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Finland and the mobile phone industry: A case study of the return on investment from government-funded research and development

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Abstract

The sudden and dramatic growth of the mobile phone manufacturing sector in Finland is an interesting case study for science and technology (S&T) policy analysts. Mostly on account of the rapidity of this growth against a relatively static situation for the other sub-sectors, the Finnish economic data over the period 1990–2001 can be used without ambiguity to quantify the return of an initial public sector research and development (R&D) expenditure on the growth of a sectoral economy. Although it is apparent from the data that this economic success story is to some extent now running out of steam, the returns to date for all the participants have been astonishing. Using the Patterson–Hartmann model, which has been developed to link company-level R&D expenditure with product revenue, it is shown that government has managed to achieve a multiplier effect of about 66 on its initial R&D expenditure through initially a leveraging of business R&D expenditure (at a level of 1:3) and then the translation of the latter into an increase in gross domestic product (GDP) (at a level of 1:22). These figures are extraordinarily high, even in comparison to the multipliers obtained by large private sector companies.

The keys to the success were both the vision and foresight of the Finnish R&D community, who identified cell phones as a major growth opportunity, the sharing of risk by the various role players (government, universities and industry) as can happen in an efficient national system of innovation, and finally a sustained commitment to R&D by the industry leaders. The latter has now reached a level of 3.5% of GDP (2005), which makes Finland a global leader in R&D expenditure (as a percentage of GDP). The lessons for developing countries such as South Africa, which are moving towards higher levels of R&D expenditure but within a resource constrained context, are apparent.

Keywords: Finland; Mobile phone industry; Industrial policy; Research gain; GOVERD

1. Introduction

The economic transformation of Finland during 1990s is a remarkable success story from a number of perspectives (Dahlman et al., 2005). Emerging from a severe economic crisis sparked by overspending, uncontrolled deregulation of the financial sector, the collapse of lucrative trade deals with the Soviet Union, and a heavy reliance on forestry and forestry-related industries, the country adopted a programme of economic reform that led to a rapid turnaround in the performance of the Finnish economy. A great deal has already been published about the components of this reform programme, such as a shift from macroeconomic to supply-side policies, the integration of research and innovation, and a policy approach that recognised the importance of interdependencies and relationships between institutions, in addition to the institutions themselves (this systems approach is captured in the discourse on the 'national system of innovation'). However, much of the analysis is qualitative; the linkage between government funding and economic growth has not been described at a quantitative level, despite the importance of this analysis.

Due to the relatively small size of the Finnish economy, and the highly focused nature of public funding, the economic data over the period 1990–2000 provide an unusual case study of the linkage between policy initiatives and economic impact. In many cases, this linkage is not evident since the effect of public expenditure on research and development (R&D), for instance, is not distinguishable from the impact of changes in other variables that also

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affect economic growth (such as changes in commodity prices, labour markets and interest rates). Previous attempts to extract the effects on various types of R&D on economic or multifactor productivity growth have used more complex, and hence less reliable data sets, and a production function which includes a decay term but not a lag term (Guellec and van Pottelsberghe, 2001; Guellec and van Pottelsberghe, 2003).

Fortunately the growth of the mobile phone manufacturing industry in Finland, subsequent to an increase in government support for R&D, can be clearly distinguished within the broader economic data, and hence provides an interesting case study for science and technology (S&T) policy analysts. Using a model previously applied to new product development within a commercial company, we investigate the relationship between government-funded R&D (GOVERD), business enterprise expenditure on R&D (BERD), electrical BERD,[1] electrical –value added[2] and gross domestic product (GDP). The model is extremely powerful in this application; it allows for lead and lag effects, and enables the extraction of several useful conclusions in respect of the impact of both public and business R&D on economic growth.

In this analysis, the effects of other factors such as the existence of a strong regional system of innovation, the overall innovation policy framework and the conditions impacting of research productivity have not been explored. The paper follows a strictly quantitative approach. At the same time it is acknowledged that funding is not the only critical success factor for a functioning system of innovation; there are many other factors, including highly trained and skilled researchers, that need to be in place and have been described in detail by other authors (Howells, 2005; Asheim and Coenen, 2005).

2. Background to the industry data and the model

The ascendance of the mobile phone industry (mainly Nokia) in Finland during the mid-90s was nothing short of remarkable. In a moment of great vision and foresight, the Finnish government, followed by the private sector, invested in the development of cell phone products, an investment which paid rich dividends and added more than $6 billion to the Finnish GDP (see Fig. 1). The data used in this analysis has been obtained from the following sources:

- GDP, GOVERD and BERD from the OECD's main S&T indicators, which are regularly published on the OECD web site.
- Electrical –value added directly from the web site of the Finland Statistical Services, which publishes data on value added from all sectors, organised according to the ISIC categories.
- Electrical BERD from the OECD's analytical business enterprise R&D database (ANBERD), the latter being available to members of the OECD through the organisation's web site; the ANBERD data is also organised according to the ISIC categories.

Many policy analysts have attempted to show the link between R&D funding and economic growth (OTA, 1986). Under normal circumstances, this causative link is so dependent on many other factors that it is difficult if not impossible to establish any significant correlation and hence draw any unambiguous conclusions. However, the Finland example is an interesting exception. First, it happened quickly and significantly within a relatively small economy so that the impact of other factors was less material. Secondly, it has been well documented through a number of annual surveys undertaken by the Finland and OECD statistical agencies. As a result, the economic data from this period form an excellent case study which can be used to explore a number of key questions including the leverage effect of GOVERD on BERD, the time delay between GOVERD and BERD, and between BERD and GDP growth, and finally the overall return that may be expected from an initial GOVERD.

In seeking to answer these questions, a model using investment and product wave shapes to simulate R&D and income data, and hence measure the gain factor between research and new product revenue, has been applied (Hartmann, 2003; Hartmann et al., 2006). The model, henceforth referred to as the Patterson–Hartmann model, was originally developed for determining the required level of R&D investment in order to support a desired growth in a company's new product sales. In this case study, its utility is extended to model the relationship between sector level R&D investment and the subsequent added value, as measured in standard economic terms. Its use in this analysis is well suited since it can accommodate lengthy time delays between investment and growth.

The Patterson–Hartmann model is based on the correlation between historical R&D investment and product revenue. The former typically takes place in the form of phased investments in discrete projects over a period of time preceding product launch (the shape of these investments is referred to as the product investment wave), whereas the latter usually takes several years to reach its maximum level before the product becomes obsolete in the market and revenues decline (the shape of the annual revenue earned from a new product following market launch is referred to as the revenue wave). The total investment in R&D is obtained from the sum of the individual project-level investments. Likewise, the total income

[1]Electrical BERD refers to the R&D expenditure of those companies categorized under sub-sector 32 of the International Standard Industrial Classification (ISIC), revision 3, and described as manufacturers of radio, television and communication equipment. Electrical BERD refers to the R&D expenditure of those companies categorized under sub-sector 32 of the ISIC, Revision 3, and described as manufacturers of radio, television and communication equipment.

[2]Electrical –value added refers to the value added by the same sub-sector (32 of ISIC, revision 3).Electrical –value added refers to the value added by the same sub-sector (32 of ISIC, revision 3).

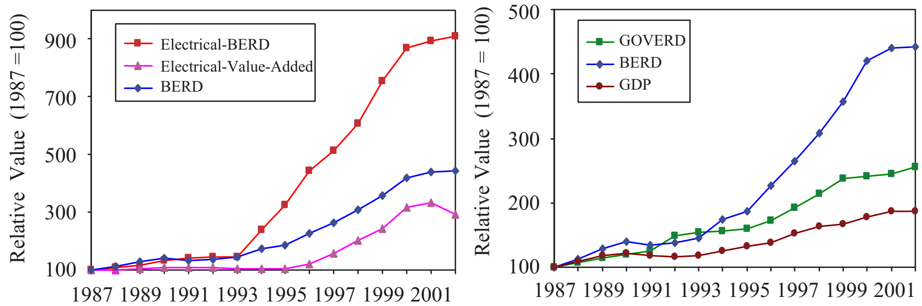

Fig. 1. Finland's Electrical BERD, electrical –value added, BERD, GOVERD and GDP all grew strongly from 1987 to 2002 (1987 = 100).

Table 1
Definition of model parameters

Metric	Description
Product investment wave shape	The development of a new product requires investment over several years prior to its launch; the wave shape reflects the typical timing and magnitude of this investment (see Fig. 2). The wave duration can be represented by the parameter $n = \Sigma i\alpha$ where i is the year prior to launch and α is the normalized investment in that year
Product revenue wave shape	A new product will take time to establish market share, will retain this share for a limited period, and will then decline in proportion to the total market as it is replaced by newer and better products; the wave shape reflects this revenue growth and decline (see Fig. 2). The revenue wave duration can be represented by the parameter $m = \Sigma i\beta$ where i is the year prior to launch and β is the normalized investment in that year
R&D intensity	The ratio of R&D expenditure to company or sector revenue (income from sales)
Growth rate (g)	The product investment growth rate (historical and future)
Sector (or company) gain	Sector or company gain is the R&D multiplier; it is the ratio between new product revenue and additional R&D investment

from sales is the sum of the individual product-level revenues. In additional to the wave shapes, two other model parameters are important; R&D intensity is the ratio between total R&D investment and total product revenue, and company gain is the ratio between new product revenue and additional R&D investment. The latter is the most important output of the model; it is indicative of the return on investment to the company from its R&D portfolio. Company or sector gain is highly variable; the higher this value, the higher the return on investment (Hartmann et al., 2006).

Implementation of the model requires the definition of a number of parameters as listed in Table 1 and derived as follows:

- using data which is characteristic of the company or sector being modelled and then applying standard curve fitting techniques, obtain the best estimates for the product investment and revenue wave shapes (and hence the parameters m and n);
- enter the company's historical revenue and R&D expenditure into the model using suitable units;
- simulate the R&D time series by adjusting the product investment growth rate (g) and the initial value; several iterations will be required;
- finally simulate the revenue time series using the company or sector gain parameter; again several iterations will be required (Fig. 2).

The parameters m and n are generally highly characteristic of the sector being modelled and the sum $m+n$ is a quantitative measure of time-to-market (in years). Examples of typical wave shapes can be obtained from previously published applications of the model (Hartmann et al., 2006; Walwyn, 2003).

3. GOVERD and BERD

Public sector funding of R&D, delivered mostly through GOVERD, plays a key role in all national systems of innovation (NSI). In general, the funds are used to support predominantly early stage research (basic or applied research as per the Frascati definitions) and the training of human resources within new research fields or knowledge domains. It is only once a critical level of expertise and research infrastructure has been established that industrial companies and businesses are willing to invest in the development of new products, processes and services, leading ultimately to new product earnings and hence a reward on their initial investment.

However the link between GOVERD and business or industry R&D expenditure (BERD) is not always clear despite being of considerable importance to government regulators. In the fulfilment of its many responsibilities, governments must always be concerned about where to allocate its funds in order to generate the greatest social

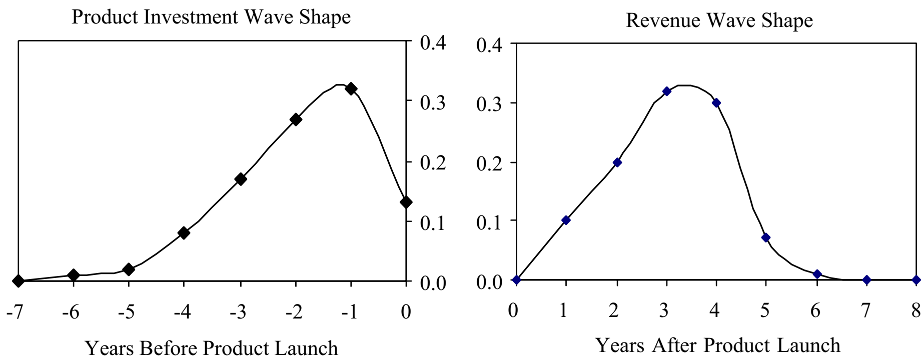

Fig. 2. Typical product investment and revenue wave shapes for the electronic industry (both wave shapes normalised to the total investment or revenue).

Table 2
Values of the model parameters for each simulation from 1980 to 2005

Model	m	n	$m+n$	Growth rate, g (Year)				Sector gain (Year)			
				⩽1991 (%)	1992–1995 (%)	1996–2002 (%)	⩾2003 (%)	⩽1990	1990–1994	1995–1999	⩾2000
GOVERD/BERD	2.34	2.70	5.04	4	12	9	1	2	3	4	3
Electrical BERD/electrical value added	2.34	2.70	5.04	0	0	34	1	19	19	19	0
BERD/GDP	1.85	3.07	4.92	6	6	19	0	180	140	100	55

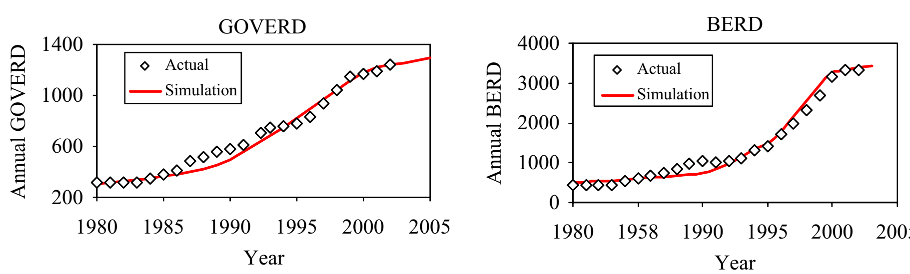

Fig. 3. GOVERD and BERD (million $) are simulated using the Patterson–Hartmann model.

returns. R&D is but one option; it must stand in the queue alongside health, housing, infrastructure, etc and must make a clear case for its worthiness.

The cell phone case study provides some clarity on this link. The data was analysed in three ways as follows:

- first the impact of GOVERD on BERD was modelled; the analysis revealed some correlation between the two variables at a multiplier of about 3 (a full listing of all the model parameters is shown in Table 2);
- second the relationship between electrical-BERD (this is the proportion of BERD allocated to research in electrical and optical goods) and electrical alue added was analysed with the model (see Section 4);
- finally the relationship between BERD and Finland's GDP was modelled (see Section 5); once again some correlation was observed at a multiplier of about 50.

The results of the GOVERD/BERD simulation using the Patterson–Hartmann model are shown in Fig. 3; the following observations are noted:

- GOVERD and BERD both grew significantly over the period 1990–2000 with GOVERD increasing about four times (average growth rate about 10%) and BERD eight times;
- on average, BERD grew 3 times faster that GOVERD; in other words for every $1 invested by government, industry invested $3 within 2 years;
- the time delay between an increase in GOVERD and a response by BERD is about 2 years and the total peak to peak time is 5 years; in other words, industry investment lags government expenditure, especially in a new sector where significant public investment in technology platforms and expertise development is required;
- the correlation between BERD and GOVERD is shown in Fig. 4 (the gain factor of 3 is confirmed by this graph); the highest correlation was obtained when the data for BERD were offset by 2 years;
- the obvious rise in GOVERD in the period 1992–1994 is a key contributor to the subsequent growth in BERD; it was the stimulus that led to massive industry uptake of a new technology and industry platform (the cell phone industry).

4. Electrical BERD and electrical value added

Investment in the development of cell phone products by Finnish industry began in earnest around 1994 and over the next 5 years grew 35% p.a. reaching levels nine times higher than the levels of 1990 and earlier (see Fig. 5). Within a couple of years, this investment began to impact strongly on the electrical value add (measured in standard economic terms; see also Fig. 5). Using the Patterson–Hartmann model, we can simulate this relationship by assuming a number of characteristics for the products being developed (how long they take to develop or the investment wave shape) and for the revenues that result from their successful commercialization (how quickly and for how long the revenues accrue or the product wave shape). The results of the simulation reveal the following interesting points:

- the prior R&D investment is spread over 4 years, with most expenditure happening in the last 2 years of its development (this is quite standard for the electronic goods sector);
- the product peaks within the first 3–4 years of product launch, then declines rapidly to zero by year 6 (again very typical of this sector);
- the 'new product' gain factor between investment and revenue from 1982 to 1999 was about 19, which is similar to the gain factor measured in a number of leading companies from the pharmaceutical and electronics sector including Merck, Pfizer, Intel and Xerox (Hartmann et al., 2006);
- over the period 1996–2002 a cumulative R&D investment R&D of $8.7 billion led to a cumulative $41.8 billion in value added, equivalent to an overall multiplier of about 4.7;
- the short product life cycle of electrical goods dictates that an R&D intensity (R&D expenditure divided by sales revenue) of about 20% is required in order to sustain a high level of growth and profitability; in this industry you cannot afford to stand still and must keep investing in order to maintain market share;
- in the early 2000s, the electrical value add began to decline sharply, presumably as the Finnish companies lost market share; as a result the R&D gain fell dramatically from 19 to almost zero leading one to the conclusion that R&D investment is a necessary but not sufficient condition for success. There are also other factors to consider.

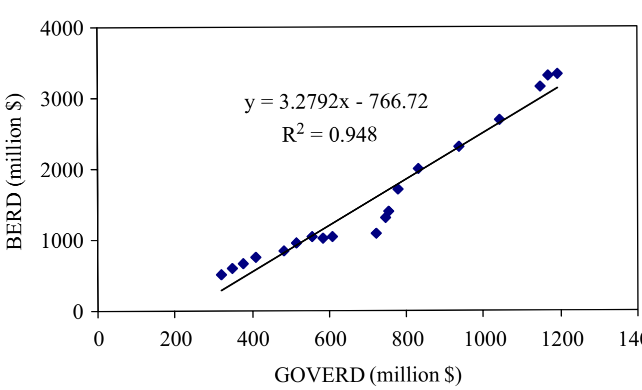

Fig. 4. BERD correlates with GOVERD over the period 1987–2002.

In conclusion to this section, it is noted that the growth of the electronic goods sector, and hence its impact on the total manufacturing output, as described in Section 3, are truly impressive. Over the period 1995–2002, the growth of this sector accounted for about 60% of the growth in manufacturing output and also about 60% of the growth in BERD. Within 5 years, the sector had grown from 12% of the manufacturing value added to 22%, from a relatively minor player in the economy to the number one spot, outgrowing even the traditional industry sector of pulp and paper.

5. BERD and GDP

The data can also be used to model the relationship between BERD and GDP (see Fig. 5). The issue of the impact of BERD on economic activity and economic growth is an important one for South Africa and other developing countries. Although the post-1994 macro economic policies in South Africa have brought stability and international credibility, the policies have not generated sufficient economic growth to bring full employment or the eradication of poverty. There has been much debate and discussion as to how this growth can be achieved including lowering interest rates, allowing a period of high inflation, higher domestic savings and increased expenditure on public employment programmes.

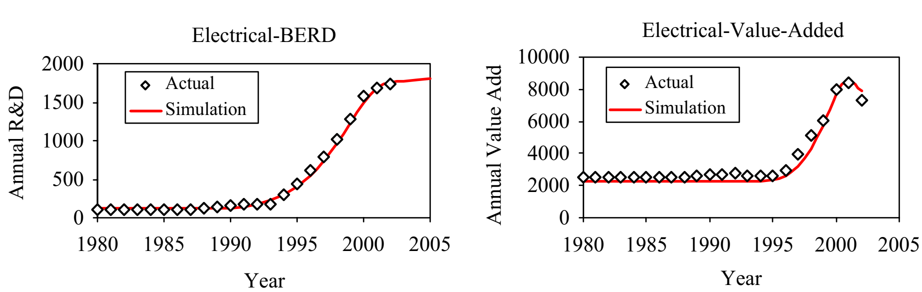

Fig. 5. Electrical-BERD and electrical –value added (million $) are simulated using the Patterson–Hartmann model.

One of the key indicators that concern economists is the slow pace of fixed capital formation (GFCF), which presently sits at 16% of the South African GDP vs. a required level of about 25% of GDP. GFCF represents the level of capital investment in the economy and is driven by the perceptions of market stability and potential demand for the products of such investment, perhaps in the form of infrastructure (such as transport) or goods and services. Clearly R&D is an important precursor to fixed investment, especially in manufacturing; new production capacity is usually accompanied by the introduction of new technology that has resulted from R&D, and in particular BERD.

The impact of increased BERD on GDP can be shown from the Finland data. Once again the Patterson–Hartmann model has been used to study this relationship (see Fig. 6). The investment and product wave shapes used in this case were more extended than those applied in Section 3, since in general product development and life cycles are longer than the typical project in the electrical sector. The results of the simulation do not confirm a causative relationship between the two variables; indeed it would be surprising if this were able to be established from such aggregated data within an acceptable confidence limit.

However some conclusions can be made as follows:

- Finland's GDP grew very strongly during periods of high BERD (1995–2000); over this period the multiplier between BERD and GDP was 22, implying that for every additional $1 spent on business R&D, the GDP grew by $22 (see Fig. 7);
- in the same period, BERD grew by 19% p.a.; however, both BERD and the GDP growth have dropped significantly in recent years (2002 onwards);
- the new product gain parameter (from the Patterson-Hartmann model) has also dropped from 180 to 55 in the late 1990s as the early high returns from the cell phone industry peaked and then declined (see Table 2) due to increased competition, lower margins and slower growth in the major cell phone markets;
- the Finland BERD as a percentage of GDP has been surprisingly robust (at about 2.5%) despite high levels of GDP growth, implying a high absorptive capacity within the Finnish R&D community and a strong commitment from its industry leaders to ongoing R&D.

It is useful to compare this national level data to information from specific companies. For instance, the product gain factors for Intel and Merck have recently been published as 29 and 28, respectively, over the period 1991–1995 (Hartmann et al., 2006). Such high-gain factors are atypical of manufacturing companies, but highly characteristic of research-intensive market leaders within sectors such as electronics and pharmaceuticals. In other words, it is not surprising that this macro-level analysis should reveal a gain factor similar to such companies, given the considerable influence of Nokia on the industry-level data.

6. Conclusions

Several important conclusions can be drawn from the success of the Finnish cell phone industry in the late 1990s. First, initial government investment through GOVERD is important to stimulate industry research investment or BERD, as has been demonstrated through the use of the Patterson–Hartmann model. Governments play a major role in reducing the risk for private sector participants in the development and exploitation of new technologies. In this case, an increase in Finland GOVERD in the early 1990s was important in laying the foundation for subsequent and much more significant BERD. Within 2 years, BERD climbed significantly with industry trebling government's initial investment.

Secondly, the central role of the cell phone industry in the BERD increase is obvious from the data; over 60% of

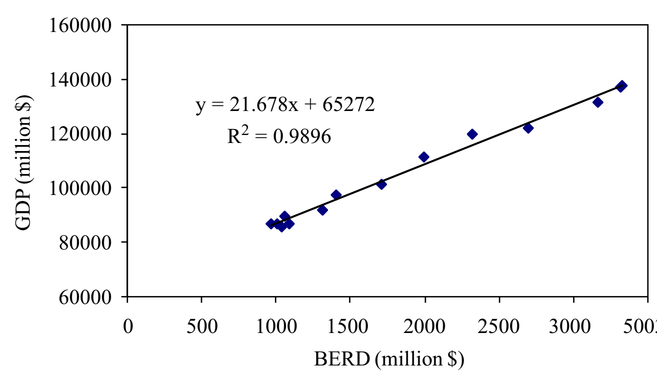

Fig. 7. BERD correlates with GDP over the period 1987–2002.

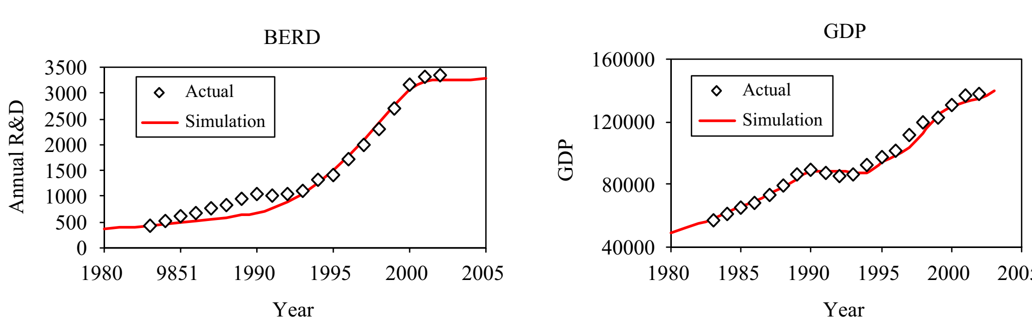

Fig. 6. The relationship between BERD and GDP (million $) is modelled using the Patterson–Hartmann model.

the increase was due to the mobile phone industry. Using the Patterson–Hartmann model, it has been established that this investment was translated into new product revenue for the sector at a product gain for 19, which is high for mature industries (normal values are between 5 and 10) but very characteristic of early market leaders in a new technology area (Hartmann et al., 2006).

Finally, the sudden rise in GDP over the same period provides a unique dataset from which to infer the impact of BERD on GDP. It is shown that the conversion factor or multiplier was about 22 during the 1990s, but has fallen in recent years as competition in the cell phone business has increased and market growth slackened. On the assumption that a strictly causative relationship exists between all the factors identified in this study, it can be concluded that the initial GOVERD achieved a multiplier effect of 66 times in terms of its impact on GDP.[3] It is noted that the equivalent Patterson–Hartmann gain factor of GOVERD to GDP is very much larger than the multiplier (about 400; see Table 2, where 400 is obtained from the product of 4 and 100, being the gain factors for GOVERD/BERD and BERD/GDP, respectively). The former must counterbalance the decline in revenue due to product redundancy and hence is always greater than ratio of revenue or value added to R&D expenditure.

Even under the most conservative assumptions, this multiplier (and the associated gain factor from the Patterson–Hartmann model) represents a very attractive return on investment to the Finnish treasury from its initial expenditure on R&D. Such a high economic return is very unusual but does makes government investment in R&D very attractive relative to its other budget options, helping to explain why Finland continues to be a world leader in its R&D expenditure, expressed in the form of GOVERD as a % of GDP (the 2005 OECD data show that Finland is second only to Sweden using this metric).

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[3]The value of the multiplier (66) is obtained from the product of the multiplier between GOVERD and BERD (3; see Fig. 4) and the multiplier between BERD and GDP (22; see Fig. 7). The value of the multiplier (66) is obtained from the product of the multiplier between GOVERD and BERD (3; see Fig. 4) and the multiplier between BERD and GDP (22; see Fig. 7).