Measuring the Social Rate of Return to R&D in Coal, Petroleum and Nuclear Manufacturing: A Study of the OECD Countries[*]

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Abstract

This paper estimates the social rate of return to research and development (R&D) in the energy manufacturing industry. Our model tries to quantify the positive contribution that lagged R&D has on total factor productivity (TFP) growth in the manufacturing of coal, petroleum products and nuclear fuel for a number of OECD countries. Using a panel of data from the OECD STAN database we are able to obtain results suggesting that R&D has a positive and significant rate of return that varies for each country.

Keywords: social rate of return to R&D, energy, R&D

JEL codes: O30, L71, O13

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Introduction

Owing to mounting geopolitical, environmental and economic concerns, investment in research and development (R&D) in the energy sector has become increasingly crucial for sustainability, security and environmental protection. A 1997 report from the President's Committee of Advisors on Science and Technology and a 2004 report from the bipartisan National Commission on Energy Policy each recommended that federal R&D spending be doubled. Several groups have called for even larger commitments, on the scale of the Manhattan Project of the 1940s (Kammen & Nemet, 2005). In his remarks to the U.S. Senate Committee on Agriculture, Nutrition and Forestry, Professor Lee Lynd of Dartmouth College recommended a several-fold increase in the amount of funding for biomass energy R&D, with clearly demarcated support for both pre-commercial research devoted to innovation and applied fundamentals as well as cost sharing for first-of-a-kind pioneer plants (2004).

Since the mid-1990s, however, both public and private sector investment in R&D in the United States has stagnated for renewable energy and energy efficiency, and has declined for fossil fuel and nuclear technology. The 2005 federal budget reduced energy R&D by 11 percent from 2004; the American Association for the Advancement of Science projects that federal energy R&D will decline 5.6 percent by 2011. In addition, investment in energy R&D by U.S. companies fell by 50 percent between 1991 and 2003 (Kammen & Nemet, 2005). Moreover, funding after earmarks for bioenergy R&D by the Department of Energy has declined yearly for the last several years (Lynd, 2004). These declines are neither new nor unique to the United States: between 1980 and 1995, international R&D fell 39 percent for energy and 56 percent for renewable energy (Margolis & Kammen, 1999).

According to economic theory, there are several reasons why the private rate of R&D may diverge from the socially optimal rate of R&D. First, firms may under-invest in R&D because there are positive spillovers involved: when a firm makes a discovery, other firms can free ride on the invention and may even imitate the invention without having paid for the R&D efforts. Even with patent protection, these spillovers reduce the payoff to investing in R&D. A second reason why the private rate of R&D is lower than the optimal rate is the appropriability effect: in the absence of perfect price discrimination, the private surplus from innovation is lower than the social surplus (Tirole, 2001). A countervailing effect that leads firms to over-invest in R&D is the business-stealing effect: a firm that introduces a new product does not internalize the loss of profit suffered by its rivals on the product market (Tirole, 2001).

The need to mitigate climate change as well as the impact of high energy prices on growth are two good reasons to draw attention to energy technology R&D in a context of economy-wide fossil fuel dependence. As noted above, market imperfections[4] in the industry of ideas tend to promote over- and underinvestment in R&D; yet, measuring the size of the distortions to R&D investment is not an easy task. Jones and Williams (1998) try to measure the overall effect of these distortions using an endogenous growth model. The authors conclude that optimal R&D investment in the US is at least two times larger than the actual investment. Furthermore, Margolis and Kammen (1999, 2001) look at the energy sector in the US and conclude that there has been a sustained pattern of underinvestment.

[4] See for example Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1991).

Determining the optimal resource allocation to R&D depends crucially on estimating the rate of return to R&D investments. This rate of return measures how much productivity increases as a result of investing resources in R&D. In principle, we would want to estimate the social rate of return as opposed to the private rate of return since the former is a more general measure that accounts for R&D spillovers. Furthermore, findings in the empirical productivity literature (Griliches, 1992) emphasize that social rates of return remain significantly above private rates.

A considerable number of empirical studies have tried to estimate the social rate of return accounting for different types of spillovers. Earlier studies estimate the social rate of return from intra-industry spillovers; see for example Sveilkauskas (1981), Griliches and Lichtenberg (1984b), and Griliches (1994). These studies regress total factor productivity (TFP) growth on lagged R&D intensity, where R&D intensity is measured as the ratio of privately financed R&D spending to sales.

Other studies have tried to incorporate inter-industry spillovers in the measure of the social rate (see e.g., Terleckyj, 1980; Scherer, 1982; Griliches & Lichtenberg, 1984a; and Jaffe, 1996). These authors try to capture the effect of R&D in one industry on measured productivity in other industries; the imputations are based on a technology flow matrix constructed from patent data or input-output flows between industries. Jaffe (1986) incorporates R&D from other industries into the R&D stock used to estimate productivity gains.

Another approach attempts to incorporate international spillovers into the measurement of the social rate of return. These models try to capture the effect that foreign R&D has in domestic productivity through trade (see e.g., Coe & Helpman, 1995;

and Nadiri & Kim, 1996). Several authors have followed the same approach but have also corrected for human capital effects and depreciation of the R&D stock (see e.g., Engelbrecht, 1997; Griffith et al., 2000; and Keller, 2002, 2004).

This paper provides estimates of the social rate of return to R&D in the energy manufacturing industry for a number of OECD countries. We use industry level productivity and R&D intensity measures to capture the inter-firm technology spillovers in the manufacturing of coal, petroleum products and nuclear fuel. We adopt a narrow definition of the social rate of return by considering only the intra-industry spillover effects within a country.

Our estimates are based on a paradigm that makes several assumptions and therefore has intrinsic limitations. Because we focus on contemporaneous within-country intra-industry R&D spillovers, we do not account for R&D spillovers between industries, intertemporal spillovers, or spillovers between countries. Another limitation is that our measure of productivity does not adjust for human capital or factor utilization differences across countries, and thus our results are not exempt from measurement error. Because these assumptions and limitations may bias our estimates downwards, our results yield a lower bound estimate of the social rate of return.

The paper is organized as follows. Section 1 outlines our theoretical framework for estimating the social rate of return. Section 2 presents a description of the data used in our study. Section 3 outlines our empirical estimation strategy. Section 4 contains an overview of the estimation results. Finally, section 5 concludes and discusses possible future ideas for expanding this research.

1 Theoretical Framework

In this paper we use a paradigm similar to the one in Jones and Williams (1998). We adopt a Cobb-Douglas production function of the form:

$$Y_t = e^{\mu t} Z_{t-1}{}^{\gamma} K_t{}^{\alpha} L_t^{1-\alpha} \tag{1}$$

$$\dot{Z}_t = R_t \tag{2}$$

where Y is output produced, Z is the R&D stock, K is capital, L is labor and R is expenditures in R&D. As we can see from equation (2), we assume no depreciation of the R&D stock.

Using some growth accounting we can derive the relationship between TFP growth and R&D:

$$TFP_t = \frac{Y_t}{K_t{}^{\alpha} L_t^{1-\alpha}} \tag{3}$$

After some manipulation we get the following equation:

$$\Delta \ln(TFP_t) = \mu + \tilde{r} \frac{R_{t-1}}{Y_{t-1}} + \varepsilon_t \tag{4}$$

where $\tilde{r} = \frac{dY}{dZ}$ is the rate of return to R&D. As we can see from our empirical specification in equation (4), TFP growth is regressed on the lagged R&D share of output. The estimated coefficient $\tilde{r}$ in (4) corresponds to our desired measure of the rate of return to R&D. As Jones and Williams (1998) point out, $\tilde{r}$ can represent the private rate of return if we are measuring at the firm level or the social rate of return if we are measuring at the industry level.

Several remarks should be made before proceeding to the actual analysis of the data. First, we are not contemplating the possibility of R&D spillovers between industries, i.e., we are not using a technology flow matrix to impute the effect of R&D in one industry on measured productivity in other industries. Second, we are not capturing intertemporal knowledge spillovers or congestion effects. Finally, we are working under the assumption of a "closed economy", which means that we don't account for technological diffusion through trade. These assumptions will give us, in principle, a lower bound estimate of the social rate of return.

2 Empirical Setting

This section provides an overview of the data used in our study. Data sources and methodological issues are discussed in detail.

2.1 Description of Country and Industry Characteristics in terms of GDP and R&D

We use data on the manufacturing industry of coke, petroleum products and nuclear fuel[5] in 13 OECD countries for the years 1987-2002. The countries are Belgium, Canada, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Spain, Sweden, United Kingdom, and United States. The data on input, output and prices comes from the Structural Analysis (STAN) database (OECD, 2005). The source for R&D expenditure[6] data is the Annual National Business Expenditures on Research and Development

[5] This industry corresponds to ISIC (Review 3) number 23.
[6] We use data on total business enterprises R&D irrespective of source of funding.

(ANBERD) database (OECD, 2006). Our sample of countries accounts for at least 75 percent of OECD value added in this specific industry. Moreover, R&D expenditures by these countries constitute at least 85 percent of the OECD's innovative activity and almost all business R&D in the energy manufacturing sector between 1987 and 2002.

Table 1 shows value added and R&D expenditures averaged over the period from 1987 to 2002 for the countries used on this study. We can see that both value added and R&D expenditures in the energy manufacturing industry vary substantially across countries.[7] The G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) conduct on average 88 percent of R&D in the sample and their share of total value added is 89 percent. Also, note that cross-country variation is higher for R&D than for GDP.

According to Table 1, Germany invests approximately six times less in R&D than the UK in the energy manufacturing industry. This appears to be a large difference, and suggest that the statistics on R&D expenditures may have some caveats.[8] First, these statistics measure private R&D expenditures, and firms do not always disclose all their numbers due to strategic reasons. Second, the use of PPP adjustment factors for energy manufacturing R&D data is problematic given the fact that these adjustment factors are based on economy-wide rather than industry-specific comparisons. Third, countries differ in their accounting principles and hence the attribution of R&D expenditures to an

[7] We are using Purchasing Power Parity exchange rates to compare across countries as in Bernard and Jones (1996). The industry value added data for Japan and Korea do not seem to be plausible. Recall that PPPs are based on a comparison of consumer goods' prices and are heavily weighted towards services. They are neither industry specific nor do they reflect relative producer prices. Conversions of industry-level indicators to a common currency based on PPPs should therefore be interpreted with caution.

[8] However, Germany does spend significantly more than UK on R&D if we look at total manufacturing, an aggregate that includes every manufacturing industry. According to the STAN data, average real R&D expenditure for the entire manufacturing industry for the years 1987-2002 was 34,477.32 million USD (PPP) in Germany and 14,337.97 million USD (PPP) in the UK.

industry may vary across countries. This can be the case in industries that are closely related through vertical integration.

TABLE 1 - DESCRIPTIVE STATISTICS (Energy Manufacturing)

Country	Size in Terms of R&D*	Relative Size (Percent)	Size in Terms of GDP**	Relative Size (Percent)	Share of Value Added*** (Percent)
Belgium	34.39	1.07%	603.36	1.13%	2.37%
Canada	84.21	2.61%	2069.79	3.86%	1.41%
Finland	19.12	0.59%	322.12	0.60%	1.54%
France	253.21	7.85%	9149.86	17.08%	2.83%
Germany	71.57	2.22%	3194.66	5.96%	0.84%
Italy	50.28	1.56%	3493.31	6.52%	1.81%
Japan	372.23	11.55%	31.81	0.06%	4.90%
Korea	165.61	5.14%	5.69	0.01%	4.17%
Netherlands	51.09	1.58%	2197.69	4.10%	2.34%
Spain	35.74	1.11%	4254.79	7.94%	2.93%
Sweden	9.92	0.31%	329.94	0.62%	0.98%
United Kingdom	428.15	13.28%	4392.80	8.20%	2.05%
United States	1766.13	54.78%	25783.74	48.12%	2.13%
G-7****	2837.60	88.01%	48115.96	89.80%	-
Total	3224.09	100.00%	53578.44	100.00%	-

* Average R&D expenditures over the period 1987-2002, measured in million 2000 $ U.S. PPP.
** Average value added over the period 1987-2002, measured in million 2000 $ U.S. PPP.
*** Average share of value added relative to total manufacturing over the period 1987-2002.
**** G-7 is composed of Canada, France, Germany, Italy, Japan, United Kingdom and United States.

2.2 Total Factor Productivity Data

We calculate the growth rate of TFP in the energy manufacturing industry using Tornqvist indexes, a superlative-index-number approach suggested by Caves, Christensen, and Diewert (1982):

$$\Delta \ln(TFP_{it}) = \Delta \ln(Y_{it}) - \alpha_{it} \Delta \ln(L_{it}) - (1-\alpha_{it}) \Delta \ln(K_{it}) \quad (5)$$

where $\alpha_{it} = 1/2\left(\alpha_{it} + \alpha_{it-1}\right)$ and α_{it} is the labor share of the value added in the energy manufacturing sector of country *i* at time *t*. Implicit in this calculation are assumptions of perfect competition and constant returns to scale.

All data used for the construction of the TFP growth rate comes from STAN database[9] (OECD, 2005), unless otherwise noted. Most of the data has been converted from current prices into constant 1995 prices using country and industry-specific deflators that are derived from the STAN database. Output (Y_{it}) is measured as industry gross value added. Changes in labor input (L_{it}) are measured through changes in labor compensation of employees. Measures of the physical capital stock (K_{it}) were available for a number of countries. For the rest of the countries[10] we constructed the capital stock from the industry investment flows using a perpetual inventory method and assuming a 10 percent rate of depreciation. The labor share of value added (α_{it}) is constructed as the ratio of compensation of employees to gross value added.[11]

Given the fact that we are using different base years in the construction of our price deflators and our physical capital stocks as well as the fact that different accounting standards are used by each national statistical office, we should be cautious with direct comparability of variables between countries. A similar issue was raised in other papers such as the one by Nadiri and Kim (1996). However, since we are interested in measuring

[9] Note: some of countries did not have a complete time series of the variables. Spain and Sweden did not have data available before 1995. Observations for Germany and West Germany were merged into one series through a rescaling factor.

[10] Capital stock was estimated using the perpetual inventory method (PIM) for Austria, Germany, Netherlands, and the United States. The capital stock for Korea comes from Pyo (1998), and the capital stock for Japan comes from Fukao et al. (2003).

[11] Note that labor costs can exceed value added in certain cases. For example, when heavy losses are incurred within a sector or, more generally, when a sector receives significant subsidies.

country-specific social rates of return, our empirical strategy will enable us to obtain estimates that are comparable across countries.

3 Empirical Model and Estimation Issues

Our first model specification has a regression equation of the form:

$$\Delta \ln(TFP_{it}) = \mu_i + \tilde{r}_i \left(Country_i * (RDint)_{it-1} \right) + \beta Period_t + \varepsilon_{it} \quad (6)$$

where $Country_i$ is a dummy variable created for each of the countries *i* in our sample; $(RDint)_{it-1}$ is R&D intensity (lagged one year), defined as the ratio of R&D expenditures to value added in each country; $Period_t$ is an indicator variable that equals 1 for time period one (1987 to 1995) and 0 for time period two (1996 to 2002). The μ_i are the country fixed effects. The parameters to be estimated are μ_i, $\tilde{r}_i$ and β; and ε_{it} is the error term which is assumed to be heteroskedastic (by country) and serially uncorrelated.

The parameter β which estimates period fixed effects captures any trend in TFP growth (see equations (1) and (4)) and divides the possible trends in TFP growth according to the specified time periods. The parameter $\tilde{r}_i$ is of central interest in this paper as it represents country-specific social rate of return to R&D in the energy manufacturing industry for each of our countries.

The parameter μ_i represents country fixed effects. We use a fixed effects rather than random effects panel estimation model since we believe that time-invariant country-level unobservables are potentially correlated with some of the regressors. The possibility of correlation between time-invariant country-level unobservables and the regressors has also been suggested by Jones and Williams (1998).

We also present an alternative model specification of the following form:

$$\Delta \ln(TFP_{it}) = \mu_i + \tilde{r}_i \left(Country_i * (RDint)_{it-1}\right) + \sum_t \beta_t Year_t + \varepsilon_{it} \qquad (7)$$

This specification includes year fixed effects as opposed to period fixed effects. The parameter β_t captures year fixed effects.

Before proceeding to the estimation results, several estimation issues should be addressed. First, measuring the social rate of return through intra-industry spillovers can be problematic due to measurement error at the firm level; yet aggregation to the industry level helps mitigate these measurement problems. Another concern is that the error term ε_{it} may not be orthogonal to the regressors, which would lead to inconsistent estimates. The disturbances capture idiosyncratic factors that affect measured productivity. Some could be country specific, such as receiving strong inter-industry spillovers, and others might be common to all countries such as shocks affecting OECD countries. We include country fixed effects to address this issue of correlation between the regressors and the error term.

4 Estimation Results

The dependent variable is growth in total factor productivity as defined in equation (5). The regressors are defined in model (6), our benchmark case, and model (7), which is used for sensitivity analysis. The estimation procedure is ordinary least squares (OLS) under two different error variance estimation methods. We acknowledge the possibility of heteroskedastic errors and use White's robust error variance estimation procedure as well as a cluster (by country) robust procedure to sharpen the precision of our estimates. After comparing both specifications (see appendix), it can be seen that cluster robust specification yields the most precise estimates. We will use this model specification of the errors when reporting our estimates of the social rate of return.

4.1 Benchmark Results

Our benchmark estimates of the social rate of return to research and development by country, which are based on equation (6) with period fixed effects, are presented in Table 2 together with a 95 percent confidence interval of the estimates. The appendix presents the coefficient estimates with their standard errors in parentheses. The rates of return estimates for each of our countries except Japan are all positive and significant at a 1 percent level, which is consistent with our original hypothesis about the existence of intra-industry spillovers and a positive social rate of return. Interesting lessons arise after careful examination of our regression results.

United States and United Kingdom, the two leaders in terms of R&D spending and size of the energy sector, have low rates of return 5.4 and 3.2 percent respectively. We suggest two possible reasons for this fact. First, these countries are the leaders in the sense that they are closer to the technological frontier; hence we should expect a lower return given that these countries may be experiencing diminishing returns to R&D. Second, these countries may also generate significant international spillovers through trade-related technological diffusion which is not captured in their own estimation of social rate of return at the country level; as we argued before, this type of spillovers are not measured in our exercise.

France has a rate of return of 5.8 percent. Being the third largest country in terms of industry size and the fourth largest R&D spending country, an argument similar to the United States may apply in this case. Belgium and Canada have also low rates of return, 3.8 and 2.9 percent respectively.

Italy and Germany have the highest rates of return of the sample studied, 26 and 18 percent respectively. While these countries are comparatively in the low and mid ranges of R&D expenditures and industry size, it is possible that they are benefiting from international spillovers from countries such as United States or the United Kingdom.

Korea has a rate of return of 8.7 percent. This country is the fifth country in R&D expenditures and has the smallest size of the industry in the sample. The Nordic countries which have relatively small industry size present rates of return of 7.9 percent (Sweden) and 10 percent (Finland).

TABLE 2 – SOCIAL RATE OF RETURN ESIMATES BY COUNTRY:

BENCHMARK RESULTS

Country	Social Rate Of Return (percent)*	Confidence Interval (Percent)**	
		Lower Bound	Upper Bound
Belgium	3.8	2.4	5.1
Canada	2.9	2.1	3.7
Finland	10.1	8.9	11.3
France	5.8	2.2	9.5
Germany	18.4	12.5	24.2
Italy	26.1	20.8	31.4
Japan***	7.9	-0.7	23.6
Korea	8.7	6.4	11
Netherlands	5	2.4	7.5
Spain	7.2	-0.6	26.1
Sweden	7.9	6.8	9.1
United Kingdom	3.4	0.7	6.1
United States	5.4	2.6	8.2

* Regression estimates based on equation (6) (specification (3) in Table A.1 in the appendix), cluster robust standard errors.
** 95% confidence interval from specification (3) in Table A.1 in the appendix.
*** Japan's estimate is not significant at 5 % level.

4.2 Sensitivity analysis

Our sensitivity analysis estimates of the social rate of return to research and development by country, which are based on equation (7) with year fixed effects, are presented in Table 3 together with a 95 percent confidence interval of the estimates. The appendix presents the coefficient estimates with their standard errors in parentheses. The rates of return estimates for each of the countries that are significant at a 5 percent level are positive, which is consistent with our original hypothesis. Estimated rates of return are higher than the benchmark case, except for Germany which is lower. The confidence interval for the estimates has a higher range. In general, sensitivity results are consistent with benchmark results.

TABLE 3 – SOCIAL RATE OF RETURN ESTIMATES BY COUNTRY: SENSITIVITY ANALYSIS

Country	Social Rate Of Return (percent)*	Confidence Interval (Percent)**	
		Lower Bound	Upper Bound
Belgium***	-3.05	-9.3	3.2
Canada	3.6	1.1	6.1
Finland	10.6	6.0	15.3
France***	7.5	-1.5	16.7
Germany	15.3	2.0	28.6
Italy	25.3	18.1	32.4
Japan***	21.2	-8.8	51.3
Korea***	5.4	-0.3	11.2
Netherlands	5.7	0.9	10.5
Spain***	-11.8	-58.1	34.3
Sweden***	0.1	-8.5	8.7
United Kingdom	6.6	0.9	12.4
United States	6.7	2.6	10.8

* Regression estimates based on equation (7) (specification (4) in Table A.1 in the appendix), cluster robust standard errors.
** 95% confidence interval from specification (4) in Table A.1 in the appendix.
*** Denotes country estimate that is not significant at 5 % level.

5 Conclusion

We have estimated the social rate of return to research and development in the energy manufacturing industry by analyzing the productivity effects of intra-industry spillovers from R&D expenditures in 13 OECD countries. The evidence suggests that these spillovers are present and are quite significant. The estimated magnitude of the rates of return varies across significantly across countries. We see that United States and United Kingdom have small rates of return even though they are the technological leaders. At the same time, our results suggest that the rates of return tend to be similar for countries that are closely related. In our sample, Japan and Korea, Italy and Germany, Sweden and Finland, Belgium and Netherlands, are examples of this. In fact, Keller (2002) suggests that geographic factors often lead to clusters of countries that have access to a common pool of knowledge. Finally, the results from our second model specification suggest that the social rates of return not only vary across countries but also across time periods.

It should also be emphasized that these results are not exempt from measurement error since our productivity index does not adjust for human capital or factor utilization differences across countries. Bearing these limitations in mind, we should also point out that the objective of this paper was to estimate a lower bound for the social rate of return by using the narrowest definition of spillover effects. To the extent that product innovations are created and used in the same industry, intra-industry spillovers would be a good proxy for the social rate of return. However, the energy sector does affect productivity in many other sectors of the economy; hence the presence of inter-industry spillovers is very plausible in the industry studied. Further, the temporal dimension of spillovers might matter as well; in our analysis we focused on contemporaneous effects of technology. Finally, international spillovers are very likely to happen among OECD countries; technological diffusion from the United States is very likely to affect productivity in the rest of the OECD countries industry through international trade.

Our results have several implications for policy. As we find that the social rate of return to R&D in energy manufacturing is significant and positive in most OECD countries, and therefore that there are intra-industry spillovers to R&D in energy manufacturing, our results point to the need for national and international funding and incentives for R&D in energy manufacturing. If international spillovers are negligible, then, according to our results, which do not account for international spillovers, countries like Italy and Germany where the social rate of return to R&D is high would particularly benefit from policies that lead to greater energy manufacturing R&D. However, if international spillovers in R&D do exist, then policymakers should still consider funding and incentivizing R&D in countries whose intra-industry spillovers may be lower, but international spillovers may be higher. In designing policy one should also keep in mind that our estimates are lower bound estimates, and therefore that the need for national and international funding and incentives for R&D in energy may be greater still.

Future research on this subject should improve the productivity measurements and augment the number of energy related industries to be studied.

APPENDIX: REGRESSION OUTPUTS

TABLE A.1 SOCIAL RATE OF RETURN ESTIMATES BY COUNTRY

Dependent Variable is Total Factor Productivity Growth

	(1)	(2)	(3)	(4)
Belgium	0.038	-0.031	0.038**	-0.031
	(0.093)	(0.097)	(0.006)	(0.029)
Canada	0.029	0.036*	0.029**	0.036**
	(0.016)	(0.017)	(0.004)	(0.011)
Finland	0.102**	0.107**	0.102**	0.107**
	(0.024)	(0.022)	(0.005)	(0.021)
France	0.059	0.076	0.059**	0.076
	(0.035)	(0.040)	(0.017)	(0.042)
Germany	0.184	0.153	0.184**	0.153*
	(0.163)	(0.129)	(0.027)	(0.061)
Italy	0.261	0.253	0.261**	0.253**
	(0.151)	(0.133)	(0.024)	(0.033)
Japan	0.079	0.213	0.079	0.213
	(0.255)	(0.300)	(0.072)	(0.138)
Korea	0.087**	0.054*	0.087**	0.054
	(0.027)	(0.027)	(0.011)	(0.027)
Netherlands	0.050	0.058	0.050**	0.058*
	(0.032)	(0.039)	(0.012)	(0.022)
Spain	0.072	-0.119	0.072**	-0.119
	(0.098)	(0.268)	(0.000)	(0.212)
Sweden	0.080**	0.001	0.080**	0.001
	(0.020)	(0.043)	(0.005)	(0.040)
United Kingdom	0.035	0.067	0.035*	0.067*
	(0.027)	(0.036)	(0.012)	(0.026)
United States	0.054	0.068	0.054**	0.068**
	(0.033)	(0.039)	(0.013)	(0.019)
Country Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	N	Y	N	Y
Period Fixed Effects	Y	N	Y	N
Robust standard errors	Y	Y		
Cluster robust standard errors			Y	Y
Observations	162	162	162	162
R-squared	0.16	0.34	0.16	0.34

Notes: Decade dummies capture observations from 1987 to 1995 and from 1996 to 2002. A constant is included in the models.
Significance codes: * 5% level, ** 1% level.

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