported) cannot detect any more autocorrelation in the residuals from lags 1 to 5.

While for the material inputs demand one lag is often enough, it is not rare that up to three lags have to be included in the capital inputs demand equation to obtain residuals that look like white noise. This supports the view that material inputs can be adjusted rather quickly, while adjustment costs for capital seem to be high and so adjustment to changes in exogenous variables is slow. The labor demand equation also requires a number of lags in most cases. This suggests that the common specification in dynamic factor demand models, where capital is assumed to be quasi-fix, while labor and material inputs are variable, may not be completely adequate. The generality of the error correction model, which allows for short-run deviations from equilibrium for all factors of production, thus appears as a definite advantage over dynamic factor demand models, where the researcher has to decide beforehand which factors of production are variable and which are not.

Country-industry specific effects are captured by estimating the constants of the factor demand equations b_M, b_L and b_K and the mark-up μ with industry-country-dummies. All other variables are assumed to be the same across industries in different countries.

To interpret results reported in Appendix B, it should be noted that the $\gamma_i s$ denote the error correction terms. As far as the suffixes are concerned, C stands for the cost function, L, K, and M for the factor input demand equations and Y for the price equation. The as denote parameters for lagged differences of optimal factor demands, cost and output prices respectively and the cs report parameters for lagged differences of the actual factor demands, cost and output prices. The number following a or c indicates whether the difference is lagged once, twice or three times. The row denoted t.stat. reports t-statistics for the error correction terms.

Each of the estimated cost functions complies with concavity restrictions. All estimates of the error correction terms are significantly negative and thus indicate reversion to equilibrium. Indeed, the majority of error correction terms is significant enough to pass the Banerjee, Dolado & Mestre (1996) test for cointegration. The test is based on the conventional t-statistics for the error correction terms, which are reported in Appendix B. If the t-statistic is small enough, the null hypothesis of no cointegration can be rejected. The critical values for a sample size of fifty with five independent variables are -4.6, for the five-percent significance level, -4.19 for the ten-percent significance level and -3.53 for the 25-percent significance level. Clearly, the t-statistics for the error correction terms cannot be viewed as an exact cointegration test for the cost function and factor demand system estimated here, because it is designed for single-equation frameworks without the complicated multiplicative terms of independent variables, which appear in cost functions of the flexible functional form. However, the test can serve as a rough guideline to judge whether the estimated cost and factor demand functions can be viewed as cointegrating relationships should some of the variables be non-stationary.

6.2 Mark-Ups and Economies of Scale

Mark-ups are significantly bigger than one in all industries but the rubber and plastic products, where the 95%-confidence interval of the estimate of μ for the US and Italy includes 1. Theory suggests that market-power should be high in industries, where a lot of R&D is performed. For this reason, one might expect a positive relationship between R&D-intensity and the size of the mark-up. Yet, for most industries estimated mark-ups are around 1.2. This seems to be rather uniform, whether or not the industries are R&D-intensive.

To get a clearer image, wether the results imply any relationship between mark-ups and economies of scale, the estimated mark-ups are regressed on the sample average of R&D-intensity. Industries are grouped in high-tech, low-tech and medium-tech industries, depending on their R&D-intensity. Low-tech industries include food, textiles, wood and publishing and printing, all of which have R&D-intensities below 0.5% for all countries but Japan. Electrical and optical equipment, transport equipment and chemicals generally have R&D-intensities well above 3%. They are therefore grouped as high-tech industries. All the rest is in the group of medium-tech industries.

The grouping is detailed in appendix C, where results of the regression of the mark-ups on R&D-intensity are shown. In a simple regression, the estimated relationship is insignificant for all of the three groups. However, there seem to be some important differences between countries, most notably the R&D-intensity is generally a lot lower in Italy than elsewhere. This also holds to a lesser extent for Canada. Therefore it is tested successively wether dummies for the different countries are significant. The same is done with industry dummies. In the medium-tech industries the dummies for Italy and Canada are significant. This also holds for the high-tech industries, although only at the 10-%-significance-level. There seem to be no important differences across countries in the low-tech industries, where the dummy of the textiles industry enters significantly, however. In the medium-tech industries, the dummy for rubber and plastic products is significant.

Including dummies in the regression results in a significantly positive relationship between R&D-intensity and mark-ups in medium-tech industries.

Table IV : Estimates of the Mark-up of Price over Marginal Cost, μ.

Industry$^+$	US	Italy	Japan	Germany	Canada	France
15	1.282	1.303	1.279	1.285	1.260	1.272
	(0.070)	(0.072)	(0.070)	(0.071)	(0.079)	(0.070)
17	1.190	1.215	-	1.188	1.210	1.182
	(0.031)	(0.038)		(0.030)	(0.031)	(0.030)
20	-	1.423	-	1.197	1.152	-
		(0.076)		(0.070)	(0.074)	
21-22	-	1.392		1.376	1.216	1.369
		(0.071)		(0.069)	(0.062)	(0.069)
24	1.242	1.257	-	1.263	1.239	-
	(0.026)	(0.035)		(0.034)	(0.035)	
25	1.099	1.167	-	1.181	1.174	-
	(0.102)	(0.084)		(0.078)	(0.080)	
26	1.577	1.649	-	1.572	1.555	1.562
	(0.076)	(0.084)		(0.077)	(0.076)	(0.077)
27-28	1.252	1.264	1.274	1.284	1.242	1.187
	(0.040)	(0.041)	(0.040)	(0.041)	(0.040)	(0.053)
29	-	1.490	1.352	1.455	1.491	1.376
		(0.203)	(0.100)	(0.197)	(0.234)	(0.105)
30-33	-	1.347	1.209	1.350	1.382	1.240
		(0.051)	(0.037)	(0.044)	(0.050)	(0.040)
34-35	1.233	1.280	1.254	1.275	1.246	1.239
	(0.038)	(0.044)	(0.035)	(0.038)	(0.040)	(0.038)
36	-	1.245	-	1.199	1.254	1.167
		(0.053)		(0.043)	(0.063)	(0.038)

$^+$ISIC Code

The relationship is also positive in the group of high-tech industries, although again this is significant only on a 10-%-significance level. Even this weak significance is dependent on barely significant country dummies being included in the regression. Thus, this result has to be treated with caution. In the low-tech industries, the relationship between R&D and mark-ups is negative but insignificant, even when dummies are included in the regression. Of course, it could be expected that in low-tech industries R&D will not matter much for market power.

Overall, there is some weak evidence in favor of the notion, that a a high amount of R&D activity should be associated with high mark-ups. The important bottom-line from the point of view of endogenous growth theory is that the estimates support the expectation that there should be a mark-up of price over marginal costs in all industries that perform R&D.

As can be verified in table VI, the estimates imply increasing returns to scale for all industries. Only in the food industry are the estimates not significantly different from one for Japan and Canada. The size of the estimates is again rather uniform. The average rate of returns to scale varies between 1.1 and 1.2 for almost all of the investigated industries. Relatively large economies of scale typically come with relatively high mark-ups. Most notably, this is the case in the non-metallic mineral products industry, but also in the transport equipment, the machinery and in the basic and fabricated metals industry. This is conform with theory, as economies of scale necessarily have to be associated with market-power, otherwise firms would make constant losses.

Most industries displaying relatively high economies of scale are also relatively R&D-intensive. On the other hand, the highly R&D-intensive chemical and electrical and optical equipment industry hold middle positions when it comes to economies of scale. Economies of scale could be expected to be high in industries where R&D activity is high, because knowledge creation is associated with a fixed cost. Likewise, because of the non-rival nature of knowledge, returns to scale should be expected to be increasing in manufacturing labor, capital and material inputs and R&D together. Since labor, capital and material inputs are not corrected for double counting, it is not surprising that the cost elasticity with respect to output should indicate increasing returns to scale.

Overall the results support endogenous growth theory. The presence of mark-ups and economies of scale is confirmed for all of the investigated industries. There is also some - although rather weak- evidence, that both mark-ups and economies of scale are linked to the amount of R&D activity.

Although earlier studies typically did not aim at investigating mark-ups, economies of scale and the role of knowledge in an integrated approach to study the relationship between these features, many researchers have investigated either mark-ups or economies of scale separately.

In prior studies, estimates for mark-ups obtained within the primal framework vary in size, but all of them point towards the existence of market-power (Hall 1988, Domowitz, Hubbard & Petersen 1988, Beccarello 1996). The same holds for estimates obained within cost function frameworks (see for example Kim & Nadiri (1996), Nadiri & Nandi (1999), and Mamuneas (1999)). The crucial factor when estimating mark-ups appears to be the definition of output. It can be shown that the use of value-added data biases results upwards. In fact, estimates obtained with gross output data are generally lower than those obtained with value-added data. Regardless of the output definition used in prior investigations, mark-up estimates obtained in

Table V: Average Rate of Returns to Scale; 1980-1998

Industry$^+$	US	Italy	Japan	Germany	Canada	France
15	1.136	1.245	1.111*	1.229	1.091*	1.215
	(0.067)	(0.008)	(0.063)	(0.007)	(0.063)	(0.074)
17	1.136	1.171		1.129	1.129	1.129
	(0.030)	(0.033)		(0.030)	(0.029)	(0.028)
20	-	1.266	-	1.196	1.156	-
		(0.092)		(0.077)	(0.076)	
21-22	-	1.213		1.140	1.095	1.169
		(0.061)		(0.055)	(0.052)	(0.058)
24	1.113	1.197	-	1.172	1.118	-
	(0.030)	(0.030)		(0.029)	(0.031)	
25	1.258	1.190	-	1.162	1.178	-
	(0.056)	(0.049)		(0.046)	(0.049)	
26	1.329	1.479	-	1.326	1.255	1.325
	(0.080)	(0.089)		(0.073)	(0.065)	(0.070)
27-28	1.213	1.234	1.222	1.189	1.208	1.174
	(0.046)	(0.049)	(0.048)	(0.045)	(0.046)	(0.043)
29	-	1.329	1.212	1.153	1.187	1.241
		(0.055)	(0.048)	(0.042)	(0.042)	(0.042)
30-33	-	1.187	1.122	1.167	1.214	1.096
		(0.037)	(0.032)	(0.036)	(0.042)	(0.032)
34-35	1.184	1.289	1.278	1.225	1.186	1.217
	(0.051)	(0.059)	(0.057)	(0.052)	(0.046)	(0.048)
36	-	1.153	-	1.085	1.100	1.028
		(0.033)		(0.028)	(0.032)	(0.026)

$^+$ISIC Code, *Estimate is not significantly different from 1

this study are in general both more homogenous across industries and lower. Mostly ranging between around 1.2 and being well below 1.5 for every industry, they seem in fact much more realistic than many estimates presented before. This may well be due to the empirical framework, which allows both for considerable flexibility, as far as the functional form is concerned, and for very general short-term deviations from equilibrium.

As far as economies of scale are concerned, the finding of moderately increasing returns to scale is a very common result of work based on the cost function approach. Studies with results in a similar range as those presented in the previous section include Flaig & Steiner (1993), Kwon & Park's (1995), Mamuneas (1999), Kim & Nadiri (1996), Morrison Paul & Siegel (1997), Morrison Paul & Siegel (1999) and Nadiri & Nandi (1999).

In contrast, results obtained with the Solow residual approach are much more mixed and controversial. Some estimates imply high increasing returns (Hall 1990), while others find only moderate economies of scale (Bartelsman, Caballero & Lyons 1994), constant (Burnside, Eichenbaum & Rebelo 1995, Burnside 1993), or even decreasing returns (Basu & Fernald 1997).

Yet, it is not difficult to argue that results obtained with a cost function are much more reliable. First, most of the production function estimations and the construction of the Solow residual in studies discussed in this section are based on the Cobb-Douglas function. In contrast, the cost function studies typically rely on flexible functional forms, which are much more general. A number of researchers who use the Hall/Solow residual framework attempt to correct their data for factors such as varying capital utilization (Basu 1996, Burnside 1993) and labor hoarding (Burnside, Eichenbaum & Rebelo 1993), because a failure to account for this is frequently believed to bias results. The dual framework, in contrast, readily encompasses varying capacity utilization without a need to recur to correction of the data.

Taking the problems associated with the primal approach into consideration, there is enough reason to conclude that overall the existing empirical literature points towards slightly increasing returns to scale. In line with the theoretical model presented above, empirical results call for a framework that allows for both non-competitive behavior and non-constant returns to scale when studying the role of knowledge for productivity growth.

6.3 The Impact of R&D and Spillovers

As a first step, only the industries' own R&D capital stocks are included in the cost function estimation to see how the decision to invest in R&D affects the productivity growth of the investor. The impact of the R&D capital stock on costs is significant for only one half of the investigated industries. As outlined in the data description, the finding that there is no significant impact of R&D on costs in some of the industries does not imply that R&D has no impact at all. It simply means that there is no excess return to R&D in these industries. Excess returns may be present because investment in R&D leads to innovations which enhance the efficiency of the production process significantly. A complementary interpretation is that there may be intra-industry spillovers between the firms in the investigated industry. Both interpretations are very much in the spirit of endogenous growth theory.

Including R&D in the cost function generally lowers the estimated productivity growth significantly. This can be verified in table VI, which reports the average "exogenous" productivity growth implied by the estimation without R&D, with only own R&D and with both own R&D and spillover variables respectively. The row denoted "no" reports productivity growth implied by the estimation without R&D variables. As should be expected with market-power and increasing returns to scale, estimates obtained within the dual framework imply invariably lower productivity growth than the Solow residual. The row denoted "own" reports productivity growth implied by the estimation with own R&D.

Table VI: Average Productivity Growth over 1980-1998, in percent

Ind.	R&D	US	Italy	Jap	Ger	Can	Fr
	no	0.1	0.1	-	0.1	0.006	-
24	spill.	0.03	0.02	-	0.02	0.006	
	no	-0.4	-0.3	-	-0.5	-0.5	-
25	spill.	-0.04	-0.02	-	-0.03	-0.01	
	no	0.03	0.005		0.001	0.02	0.02
26	own	0	0		0	0	0
	spill.	-0.3	-0.3	-	-0.3	-0.03	-0.03
	no	0.36	0.34	0.29	0.33	0.38	0.33
27-28	own	0.33	0.30	0.25	0.019	0.35	0.30
	spill.	0.43	0.40	0.34	0.38	0.42	0.38
	no	-	0.3	0.3	0.3	0.4	0.3
29	own	-	-0.3	-0.3	-0.3	-0.2	-0.2
	spill.	-	-0.6	-0.7	-0.7	-0.6	-0.6
	no	-	1	0.8	1	1	1
30-33	own	-	0.7	0.5	0.7	0.2	0.3
	spill.	-	-0.6	-0.7	-0.7	-0.6	-0.6
	no	0.1	0.1	0.1	0.1	0.2	0.1
34-35	own	-0.09	-0.07	-0.07	-0.005	0.008	-0.004

According to endogenous growth theory, R&D may not only enhance productivity growth in the firm that invests in it. Other economic agents may benefit from this investment through knowledge spillovers. To see whether it is possible to pin down knowledge externalities empirically, the spillover variables described in section 3 are included in the cost function as external factors.

Because the spillover variables are highly collinear, the impact of each spillover variable is investigated individually. It is then tested whether the result, that the impact is significant, is robust to excluding own R&D and the trend term from the regression. Estimation results with spillover variables that prove to have a significant impact on costs are reported in Appendix D, if this result is robust in the sense just defined.

In four industries, food, wood, publishing and printing and manufacturing not elsewhere classified, none of the spillover variables has a significant impact. Since "exogenous" technological change is negative in the estimation without R&D variables for all of these industries, this result is not surprising. There just is no productivity growth to be explained, at least in the sample period considered here.

As an overall picture, knowledge created in the same industry abroad seems to be the most important source of spillovers. If a significant impact of any of the spillover variables can be found at all, the intra-industry spillover variable is among it for almost all the industries. The only exception is the non-metallic mineral products industry, where only domestic spillovers have a significant impact. Consequently, the specification with own R&D and domestic spillovers is reported for non-metallic mineral products in Appendix D. For all other industries, the intra-industry spillover variable is chosen instead. If both the R&D variable and the intra-industry spillover variable are significant, both are included in the estimation. If, instead, only the spillover variable is significant, it is included alone. This is the case for the chemical and the rubber and plastic industry.

As endogenous growth theory would suggest, the spillover variables apparently explain a portion of the observed productivity growth. Including spillover variables lowers the dual measure of technological change. An exception is the basic and fabricated metal industry, where the implied productivity growth rises somewhat, when a spillover variable is included in the estimation in addition to own R&D. For all other industries, unspecific productivity growth measured by the trend term becomes zero or negative, as soon as both own R&D and spillover variables are taken into account. This can be verified in table VI, where the row denoted "spill." reports the productivity growth implied by the cost function estimation with both own R&D and spillover variables.

Overall the estimation results support endogenous growth theory in that R&D investments seem to lower costs, and thus enhance productivity. Both the investor and other industries may benefit from investments in knowledge creation. The trend term seems to pick up some of the productivity growth, which can be attributed to knowledge creation when R&D is not accounted for in the cost function estimation. When, instead, investments in R&D are taken into account, other sources of technological growth appear to play no role at all, or if they do, their impact is negative.

The estimated internal rate of returns to scale is quite robust to the inclusion of further knowledge variables. However, overall returns to scale in traditional factors, own R&D and knowledge spillovers are higher than internal economies of scale alone. For some industries, most notably non-

Table VII: Internal and External Returns to Scale

Industry	R&D	US	Italy	Japan	Germany	Canada	France
17	$\frac{1}{\varepsilon_{CY}}$	1.172	1.138	-	1.186	1.214	1.168
	η	1.224	1.158	-	1.277	1.502	1.247
24	$\frac{1}{\varepsilon_{CY}}$	1.030	1.135		1.130	1.077	-
	η	1.033	1.16	-	1.147	1.232	
25	$\frac{1}{\varepsilon_{CY}}$	1.297	1.208	-	1.180	1.208	-
	η	1.303	1.233	-	1.200	1.444	-
26	$\frac{1}{\varepsilon_{CY}}$	1.423	1.443	-	1.360	1.248	1.347
	η	1.698	1.481		1.559	1.305	1.504
27-28	$\frac{1}{\varepsilon_{CY}}$	1.181	1.203	1.258	1.210	1.208	1.166
	η	1.240	1.320	1.384	1.326	1.835	1.326
29	$\frac{1}{\varepsilon_{CY}}$	-	1.157	1.302	1.304	1.160	1.292
	η	-	1.222	1.510	1.589	1.528	1.491

metallic mineral products, the machinery industry and to some extent the basic and fabricated metal industry, the difference is substantial. In the first two industries, internal and external economies together imply a rate of returns to scale that is close to 1.5 and higher in many countries In accordance with the theoretical model, the empirical results imply economies of scale due to knowledge externalities.

Qualitatively the finding that knowledge and spillovers have a positive impact on productivity growth is a very well established result in the empirical literature. It has been found with different kinds of data sets, varying aggregation level and different sample periods, for different countries, with different estimation techniques and different specifications of the estimation function (for an overview see Nadiri (1993)).

This study adds to the existing literatures in several ways. First it confirms the theoretical reasoning that a role of knowledge for technological change should be associated with market power and economies of scale. Clearly, the empirical framework should account for this. Second, results suggest that the impact of R&D on technological change differs considerably across industries. Excess returns to R&D are found primarily in particularly R&D-intensive industries. In several industries, both the industries' own R&D capital stocks and spillovers are shown to explain part of the observed productivity growth. In accordance with theory, results imply that spillovers are an external source of economies of scale.

7 Conclusions

Using R&D-based growth theory as a foundation, it is argued that an appropriate empirical framework to investigate this theory should encompass imperfect competition and non-constant returns to scale. This is important, because R&D as an engine of productivity growth is necessarily linked to market-power and economies of scale, once it is agreed upon that knowledge is at least partially a non-rival good.

An empirical investigation with a new international industry data set for several OECD countries reveals, in fact, the presence of both market-power and economies of scale in all of the investigated industries. In accordance with theory, there is also some evidence, that these features are linked to the intensity of industries' R&D activity.

The Solow residual is highly popular in empirical work on R&D-based growth models. Yet, results of this study suggest that, relying on the assumptions of perfect competition and constant returns to scale, it may not be the best framework to investigate the role of knowledge for economic growth. Both theoretical reasoning and the available evidence suggest the presence of market-power and economies of scale. In that case, the Solow residual is biased upward as a measure of productivity growth.

In this study, the impact of the industries' investments in R&D is studied in a dynamic cost function framework. Unlike the Solow residual, the presence of market-power and economies of scale does not bias results in this framework. In fact, productivity growth estimates derived from the cost function are invariably lower than the Solow residual.

Excess returns to R&D, which are beyond returns to manufacturing labor, capital and material inputs, are found in roughly one half of the industries. Most of them are especially R&D-intensive. Even more industries benefit from knowledge spillovers. R&D and spillovers explain at least a part, if not all of the observed productivity growth.

While it is a well established result of this study that spillovers matter in many industries, it also turns out that attributing spillovers to a specific source is highly difficult because of multicollinearity problems. It can nevertheless be concluded from the results, that international intra-industry spillovers seem to be more important than spillovers between different industries. Spillover are shown to be an external source of economies of scale.

The findings suggest that it is revealing to investigate each industry individually. The importance of R&D for productivity growth and spillovers, as well as their link with market-power and economies of scale differs considerably across industries.

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A. Industry List

Table AI: The ISIC, Rev. 3 Industry classification

ISIC-Code	Industry
15-16	Food Products, Beverages and Tobacco
17-19	Textiles, Textile products, Leather and Footwear
20	Wood and Products of Wood and Cork
21-22	Paper, Publishing and Printing
23-25	Chemical, Rubber, Plastic and Fuel Products
23	Coke, Refined Petroleum Products And Nuclear Fuel
24	Chemicals And Chemical Products
25	Rubber and Plastic Products
26	Other Non-Metallic Mineral Products
27	Basic Metals
28	Fabricated Metal products
27-28	Basic and Fabricated Metal Products
29-33	Machinery and Equipment
29	Machinery, n.e.c.
30-33	Electrical and Optical Equipment
30	Office, Accounting and Computing Machinery
31	Electrical Machinery and Apparatus, n.e..c
32	Radio, Television and Communication Equipment
33	Medical, Precision and Optical Instruments
34-35	Transport Equipment
34	Motor Vehicles, Trailers and Semi-Trailers
35	Other Transport Euipment
36-37	Manufacturing, nec, Recycling

B. Results without R&D

Table B1: Estimation Results for the Food and Beverages Industry (15-16) in the US, Italy, Japan, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.146	-1.017	0.296	0.284	-0.126	0.240
(0.054)	(0.370)	(0.131)	(0.087)	(0.348)	(0.112)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.021	0.061	0.085	0.002	0.041	0.061
(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-0.356	-0.156	-0.063	-0.249	-0.394	-0.115
(0.170)	(0.164)	(0.157)	(0.174)	(0.165)	(0.162)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.063	0.082	-0.047	0.131	0.022	-0.0003
(0.030)	(0.032)	(0.031)	(0.030)	(0.030)	$(7*10^{-5})$
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
0.001	0.0009	0.009	-0.0002	-0.067	$1*10^{-6}$
(0.0007)	(0.003)	(0.002)	(0.001)	(0.015)	$(6*10^{-7})$
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.282	1.303	1.279	1.285	1.260	1.272
(0.070)	(0.072)	(0.070)	(0.071)	(0.079)	(0.070)
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a1_{M}$
0.976	0.739	0.072	1.151	0.992	1.151
(0.015)	(0.131)	(0.035)	(0.052)	(0.071)	(0.052)
$a2_{L}$	$c1_{L}$	$c1_{K}$	$c1_{Y}$	$c2_{K}$	$c2_{Y}$
-0.159	0.085	0.899	0.065	-0.403	0.073
(0.058)	(0.040)	(0.086)	(0.036)	(0.087)	(0.035)
γ_{C}	γ_{L}	γ_{K}	γ_{M}	γ_{Y}	
-0.077	-0.121	-0.032	-0.126	-0.211	
(0.020)	(0.020)	(0.009)	(0.020)	(0.039)	

	Cost	Labor:	Capital	Material	Price
R^2	0.875	0.429	0.800	0.708	0.880
D.W.	2.382	1.844	1.686	2.324	1.911
t.stat.	-3.775	-5.903	-3.532	-6.402	-5.403
Obs.	93	93	93	93	93

(Standard Errors in Parentheses)

Table B2: Estimation Results for the Textiles Industry (17-19) in the US, Italy, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.162	-0.161	0.087	0.301	0.214	0.666
(0.068)	(0.265)	(0.123)	(0.070)	(0.242)	(0.081)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.119	0.099	-	0.047	0.145	0.109
(0.019)	(0.019)	-	(0.018)	(0.019)	(0.018)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.005	0.167	-	0.113	-0.050	0.035
(0.111)	(0.105)	-	(0.120)	(0.106)	(0.105)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.014	0.041	-	0.062	-0.008	0.020
(0.026)	(0.026)	-	(0.023)	(0.025)	(0.024)
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
-0.007	-0.001	0.0007	-0.002	-0.001	$5*10^{-5}$
(0.001)	(0.002)	(0.002)	(0.001)	(0.008)	$(7*10^{-5})$
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.190	1.215	-	1.188	1.210	1.182
(0.031)	(0.038)	-	(0.030)	(0.031)	(0.030)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
0.939	0.849	0.108	1.015	0.844	-0.165
(0.010)	(0.040)	(0.043)	(0.030)	(0.048)	(0.046)
$a2_L$	$a2_K$	$a2_M$	$c1_C$	$c1_L$	$c1_K$
0.008	0.073	-0.214	0.211	0.176	0.579
(0.055)	(0.042)	(0.049)	(0.047)	(0.076)	(0.064)
$c1_M$	$c1_Y$	γ_C	γ_L	γ_K	γ_M
0.190	0.230	-0.080	-0.161	-0.045	-0.109
(0.045)	(0.042)	(0.022)	(0.021)	(0.011)	(0.021)
γ_C					
-0.140					
(0.043)					

	Cost	Labor	Capital	Material	Price
R^2	0.976	0.771	0.829	0.949	0.935
D.W.	2.277	2.180	1.650	1.880	2.395
t.-stat	-3.639	-7.522	-4.107	-5.218	-3.270
Obs.	82	82	82	82	82

(Standard Errors in Parentheses)

Table B3: Estimation Results for the Wood Industry (20)
in Italy, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.028	-0.430	0.095	0.043	0.368	0.701
(0.020)	(0.350)	(0.083)	(0.028)	(0.322)	(0.130)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.185	-	0.170	0.194	-
-	(0.030)	-	(0.023)	(0.024)	-
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	0.249	-	-0.013	-0.068	-
-	(0.198)	-	(0.037)	(0.041)	-
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	-0.036	-	-0.052	0.0003	-
-	(0.042)	-	(0.043)	(0.038)	-
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
$-5*10^{-5}$	-0.008	0.005	0.0005	-0.006	$-2*10^{-7}$
$(3*10^{-4})$	(0.005)	(0.001)	(0.001)	(0.009)	$(1*10^{-5})$
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
-	1.423	-	1.310	1.393	-
-	(0.076)	-	(0.070)	(0.074)	-
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{M}$	$a1_{Y}$
1.182	13.972	0.050	1.155	1.222	1.461
(0.055)	(15.420)	(0.034)	(0.058)	(0.135)	(0.166)
$a2_{K}$	$c1_{C}$	$c1_{L}$	$c1_{K}$	$c1_{Y}$	γ_{C}
0.102	0.071	0.289	0.683	0.291	-0.115
(0.044)	(0.012)	(0.050)	(0.092)	(0.067)	(0.032)
γ_{L}	γ_{K}	γ_{M}	γ_{Y}		
-0.074	-0.060	-0.115	-0.555		
(0.019)	(0.022)	(0.030)	(0.093)		

	Cost	Labor	Material	Capital	Price
R^2	0.964	0.871	0.948	0.700	0.800
t.-stat.	-3.628	-3.916	-3.797	-2.674	-5.967
D.W.	2.204	2.395	2.006	1.689	2.020
Obs.	48	48	48	48	48

(Standard Errors in Parentheses)

Table B4: Estimation Results for the Publishing and Printing Industry (21-22) in Italy, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.013	-0.036	-0.009	0.138	-0.091	0.704
(0.030)	(0.156)	(0.064)	(0.050)	(0.118)	(0.061)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.134	-	0.117	0.118	0.161
-	(0.030)	-	(0.031)	(0.029)	(0.033)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	0.134	-	0.323	0.303	0.150
-	(0.089)	-	(0.086)	(0.081)	(0.083)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	-0.104	-	-0.149	-0.211	-0.136
-	(0.041)	-	(0.038)	(0.037)	(0.039)
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
0.002	0.021	0.010	0.002	-0.067	-0.0004
(0.002)	(0.003)	(0.002)	(0.002)	(0.014)	($1*10^{-4}$)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
-	1.392	-	1.376	1.216	1.369
-	(0.071)	-	(0.069)	(0.062)	(0.069)
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{C}$
1.066	0.800	0.579	1.098	1.397	-0.117
(0.033)	(0.233)	(0.421)	(0.065)	(0.094)	(0.072)
$a2_{L}$	$a2_{K}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$	$c1_{K}$
0.567	1.338	-0.922	0.175	0.181	0.961
(0.241)	(0.624)	(0.168)	(0.065)	(0.078)	(0.099)
$c1_{Y}$	$c2_{K}$	γ_{C}	γ_{K}	γ_{L}	γ_{M}
0.760	-0.281	-0.112	-0.125	-0.196	-0.154
(0.118)	(0.121)	(0.026)	(0.041)	(0.047)	(0.037)
γ_{Y}					
-0.638					
(0.096)					

	Cost	Labor	Capital	Material	Price
R^2	0.980	0.730	0.803	0.907	0.932
D.W.	2.045	1.498	2.407	2.016	2.509
t.stat.	-4.317	-4.195	-3.066	-4.188	-6.616
Obs.	58	58	58	58	58

(Standard Deviations in Parentheses)

Table B5: Estimation Results for the Chemical Industry (24) in the US, Italy, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.052	-0.097	0.046	0.064	-0.019	0.739
(0.017)	(0.078)	(0.031)	(0.024)	(0.079)	(0.038)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.189	0.167	-	0.191	0.139	-
(0.017)	(0.017)	-	(0.017)	(0.016)	-
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.549	0.625	-	0.581	0.607	-
(0.033)	(0.035)	-	(0.032)	(0.033)	-
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-0.131	-0.047	-	-0.057	-0.109	-
(0.024)	(0.022)	-	(0.022)	(0.024)	-
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
0.0007	0.012	0.006	-0.003	-0.0006	-0.0003
(0.001)	(0.003)	(0.002)	(0.001)	(0.016)	(0.0001)
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
1.242	1.257	-	1.263	1.239	-
(0.026)	(0.035)	-	(0.034)	(0.035)	-
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
1.001	0.765	2.385	1.005	1.142	
(0.011)	(0.138)	(0.680)	(0.014)	(0.063)	()
$a2_C$	$a2_L$	$a2_M$	$a2_Y$	$c1_C$	$c1_L$
-0.470	0.367	-0.451	-0.175	0.489	0.353
(0.053)	(0.171)	(0.053)	(0.123)	(0.052)	(0.054)
$c1_K$	$c1_M$	$c1_Y$	$c2_L$	$c2_K$	γ_C
0.717	0.440	0.186	-0.090	-0.146	-0.183
(0.085)	(0.048)	(0.105)	(0.037)	(0.087)	(0.026)
γ_L	γ_K	γ_M	γ_Y		
-0.155	-0.174	-0.202	-0.370		
(0.034)	(0.043)	(0.024)	(0.082)		

	Cost	Labor	Capital	Material	Price
R^2	0.936	0.419	0.725	0.885	0.868
D.W.	2.505	1.723	1.703	2.407	1.990
t.stat.	-6.934	-4.626	-4.055	-8.418	-4.530
Obs.	60	60	60	60	60

(Standard Errors in Parentheses)

Table B6: Estimation Results for the Rubber and Plastic Industry (25) in the US, Italy, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.209	-0.948	0.414	0.410	-0.479	0.658
(0.081)	(0.374)	(0.161)	(0.083)	(0.302)	(0.094)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.100	0.025	-	0.075	0.087	-
(0.017)	(0.017)	-	(0.017)	(0.017)	-
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.098	0.299	-	0.235	0.130	-
(0.072)	(0.071)	-	(0.072)	(0.069)	-
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.112	0.100	-	0.045	0.044	-
(0.025)	(0.024)	-	(0.025)	(0.025)	-
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
0.0005	0.006	0.013	-0.001	0.002	-0.0004
(0.002)	(0.005)	(0.313)	(0.003)	(0.010)	(0.0001)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.099	1.167	-	1.181	1.174	-
(0.102)	(0.084)	-	(0.078)	(0.080)	-
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{C}$
0.997	0.775	-0.015	1.175	-0.103	-0.175
(0.013)	(0.063)	(0.054)	(0.035)	(0.028)	(0.048)
$a2_{M}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$	$c1_{K}$	$c1_{M}$
-0.291	0.250	0.185	0.189	0.516	0.195
(0.064)	(0.051)	(0.047)	(0.040)	(0.069)	(0.044)
γ_{C}	γ_{L}	γ_{K}	γ_{M}	γ_{Y}	
-0.233	-0.351	-0.164	-0.239	-0.103	
(0.036)	(0.046)	(0.031)	(0.033)	(0.028)	

	Cost	Labor	Capital	Material	Price
R^2	0.955	0.728	0.693	0.889	0.901
D.W.	2.165	1.919	1.729	2.092	1.886
t.stat.	-6.547	-7.672	-5.239	-7.297	-3.638
Obs.	64	64	64	64	64

(Standard Errors in Parentheses)

Table B7: Estimation Results for the Other Non-Metallic Mineral Products Industry (26) in the US, Italy, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.232	-1.060	0.398	0.397	-0.379	0.637
(0.095)	(0.295)	(0.154)	(0.086)	(0.311)	(0.080)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.142	0.100	-	0.069	0.103	0.109
(0.018)	(0.020)	-	(0.020)	(0.019)	(0.020)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.032	0.240	-	0.222	-0.012	0.034
(0.135)	(0.128)	-	(0.131)	(0.140)	(0.130)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.065	0.167	-	0.107	0.062	0.098
(0.040)	(0.038)	-	(0.033)	(0.033)	(0.029)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
-0.006	-0.002	0.0004	0.003	0.020	$3*10^{-5}$
(0.001)	(0.003)	(0.001)	(0.001)	(0.009)	($7*10^{-5}$)
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
1.577	1.649	-	1.572	1.555	1.562
(0.076)	(0.084)	-	(0.077)	(0.076)	(0.077)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_L$
1.063	0.837	0.053	1.399	0.854	0.127
(0.050)	(0.068)	(0.033)	(0.119)	(0.090)	(0.026)
$c1_C$	$c1_K$	$c1_Y$	$c2_K$	$c2_Y$	γ_C
0.048	0.595	0.444	-0.108	-0.227	-0.049
(0.780)	(0.073)	(0.066)	(0.076)	(0.061)	(0.020)
γ_L	γ_K	γ_M	γ_Y		
-0.171	-0.118	-0.062	-0.229		
(0.022)	(0.023)	(0.020)	(0.048)		

	Cost	Labor	Capital	Material	Price
R^2	0.904	0.757	0.665	0.898	0.845
D.W.	2.248	1.780	1.812	2.398	1.605
t.stat.	-2.448	-7.789	-5.108	-3.165	-4.798
Obs.	77	77	77	77	77

(Standard Errors in Parentheses)

Table B8: Estimation Results: Basic and Fabricated Metals (27-28) in the US, Italy, Japan, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.089	-0.455	0.161	0.220	0.216	0.703
(0.060)	(0.307)	(0.127)	(0.080)	(0.335)	(0.091)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.170	0.144	0.112	0.168	0.136	0.136
(0.024)	(0.024)	(0.025)	(0.024)	(0.025)	(0.025)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.057	0.083	0.553	0.104	-0.052	0.034
(0.161)	(0.164)	(0.169)	(0.166)	(0.161)	(0.166)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.022	0.059	0.044	0.015	0.063	0.006
(0.024)	(0.024)	(0.023)	(0.024)	(0.025)	(0.024)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
-0.003	-0.005	0.0008	-0.001	0.012	$1*10^{-6}$
(0.001)	(0.003)	(0.0001)	(0.001)	(0.008)	$(1*10^{-5})$
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
1.252	1.264	1.274	1..284	1.242	1.187
(0.040)	(0.041)	(0.040)	(0.041)	(0.040)	(0.053)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
1.015	0.840	-0.002	1.205	1.187	-0.235
(0.018)	(0.133)	(0.026)	(0.044)	(0.053)	(0.049)
$a2_L$	$a2_K$	$a2_M$	$a2_Y$	$c1_C$	$c1_L$
0.276	0.061	-0.329	-0.049	0.246	0.198
(0.097)	(0.033)	(0.061)	(0.028)	(0.047)	(0.045)
$c1_K$	$c1_M$	$c1_Y$	$c2_K$	$c2_Y$	γc
0.872	0.205	0.340	-0.344	-0.049	-0.135
(0.080)	(0.047)	(0.088)	(0.077)	(0.028)	(0.028)
γ_L	γ_K	γ_M	γ_Y		
-0.156	-0.046	-0.088	-0.444		
(0.024)	(0.001)	(0.023)	(0.074)		

	Cost	Labor	Capital	Material	Price
R^2	0.973	0.767	0.815	0.938	0.957
D.W.	2.318	1.657	1.583	2.496	1.916
t.stat.	-4.896	-6.583	-4.713	-3.874	-5.991
Obs.	92	92	92	92	92

(Standard Errors in Parentheses)

Table B9: Estimation results for the Electrical and Optical Equipment Industry (30-33) in Italy, Japan, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.052	-0.049	0.041	0.320	0.134	0.873
(0.041)	(0.161)	(0.072)	(0.050)	(0.124)	(0.054)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.143	0.138	0.150	0.096	0.174
-	(0.020)	(0.020)	(0.020)	(0.020)	(0.021)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	0.474	0.324	0.504	0.113	0.309
-	(0.076)	(0.074)	(0.069)	(0.061)	(0.070)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	-0.151	-0.130	-0.175	-0.040	-0.190
-	(0.024)	(0.021)	(0.023)	(0.022)	(0.020)
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
-0.014	-0.008	-0.015	0.007	-0.032	0.0005
(0.002)	(0.003)	(0.003)	(0.003)	(0.012)	(0.0001)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
-	1.347	1.209	1.350	1.382	1.240
-	(0.051)	(0.037)	(0.044)	(0.050)	(0.040)
$a1_{C}$	$a1_{L}$	$a1_{M}$	$a1_{Y}$	$a2_{C}$	$a2_{L}$
0.978	0.922	1.002	0.699	-0.372	-0.131
(0.016)	(0.074)	(0.026)	(0.060)	(0.049)	(0.074)
$a2_{K}$	$a2_{M}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$	$c1_{K}$
0.655	-0.378	-0.169	0.373	0.338	0.824
(0.425)	(0.055)	(0.083)	(0.050)	(0.047)	(0.085)
$c1_{M}$	$c1_{Y}$	$c2_{L}$	$c2_{K}$	$c2_{Y}$	γ_{C}
0.334	0.327	0.046	-0.104	-0.168	-0.121
(0.055)	(0.093)	(0.017)	(0.078)	(0.058)	(0.020)
γ_{L}	γ_{K}	γ_{M}	γ_{Y}		
-0.180	-0.029	-0.111	-0.184		
(0.023)	(0.009)	(0.021)	(0.031)		

	Cost	Labor	Capital	Material	Price
R^2	0.938	0.742	0.803	0.932	0.911
D.W.	1.645	1.786	1.684	1.797	1.944
t.stat.	–6.044	-7.718	-3.144	-5.205	-5.993
Obs.	76	76	76	76	76

(Standard Errors in Parentheses)

Table B10: Estimation Results for the Machinery Industry (29)
in France, Italy, Japan, Germany and Canada

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.272	-0.918	0.449	0.487	-0.043	0.690
(0.083)	(0.267)	(0.144)	(0.084)	(0.245)	(0.066)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.090	0.123	0.109	0.130	0.117
-	(0.027)	(0.026)	(0.025)	(0.028)	(0.026)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	-0.072	-0.007	-0.402	-0.300	-0.211
-	(0.105)	(0.103)	(0.118)	(0.102)	(0.108)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	0.152	0.036	0.051	0.052	0.091
-	(0.034)	(0.030)	(0.029)	(0.028)	(0.023)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
-0.009	-0.012	-0.003	0.002	0.0003	0.0003
(0.002)	(0.003)	(0.002)	(0.003)	(0.007)	(0.008)
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
-	1.479	1. 344	1.439	1.460	1.366
-	(0.191)	(0.098)	(0.184)	(0.209)	(0.099)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
0.973	0.765	0.046	1.181	0.862	-0.261
(0.021)	(0.061)	(0.014)	(0.050)	(0.082)	(0.034)
$a2_M$	$c1_C$	$c1_L$	$c1_K$	$c1_Y$	$c2_K$
-0.359	0.299	0.267	0.609	0.226	-0.150
(0.056)	(0.034)	(0.030)	(0.100)	(0.059)	(0.088)
γc	γ_L	γ_K	γ_M	γ_Y	
-0.078	-0.102	-0.054	-0.095	-0.050	
(0.016)	(0.015)	(0.010)	(0.016)	(0.034)	

	Cost	Labor	Capital	Material	Price
R^2	0.964	0.837	0.821	0.955	0.830
D.W.	2.081	1.919	1.561	2.275	1.980
t.stat.	-4.935	-6.860	-5.314	-5.953	-1.462
Obs.	78	78	78	78	78

(Standard Errors in Parentheses)

Table B11: Estimation Results for the Transport Equipment Industry (34-35) in the US, Italy, Japan, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.152	-0.700	0.252	0.299	-0.162	0.844
(0.064)	(0.403)	(0.403)	(0.081)	(0.323)	(0.118)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.167	0.113	0.127	0.110	0.060	0.058
(0.021)	(0.019)	(0.020)	(0.020)	(0.021)	(0.019)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-0.041	0.323	0.382	0.237	0.006	0.073
(0.103)	(0.095)	(0.104)	(0.097)	(0.093)	(0.099)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-0.010	0.055	0.046	0.025	0.068	0.089
(0.025)	(0.025)	(0.025)	(0.025)	(0.022)	(0.022)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
-0.006	0.002	-0.004	0.0005	-0.013	0.003
(0.001)	(0.003)	(0.002)	(0.001)	(0.007)	(0.001)
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
1.233	1.280	1.254	1.275	1.246	1.239
(0.038)	(0.044)	(0.035)	(0.038)	(0.040)	(0.038)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_L$
0.984	0.683	0.011	1.124	0.800	0.130
(0.017)	(0.084)	(0.026)	(0.032)	(0.064)	(0.050)
$a2_Y$	$c1_L$	$c1_K$	$c1_M$	$c1_Y$	$c2_K$
-0.180	0.053	0.675	-0.016	0.343	-0.258
(0.097)	(0.029)	(0.081)	(0.007)	(0.081)	(0.070)
γ_C	γ_L	γ_K	γ_M	γ_Y	
-0.109	-0.137	-0.053	-0.133	-0.162	
(0.021)	(0.021)	(0.012)	(0.021)	(0.041)	

	Cost	Labor	Capital	Material	Price
R^2	0.957	0.719	0.688	0.956	0.853
D.W.	2.123	1.656	1.779	2.215	2.173
t.stat.	-5.113	-6.258	-4.355	-6.258	-3.928
Obs.	94	94	94	94	94

(Standard Errors of Parentheses)

Table B12: Estimation Results for Manufacturing Industries , nec.,Recycling (36-37)
in Italy, Japan, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.156	-0.123	0.033	0.190	0.039	0.639
(0.068)	(0.311)	(0.129)	(0.065)	(0.227)	(0.084)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.065	-	0.070	0.180	0.114
-	(0.019)	-	(0.018)	(0.018)	(0.019)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	0.304	-	0.127	0.008	0.300
-	(0.059)	-	(0.061)	(0.055)	(0.061)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	0.011	-	-0.030	-0.110	-0.123
-	(0.025)	-	(0.025)	(0.024)	(0.023)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
0.006	0.013	0.018	-0.0007	-0.022	-0.0009
(0.016)	(0.003)	(0.002)	(0.002)	(0.014)	(0.001)
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
-	1.245	-	1.199	1.254	1.167
-	(0.053)	-	(0.043)	(0.063)	(0.038)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
0.959	0.897	0.085	1.015	0.839	-0.135
(0.010)	(0.043)	(0.066)	(0.018)	(0.064)	(0.033)
$a2_K$	$a2_M$	$a2_Y$	$c1_C$	$c1_L$	$c1_M$
0.220	-0.151	-0.325	0.180	0.156	0.163
(0.110)	(0.040)	(0.101)	(0.036)	(0.029)	(0.034)
$c1_Y$	γc	γ_L	γ_K	γ_M	γ_Y
0.356	-0.275	-0.273	-0.097	-0.292	-0.143
(0.104)	(0.029)	(0.026)	(0.020)	(0.026)	(0.062)

	Cost	Labor	Capital	Material	Price
R^2	0.953	0.738	0.707	0.911	0.738
D.W.	1.823	1.718	1.738	1.953	1.718
t.stat.	-9.489	-10.460	-4.743	-11.211	–2.297
Obs.	62	62	62	62	62

(Standard Errors in Parentheses)

Appendix C: Mark-ups and R&D-Intensity

Tables show the results of the OLS-estimation:

$$\mu = c + b_{RDI} RDI + \varepsilon,$$

where μ is the estimated mark-up, and RDI is the average R&D-intensity over the sample period, and ε is an error term

A. Low-Tech Industries (ISIC 15-16, ISIC 17-19, ISIC 20, ISIC 21-22):

Table C1:Relation of Mark-ups
and R&D-Intensity in Low-Tech Industries

c	b_{RDI}	R^2
1.308	-0.205	0.131
(0.034)	(0.133)	

Table C2: Relation of Mark-ups and R&D-Intensity in Low-Tech Industries;
Dummies for Canada, Italy and the Textiles Industry (ISIC17-19)

c	b_{RDI}	d_{17}	R^2
1.325	-0.167	-0.089	0.580
(0.029)	(0.116)	(0.035)	

B.Medium-Tech Industries (ISIC 25, ISIC 26, ISIC 27-28, ISIC 29, ISIC 36):

Table C3: Relation of Mark-ups
and R&D-Intensity in Medium-Tech Industries

c	b_{RDI}	R^2
1.306	0.039	0.017
(0.059)	(0.064)	

Table C4: Relation of Mark-ups and R&D-Intensity in Medium-Tech Industries;
Dummies for Canada, Italy and the Rubber and Plastics Industry (ISIC 26)

c	b_{RDI}	d_{26}	d_c	d_i	R^2
1.091	0.156	0.348	0.102	0.157	0.580
(0.048)	(0.039)	(0.042)	(0.047)	(0.051)	

C.High-Tech Industries (ISIC 24, ISIC 30-33, ISIC 34-35):

Table C5: Relation between the Mark-ups and R&D-Intensity in High-Tech Industries

c	b_{RDI}	R^2
1.248	0.005	0.045
(0.030)	(0.006)	

Table C6: Relation of Mark-ups and R&D-Intensity in High-Tech Industries; Dummies for Canada, Italy

c	b_{RDI}	d_c	d_i	R^2
1.187	0.012	0.057	0.072	0.36
(0.037)	(0.006)	(0.032)	(0.034)	

D. Results with R&D and Spillovers

Table D1a: Estimation Results for the Textiles Industry (17-19) in the US, Italy, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.273	-0.224	0.124	0.228	0.090	0.734
(0.049)	(0.230)	(0.092)	(0.051)	(0.210)	(0.077)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.146	0.103	-	0.060	0.238	0.124
(0.018)	(0.018)	-	(0.017)	(0.022)	(0.016)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.044	0.204	-	0.181	0.143	0.115
(0.111)	(0.102)	-	(0.117)	(0.117)	(0.103)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-0.007	-0.003	-	0.070	0.108	0.016
(0.025)	(0.027)	-	(0.022)	(0.036)	(0.023)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.215	1.152	-	1.254	1.267	1.228
(0.037)	(0.041)	-	(0.042)	(0.042)	(0.035)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
0.944	0.918	0.168	0.982	0.885	-0.245
(0.010)	(0.036)	(0.081)	(0.023)	(0.045)	(0.048)
$a2_L$	$a2_K$	$a2_M$	$c1_C$	$c1_L$	$c1_K$
-0.137	0.131	-0.248	0.291	0.221	0.652
(0.057)	(0.077)	(0.047)	(0.048)	(0.047)	(0.065)
$c1_M$	$c1_Y$	γ_C	γ_L	γ_K	γ_M
-0.247	0.262	-0.071	-0.135	-0.030	-0.105
(0.047)	(0.032)	(0.016)	(0.013)	(0.009)	(0.015)
γ_C	b_{YY}	b_{RY}	b_{sfs}		
-0.071	-0.014	-2.324	-1.295		
(0.016)	(0.008)	(0.765)	(0.290)		

	Cost	Labor	Capital	Material	Price
R^2	0.976	0.683	0.829	0.945	0.935
D.W.	2.089	1.732	1.746	2.049	2.348
t.-stat	-4.540	-10.243	-3.411	-7.192	-2.830
Obs.	82	82	82	82	82

(Standard Errors in Parentheses)

Table D2a: Estimation Results for the Chemical Industry (24) in the US, Italy, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.102	-0.618	0.184	0.145	-0.109	0.873
(0.044)	(0.208)	(0.088)	(0.055)	(0.217)	(0.068)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.158	0.149	-	0.169	0.150	-
(0.022)	(0.022)	-	(0.022)	(0.023)	-
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.179	0.260	-	0.181	0.338	-
(0.113)	(0.115)	-	(0.117)	(0.118)	-
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-0.123	-0.015	-	-0.022	0.008	-
(0.024)	(0.022)	-	(0.021)	(0.038)	-
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
0.0001	-0.00004	0.005	-0.001	-0.0004	-0.0002
(0.001)	(0.004)	(0.002)	(0.002)	(0.016)	(0.0001)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.159	1.195	-	1.269	1.150	-
(0.036)	(0.035)	-	(0.035)	(0.037)	-
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{L}$
0.978	0.566	0.003	1.074	1.152	0.176
(0.011)	(0.110)	(0.074)	(0.022)	(0.060)	(0.107)
$a2_{M}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$	$c1_{K}$	$c1_{M}$
-0.465	-0.219	0.468	0.362	0.578	0.421
(0.054)	(0.119)	(0.050)	(0.050)	(0.088)	(0.047)
$c1_{Y}$	$c2_{L}$	$c2_{K}$	γ_{C}	γ_{L}	γ_{K}
0.222	-0.113	-0.090	-0.173	-0.139	-0.203
(0.100)	(0.034)	(0.078)	(0.029)	(0.028)	(0.041)
γ_{M}	γ_{Y}	b_{sfs}			
-0.178	-0.433	-0.033			
(0.028)	(0.080)	(0.011)			

	Cost	Labor	Capital	Material	Price
R^2	0.935	0.400	0.661	0.887	0.866
D.W.	2.506	1.585	1.703	2.509	1.880
t.stat.	-5.885	-4.934	-4.952	-6.478	-5.422
Obs.	60	60	60	60	60

(Standard Errors in Parenthesis)

Table D3a: Estimation Results for the Rubber and Plastic Industry (25) in the US, Italy, Germany and Canada; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.200	-0.900	0.397	0.402	-0.438	0.638
(0.077)	(0.365)	(0.156)	(0.080)	(0.293)	(0.092)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.099	0.030	-	0.077	0.132	-
(0.017)	(0.017)	-	(0.017)	(0.028)	-
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.097	0.305	-	0.240	0.212	-
(0.071)	(0.071)	-	(0.072)	(0.077)	-
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.113	0.112	-	0.054	0.157	-
(0.025)	(0.025)	-	(0.026)	(0.061)	-
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
0.0005	0.006	0.013	-0.0006	0.001	-0.0004
(0.002)	(0.005)	(0.003)	(0.003)	(0.010)	(0.0001)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.092	1.158	-	1.177	1.185	-
(0.105)	(0.087)	-	(0.081)	(0.081)	-
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{C}$
1.001	0.790	-0.020	1.180	1.047	-0.170
(0.014)	(0.064)	(0.053)	(0.034)	(0.059)	(0.049)
$a2_{M}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$	$c1_{K}$	$c1_{M}$
-0.280	0.252	0.177	0.176	0.500	0.180
(0.065)	(0.052)	(0.048)	(0.040)	(0.068)	(0.034)
γ_{C}	γ_{L}	γ_{K}	γ_{M}	γ_{Y}	b_{sfs}
-0.289	-0.356	-0.165	-0.240	-0.101	-0.132
(0.036)	(0.046)	(0.031)	(0.033)	(0.027)	(0.066)

	Cost	Labor	Capital	Material	Price
R^2	0.956	0.729	0.698	0.890	0.902
D.W.	2.228	1.880	1.713	2.168	1.881
t.stat.	-6.649	-7.694	-5.370	-7.305	-3.675
Obs.	64	64	64	64	64

(Standard Errors in Parentheses)

Table D4a: Estimation Results for the Other Non-Metallic Mineral Products Industry (26) in the US, Italy, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.254	-1.114	0.444	0.435	-0.462	0.645
(0.098)	(0.304)	(0.159)	(0.088)	(0.308)	(0.081)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.184	0.082	-	0.094	0.094	0.124
(0.024)	(0.021)	-	(0.022)	(0.019)	(0.021)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.173	0.269	-	0.332	0.042	0.123
(0.119)	(0.109)	-	(0.113)	(0.118)	(0.111)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.166	0.155	-	0.162	0.063	0.137
(0.054)	(0.038)	-	(0.040)	(0.032)	(0.034)
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
-0.006	-0.002	0.0007	0.0007	0.019	$2*10^{-5}$
(0.001)	(0.003)	(0.001)	(0.001)	(0.009)	$(8*10^{-5})$
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.655	1.623	-	1.616	1.547	1.596
(0.099)	(0.084)	-	(0.088)	(0.077)	(0.085)
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{L}$
1.058	0.802	0.062	1.388	0.859	0.121
(0.043)	(0.064)	(0.037)	(0.107)	(0.087)	(0.026)
$c1_{C}$	$c1_{K}$	$c1_{Y}$	$c2_{K}$	$c2_{Y}$	γ_{C}
0.048	0.572	0.431	-0.070	-0.431	-0.053
(0.008)	(0.073)	(0.065)	(0.076)	(0.065)	(0.021)
γ_{L}	γ_{K}	γ_{M}	γ_{Y}	b_{RY}	b_{sd}
-0.180	-0.131	-0.069	-0.230	-0.376	-0.947
(0.023)	(0.023)	(0.022)	(0.048)	(0.226)	(0.419)

	Cost	Labor	Capital	Material	Price
R^2	0.907	0.784	0.745	0.879	0.877
D.W.	2.433	2.152	1.780	2.477	2.162
t.stat.	-2.460	-7.532	-5.663	-3.108	-4.820
Obs.	77	77	77	77	77

(Standard Errors in Parentheses)

Table D5a: Estimation Results: Basic and Fabricated Metals (27-28) in the US, Italy, Japan, Germany, Canada and France; 1980-1998

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.069	-0.285	0.107	0.219	0.430	0.671
(0.062)	(0.323)	(0.133)	(0.081)	(0.331)	(0.094)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
0.166	0.156	0.133	0.183	0.274	0.206
(0.025)	(0.025)	(0.025)	(0.024)	(0.044)	(0.027)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
0.004	0.102	0.585	0.131	0.206	0.049
(0.159)	(0.162)	(0.169)	(0.164)	(0.196)	(0.167)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
0.052	0.131	0.130	0.092	0.418	0.103
(0.026)	(0.028)	(0.027)	(0.026)	(0.093)	(0.031)
b_{LT}	b_{KT}	b_{MT}	b_{T}	b_{YY}	b_{TT}
-0.003	-0.004	0.002	-0.002	0.013	$3*10^{-5}$
(0.001)	(0.003)	(0.001)	(0.001)	(0.008)	($7*10^{-5}$)
μ_{US}	μ_{I}	μ_{JP}	μ_{D}	μ_{C}	μ_{F}
1.193	1.182	1.247	1..250	1.164	1.185
(0.037)	(0.039)	(0.041)	(0.040)	(0.038)	(0.037)
$a1_{C}$	$a1_{L}$	$a1_{K}$	$a1_{M}$	$a1_{Y}$	$a2_{C}$
0.976	0.776	-0.0007	1.168	1.158	-0.175
(0.016)	(0.096)	(0.024)	(0.048)	(0.054)	(0.046)
$a2_{L}$	$a2_{K}$	$a2_{M}$	$a2_{Y}$	$c1_{C}$	$c1_{L}$
0.259	0.047	-0.317	-0.304	0.187	0.169
(0.079)	(0.028)	(0.057)	(0.105)	(0.046)	(0.042)
$c1_{K}$	$c1_{M}$	$c1_{Y}$	$c2_{K}$	$c2_{Y}$	γc
0.766	0.192	0.329	-0.275	-0.048	-0.083
(0.075)	(0.044)	(0.085)	(0.071)	(0.028)	(0.019)
γ_{L}	γ_{K}	γ_{M}	γ_{Y}	b_{RY}	b_{sfs}
-0.150	-0.050	-0.100	-0.397	-0.423	-1.212
(0.023)	(0.011)	(0.021)	(0.071)	(0.230)	(0.333)

	Cost	Labor	Capital	Material	Price
R^2	0.973	0.765	0.807	0.942	0.955
D.W.	2.174	1.647	1.426	2.433	1.894
t.stat.	-4.364	-6.635	-4.573	-4.814	-5.628
Obs.	92	92	92	92	92

(Standard Errors in Parentheses)

Table D7a: Estimation Results for the Machinery Industry (29) in France, Italy, Japan, Germany and Canada

s_{LL}	s_{KK}	s_{LK}	b_{LL}	b_{KK}	b_{MM}
-0.272	-0.823	0.428	0.476	0.093	0.634
(0.081)	(0.248)	(0.137)	(0.079)	(0.216)	(0.060)
b_{LUS}	b_{LI}	b_{LJP}	b_{LD}	b_{LC}	b_{LF}
-	0.047	0.129	0.129	0.184	0.127
-	(0.024)	(0.022)	(0.023)	(0.042)	(0.024)
b_{KUS}	b_{KI}	b_{KJP}	b_{KD}	b_{KC}	b_{KF}
-	-0.143	-0.007	-0.430	-0.283	-0.246
-	(0.091)	(0.100)	(0.103)	(0.101)	(0.099)
b_{MUS}	b_{MI}	b_{MJP}	b_{MD}	b_{MC}	b_{MF}
-	0.098	0.087	0.128	0.180	0.148
-	(0.034)	(0.027)	(0.028)	(0.066)	(0.022)
b_{LT}	b_{KT}	b_{MT}	b_T	b_{YY}	b_{TT}
-0.004	-0.008	-0.004	0.003	-0.0004	0.0002
(0.002)	(0.003)	(0.002)	(0.002)	(0.007)	$(1*10^{-6})$
μ_{US}	μ_I	μ_{JP}	μ_D	μ_C	μ_F
-	1.117	1.431	1.549	1.248	1.368
-	(0.112)	(0.080)	(0.121)	(0.093)	(0.077)
$a1_C$	$a1_L$	$a1_K$	$a1_M$	$a1_Y$	$a2_C$
0.997	0.798	0.037	1.236	1.004	-0.200
(0.021)	(0.063)	(0.013)	(0.053)	(0.083)	(0.048)
$a2_M$	$c1_C$	$c1_L$	$c1_K$	$c1_Y$	$c2_K$
-0.266	0.230	0.215	0.648	0.157	-0.174
(0.065)	(0.047)	(0.044)	(0.102)	(0.094)	(0.096)
γc	γ_L	γ_K	γ_M	γ_Y	b_{RY}
-0.085	-0.116	-0.045	-0.098	-0.074	-1.012
(0.017)	(0.017)	(0.010)	(0.019)	(0.042)	(0.187)
b_{sfs}					
-0.079					
(0.038)					

	Cost	Labor	Capital	Material	Price
R^2	0.959	0.812	0.827	0.957	0.826
D.W.	1.831	1.686	1.658	2.266	1.907
t.stat.	-5.154	-6.954	-4.429	-5.259	-1.769
Obs.	78	78	78	78	78

(Standard Errors in Parentheses)