Measurement of R&D Multipliers: The Case of Greece

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ABSTRACT. The present paper applies empirically the methodology of backward and forward R & D multipliers for the case of Greece, which, despite its high growth rates in output (G.D.P.), ranks last among European Union (E.U) countries in R&D expenditure. The backward R&D multipliers measure the total amount of R&D expenditure embodied in one unit of an industry's final demand. On the other hand, forward multipliers reflect the percentage of an industry's R&D expenditures that is embodied in the final output categories. The results show that the Greek economy experiences a decrease in backward R&D multipliers over the time period 1993–1997, and some policy implications are discussed, regarding the country's priority to increase R&D diffusion and stimulate R&D financing.

Keywords: R&D, multipliers, input-output, Greece

JEL Classification: C67, O32, O52

1. Introduction

There is no doubt that technological progress is nowadays viewed as a major driving force of long-term economic growth (O.E.C.D., 1996, p. 53).[1] In fact, economic research has consistently shown that technological progress accounts for the majority of long-term productivity growth (Tassey, 2004, p. 165).[2]

There has also been widespread agreement that investment in Research and Development (R&D) has been one of the most important factors for a successful company or industry and attempts to initiate technological progress and innovation usually involve costly investments in R&D (Dietzenbacher and Los, 2002, p. 407). For purposes of measurement, R&D is defined as "expenditures devoted to the discovery and application of new scientific and engineering knowledge" (Jankowski, 2001, p. 323).

The fact that the benefits of R&D[3] are not limited to the industry that generates them attracts attention. The diffusion of technological progress encompasses two types: *Disembodied diffusion*,[4] and *Product-embodied diffusion,* which is the focus of our paper.

Product Embodied diffusion occurs when an initial innovation is embodied in the industry's product. Since other industries use this commodity as an intermediate input or capital good, the innovation becomes embodied in more commodities (Dietzenbacher and Los, 2002, p. 408). This type of diffusion is analyzed in an input–output context.

The paper applies empirically the input–output methodology for the case of Greece, in the time period 1993–1997, when data are available. The remainder of the paper is organized as follows: Section 2 discusses the research question for Greece; Section 3 presents the methodology of input–output multipliers; Section 4 presents the empirical results, while Section 5 offers policy insights and concludes the paper.

2. R&D in Greece: The research question

The measurement of R&D multipliers for the Greek economy is of great interest since Greece constitutes an original member of the O.E.C.D., and an old member of the European Union (E.U.). Also, real Gross Domestic Product (G.D.P.) growth in Greece exceeded the E.U. average for the fourth consecutive year, placing Greece first among E.U. countries[5] (European Commission (E.C.), 2000, p. 30). However,

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despite its high growth rates, Greece ranked last among E.U. members (E.C., 2003) in R&D expenditures with less than 0.5% of G.D.P.(E.C., 2000). Thus, "Greece should give high priority to [...] taking further measures to increase R&D [...] diffusion and stimulate [...] R&D financing" (E.C., 2000, p. 31), which could improve the economy's competitiveness.

In the present paper we attempt to answer the following two questions:

(a) *How much R&D, as a proxy for technological progress, is embodied in an industry's final output or,* alternatively, a*n increase in an industry's demand for output, what increase in the economy's total amount of R&D will generate?*
(b) *How much of an industry's R&D, as a proxy for technological progress, is embodied in the final output categories (e.g.exports) or, alternatively, an increase in an industry's amount of R&D, what increases in the economy's final demand categories will generate?*

Our investigation has direct relevance for policy issues for Greece. The backward multipliers pinpoint the industry for which total effects will be the largest, in case the Greek government decides to stimulate R&D by creating extra demand for the output of some industry. On the other hand, the Greek government might wish to subsidize R&D in a certain industry and in this case, the forward multipliers indicate the share of the amount of an industry's R&D which ends up in e.g.the exports.[6]

The first question will be answered by means of backward multipliers (e.g. Miller and Blair, 1985; Dietzenbacher and Los, 2000) and the second by means of forward multipliers (e.g. Jones, 1976; Dietzenbacher and Los, 2000).

3. The methodology of R&D multipliers

The input–output approach is based on certain assumptions (see e.g. O.E.C.D., 1996; Dietzenbacher and Los, 2002): First, R&D expenditures express technological progress and involve improvements in the production process, as well as improvements in product quality. Second, intermediate goods and services act as carriers of improved technology and thus inter-industry transactions transmit these improvements across industries. Third, R&D embodiment in each product is the same for every purchaser. Finally, we assume that capital good flows do not act as carriers of technology.[7]

Now, consider the vector of gross outputs, the vector of final demands and the Leontief inverse matrix. The typical element l_{ij} of Leontief's inverse denotes the output of industry i that is required (directly and indirectly) per drachma of final demand for product j. Thus, to satisfy one drachma of final demand for product j, industry I produces l_{ij} which embodies $r_i l_{ij}$ of R&D, where r_i denotes the R&D intensity (R&D to sales ratio). Summation over industries i, yields the total amount of R&D embodied per drachma of final demand for industry j, which is known as the backward multiplier.

Analogously to the Leontief's matrix, a similar matrix is constructed whose typical element g_{ij} denotes the increase in the output of industry j, which is caused by a drachma increase in industry i. Thus, a drachma increase of the R&D in industry i implies an increase of $g_{ij}e_j$ in the value of exports of product j, where e_i denotes the fraction of output that is exported. So $g_{ij}e_j$, indicates how much of the drachma increase of R&D in industry i is embodied in the exports of industry j. Summation over industries j, yields the total embodiment of a drachma of industry is R&D expenditures in all exports, which expresses the forward multiplier with respect to exports. In the same way we get the forward multipliers with respect to investments.[8]

4. Empirical results

We investigate empirically the case of Greece for the time period 1993–1997, when relevant data are available. The input–output tables *for each year* come from the National Accounts of Greece. However, their industry classification was not identical to the classification used by O.E.C.D. (see Table A.1). Because the figures on R&D expenditure obtained from the Greek Ministry of Development are in current prices, following Dietzenbacher and Los (2000), we used input–output tables in current prices.

Table I presents the backward multipliers for the case of Greece.

In general, the total backward multipliers have decreased over the 1993–1997 period, except for four (4) industries.[9] The "Shipbuilding and other transport, motor vehicles, aircraft, electrical apparatus, etc" industry present the highest backward linkages, since in one drachma of the industry's output, embodied are 1.32 cents of R&D expenditure. On the other hand, the backward linkages for "Finance and Insurance" are the lowest, since in one drachma of the industry's output, embodied are 0.06 cents of R&D expenditure.

The forward multipliers with respect to gross fixed capital investment are documented in Table II.

In general, the R&D embodied in investment has slightly increased in the time period 1993–1997. The highest total forward multipliers are found for the "Wholesale and retail trade" and "Construction" industries, where for each drachma of the industry's R&D expenditure, on average 76 and 72 cents are invested, respectively. The "national defense and public administration" and "hotels and Restaurants" industries rank last by far, with less that 1 cent invested for each drachma of R&D expenditure.

Table I
Backward R&D multipliers (%), Greece (various years)

Industry	1993	1995	1996	1997
1	0.28	0.10	0.09	0.10
2	2.16	0.65	0.62	0.54
3	0.26	0.20	0.17	0.19
4	0.19	0.17	0.16	0.20
5	0.22	0.40	0.29	0.42
6	0.31	0.37	0.31	0.36
7	0.80	0.56	0.55	0.51
8	1.17	0.88	0.68	0.79
9	0.66	0.55	0.50	0.40
10	0.96	0.47	0.34	0.40
11	0.60	0.57	0.44	0.55
12	1.86	1.18	0.98	1.32
13	1.03	0.31	0.30	0.30
14	0.31	0.26	0.21	0.23
15	0.14	0.15	0.12	0.13
16	0.12	0.09	0.08	0.08
17	0.19	0.11	0.11	0.12
18	1.14	0.34	0.09	0.06
19	0.08	0.22	0.20	0.22
20	0.20	0.17	0.12	0.18
21	0.20	0.11	0.09	0.09

Table II
Forward R&D multipliers (%), Greek investments (various years)

Industry	1993	1995	1996	1997
1	6.70	8.89	7.77	8.43
2	1.10	0.89	0.87	1.21
3	1.42	1.44	1.29	1.58
4	3.12	2.48	2.32	3.01
5	3.39	3.00	2.69	2.72
6	1.25	2.23	1.86	2.19
7	1.81	1.56	1.98	2.81
8	8.69	10.12	8.35	10.3
9	1.65	1.26	1.27	1.57
10	12.09	15.67	10.11	13.89
11	9.57	8.28	7.51	7.56
12	13.75	12.09	11.18	15.19
13	5.27	5.55	4.64	5.80
14	79.96	77.88	70.18	71.98
15	79.91	77.45	75.04	76.31
16	0.99	0.94	0.60	0.82
17	7.23	9.64	8.66	11.66
18	8.87	14.5	14.75	16.52
19	41.69	48.91	42.88	57.54
20	0.68	0.83	0.65	0.87
21	3.05	3.01	2.23	3.02

Table III shows the forward multipliers with respect to exports.

In general, the R&D embodied in exports increased over the time period 1993–1997.The highest total forward multipliers are found for the "Iron, steel and non-ferrous metals" industry, where for each drachma of the industry's R&D expenditure 82 cents are exported. The "Communication, social and personal services" industry ranks last with less that 1 cent exported for each drachma of R&D expenditure.

5. Conclusions and policy implications

A first conclusion that is drawn from the present paper is that the total backward multipliers have decreased over the time period 1993–1997, meaning that in 1997 *less* R&D expenditure is embodied in a drachma of an industry's final demand, than in 1993.

Also, the average value of backward multipliers among industries in 1997 is consistent, roughly speaking, with the figure that the E.C. (2000, p. 22) has presented.[10]

Given the fact that technology is critical for productivity and economic growth, and, because

Table III
Forward R&D multipliers (%), Greek exports (various years)

Industry	1993	1995	1996	1997
1	43.40	63.38	56.47	48.96
2	40.22	35.74	30.98	29.68
3	30.31	39.35	37.66	26.63
4	41.42	38.64	39.51	44.48
5	7.84	7.06	6.54	6.95
6	7.47	14.36	12.77	9.78
7	50.51	48.17	51.39	49.08
8	42.07	49.47	47.62	50.36
9	22.12	25.63	26.36	24.25
10	65.44	79.10	74.74	82.12
11	18.02	18.47	20.88	21.64
12	64.29	63.18	64.85	67.48
13	26.24	28.82	28.02	28.76
14	12.78	15.31	14.30	13.81
15	14.59	16.76	18.42	18.45
16	36.10	41.55	38.65	30.80
17	42.87	52.34	49.86	54.91
18	26.07	48.48	50.89	47.33
19	15.28	18.85	17.44	18.66
20	2.40	2.93	2.49	2.84
21	0.002	0.001	0.001	0.001

most technology results from R&D spending (Tassey, 2004, p. 166), the R&D multipliers are important policy variables, as well.

Thus, our investigation has direct relevance for policy issues for Greece. In case the Greek government decides to stimulate R&D—following the E.C.(2000, p. 31)—by creating extra (final) demand for the output of some industry, it could choose the "Shipbuilding and other transport, motor vehicles, aircraft, electrical apparatus, etc" industry, which yielded the highest backward linkages.

Similarly, the Greek government might wish to subsidize R&D in a certain industry aiming at creating sustainable competitive advantage over other countries (Dietzenbacher and Los, 2000, p. 3). In this case, the forward multipliers indicate the share of R&D in the specific Greek industry, which ends up in the exports. Increasing the R&D expenditures in the industry with the largest export multiplier, namely the "iron, steel and non-ferrous metals" industry, would yield the largest effects.

Consequently, our findings which are, in general terms, consistent with those of the E.C., suggest that "Greece should give high priority to [...] taking further measures to increase R&D [...] diffusion" (E.C., 2000, p. 31). Although

Table A.1
Industry classification

Industry	Description	I.S.I.C.rev.2
1	Agriculture, forestry and fishing	1
2	Mining	2
3	Food, Beverages and Tobacco	31
4	Textiles, apparel and leather	32
5	Wood products and furniture	33
6	Paper, paper products and printing	34
7	Petroleum and coal products	353 + 354
8	Industrial chemicals, rubber and plastic products	351 + 352 – 3522 + 355 + 356
9	Non-metallic mineral products	36
10	Iron and steel, non-ferrous metals	371 + 372
11	Metal products	381
12	Shipbuilding and other transport, motor vehicles, aircraft, electrical apparatus, non electrical apparatus, professional goods, other manufacturing	382 – 3825 + 383 + 3832 + 3841 + 3842 + 3844 + 3849 + 3843 + 3845 + 385 + 39
13	Electricity, gas, and water	4
14	Construction	5
15	Wholesale and retail trade	61
16	Hotels and restaurants	62
17	Transport, storage, and communication	71 + 72
18	Finance and insurance	81
19	Real estate and business services	82
20	National defense and public administration	–
21	Communication, social, and personal services	9

some European countries report increasing R&D (E.C., 2003), the lack of comparability in methodology hampers multi-country analyses of R&D trends and technology diffusion. We believe that future research on the subject would be of great interest. The measurement of R&D multipliers for other European countries could be a good example for future investigation.

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Notes

1. By technological progress we mean "any change in the application of information to the production process in such a way as to increase efficiency, resulting either in the production of a given output with fewer resources (i.e. lower costs), or the production of better or new products" (Mokyr, 1990, p. 6). However, "it does not really matter whether income grows because of the application of *entirely new* information to production [...] or the diffusion of *existing* information to new users" (Mokyr, 1990, p. 6). Consequently, the choice of the words "application of information" by Mokyr (1990, p. 6) is deliberate since growth can as well be derived from the deployment of previously available information rather than the generation of new knowledge (Rosenberg, 1982, p. 143).
2. For example, a recent study by Oliner and Sichel (2000) estimated that for the 1995–1999 time span, the combination of innovation and acquisition of technology through capital investment accounted for two-thirds of total productivity growth. However, these two sources of productivity growth—technological change and capital deepening—have significantly different roles in determining long-run economic growth.
3. In brief, investment in R&D is good for a country's economy, important for its national defence and health care (Jankowski, 2001), enhances its academic research (Caloghirou *et al.*, 2001) and contributes to society's welfare (Georghiou, 1999).
4. This type of diffusion is related to the transmission of ideas, knowledge, etc, and is related to the ability of industries to produce innovations, given an amount of R&D of their own. It is typically studied by means of analyzing patent-information flow matrices or patent citation matrices (Los and Verspangen, 2000), or technological proximity matrices (see Goto and Suzuki, 1989).
5. Greece had an average annual growth rate over the last decade, in terms of G.D.P, equal to 2.3%, in 1995 market prices (E.C., 2000, p. 172).
6. This kind of inter-industry product diffusion is traditionally analyzed in the context of input-output or investment flow matrices (e.g.Sakurai *et al,* 1997). The methodology for constructing embodied R&D indicators builds on the seminal work of Terleckyj (1974), who used input-output data to measure inter-sectoral flows of technology, while the R&D embodiment indicators have been formulated on the basis of a modified version of the Leontief inverse (Leontief, 1986).
7. The only industries that are characterized by increasing backward multipliers are "Textiles, apparel and leather", "Wood products and furniture", "Paper, paper products and printing" and the "Real estate and business services" industries.
8. The supply driven input–output model presented by Ghosh (1958), which constitutes the basis for the application of forward multipliers, has been viewed as implausible and Oosterhaven (1988) convincingly showed its flaws. However, Dietzenbacher (1997) recently demonstrated that Ghosh's model should be considered as a price model instead of as a quantity model, which was the—until then—common practice (Los, 2001) and this way all implausibility vanishes.
9. It is should not be surprising that the average value of the backward multipliers is in line with the E.C. figure, since these backward multipliers express the weighted average of industry—level R&D intensities.
10. Respectively, the "Wholesale and retail trade" and "Construction" industries have the largest forward multipliers with respect to investments.

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