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MEASUREMENT OF RESEARCH AND DEVELOPMENT IN NATIONAL ACCOUNTS

SERVICE LIVES OF RESEARCH AND DEVELOPMENT

Note by Central Bureau of Statistics, Israel[1]

Summary

The paper gives a short background on existing empirical work on service lives of research and development (R&D) and describes the results of a pilot survey, where some important R&D performers were asked to estimate average service lives of types of R&D. The impression is that service lives are similar for specific types of R&D, and that experts opinions may possibly supply satisfactory data.

[1] Prepared by Soli Peleg. Collection of information with the participation of Sima Ofir and Ofer Zelkind (both from the Survey Department), Central Bureau of Statistics, Israel.

INTRODUCTION

1. One of the important and difficult problems to be tackled in order to include Research and Development (R&D) in capital formation in the national accounts is the estimation of stocks of R&D and the gradual decline in the value of such stocks over time.

2. For other fixed capital the measurement of capital stocks is made either directly, through surveys, or through the perpetual inventory method. Market prices for types of equipment and vehicles are often available, so that the stocks of certain types of assets may be estimated at market prices relatively easily. The direct measurement of the value of stocks of R&D is much more difficult, since R&D is by definition unique and the major parts of R&D are produced on own account, so that market prices for types of R&D will not be available. In many cases the R&D will not be registered as an asset by the enterprises, so that only costs in the current year may be measured. This means that the estimation of R&D stocks will have to be done through the perpetual inventory method (PIM) or other methods based on accumulated expenditure. Such methods of measurement are based on assumption of a finite service life of assets and calculation of the stocks are made using existing estimates of length of service lives and patterns of depreciation or obsolescence of the assets over time. Estimation of service lives and depreciation for tangible fixed assets is mostly gathered through enterprise surveys or expert consultations.

3. The estimation of the length of the economic service life of R&D does not seem straightforward at first glance. R&D could in principle have an infinite service life, since there is apparently no wear and tear of it, and one could even argue that new R&D in most cases is based on former R&D, so that there is an ever-growing stock of R&D. However, most researchers investigating the subject have concluded that R&D used in production becomes obsolete after a certain time and only the newer R&D has a value as an asset for the producer.

4. Academic research examining the role of R&D has been conducted for many years, and such research has estimated stocks of R&D using assumptions of a finite service life – often using an assumption of an annual depreciation of 10-15%. In many cases such assumptions have not been based on any empirical data, but some of the researchers have tried to estimate the depreciation pattern of R&D using various models. Some well-known examples of papers on depreciation of R&D are by Ariel Pakes and Mark Schankerman (1984), M. Ishaq Nadiri and Ingmar Prucha (1993), Ballester, M., M. Garcia Ayuso and J. Livnat (2000) and Lev, Baruch, Doron Nissim and Jacob Thomas (2002). These researchers have either used data on patent renewal as an indicator of the use of R&D or examined the link between R&D and profits or market value of the enterprise performing the R&D. More recently there has been a renewed interest in the subject, and overviews of models have been given in papers by Rosa, Julio-Miguel, and Antoine Rose (2004), Erwin Diewert (2005), Sid Shanks and Simon Zheng (2006), Leo Sveikauskas (2007), Charles Ian Mead (2007), and new research on depreciation has been published by Jeffrey I. Bernstein and Theofanis P. Mamuneas (2004), and Ning Huang (2007), van Rooijen, Tanriseven, de Haan (2007), Erwin Diewert and Nin Huang (2008).

5. The researchers have explained the depreciation in the value of R&D in various ways. Some researchers have argued that the duration of a patent could indicate the length of the service life of the R&D underlying the patent. The implicit assumption is that once the patent

expires, the produced knowledge will become a public good with zero value for the owners or for the potential users.

6. Some (Bitzer, Stephan, 2002, Boucekinne, del Rio, Licandro 2001) have used an explanation of creative destruction linked to Schumpeter's work. This assumption also leads to patterns of decrease in value of R&D stocks. The development of R&D capital stocks is perceived as a process of creative destruction. Newly generated knowledge is assumed to add to capital stock, but also to displace and destroy part of the existing capital, so that the actions of agents performing R&D determine the depreciation of knowledge.

7. An alternative plausible explanation of finite economic service life could be a gradual spill-over. In the first years the R&D is not available to everybody and the access to knowledge about it has a certain value. The economic value goes down after the knowledge becomes available (is “spilt”) to more and more producers, until it reaches zero, when the R&D has become common knowledge in all countries.

8. Although different models and methods were used, the researchers arrived at empirical estimates of finite service lives and depreciation patterns. In more recent work, panel data detailed by industry were used, and differences in service lives over time and between industries were explored. In his review of the literature in 2005 on the subject Erwin Diewert came to the conclusion that the econometric models used in most cases were not satisfactory – for example they often wrongly attributed all technological change to R&D capital formation. He does, however, consider it possible to estimate the depreciation patterns using improved models, and in a recent paper with Ning Huang he has proposed an alternative model.
Table 1 below, based on a similar table from Shanks and Zheng, and Rosa and Rose, gives an overview of the methods and results of the empirical work done by different researchers.

9. However, in the framework of the Canberra II group Charles Aspden of the OECD brought up the idea of trying to obtain information on service lives directly from the users of R&D, similarly to what is done to estimate service lives for tangible assets. It is worthwhile mentioning that a survey on "life span" has been conducted in the past by the Japanese Science and Technology Agency, although it only concerned patents and had a questionnaire with questions on the length of time when a patent generated royalty revenues, or the average length of time the products that embodied patented technologies generated profits (the survey is mentioned in Goto and Suzuki, 1989). Following this suggestion the Central Bureau of Statistics in Israel undertook a pilot survey from the beginning of 2007. The results of this survey indicate that this option is a promising alternative, and the information gathered in connection with the pilot survey also confirms some of the common assumptions made by researchers about reasons for depreciation and obsolescence. The pilot survey, the findings of the survey, and the recommendations emerging from the survey are described below.

Table 1. Empirical research on Depreciation of R&D

Authors	Year of publication	Method	Data	Findings
Pakes,Ariel, and Mark Schankerman	1978	Econometric estimation from a patent renewal model	France, UK, Netherlands, Switzerland 1930 to 1939 (57 observations)	Depreciation rate 25%,confidence interval of 95%: 18 to 36%
Pakes,Ariel, and Mark Schankerman	1986	Econometric estimation from a patent renewal model	France, UK, Germany	Depreciation rate for UK 17-26%, France 11%, Germany 11-12%
Nadiri,M.Ishaq and Ingmar Prucha	1993	Econometric simultaneous estimation (using FIML) of a cost function	US total manufacturing data 1960 to 1986	Depreciation rate 12 % for R&D
Lev, B. and T. Sougiannis	1996	Econometric estimation from an accountable function. Assumption: percent of R&D expenditures and amortization rates are constant for all firms in the same industry	US data for 3-digit SIC levels 1975 to 1991 (5653 observations)	Amortization rate for Chemical and Pharmaceuticals 0.05 to 0.16 (9 years), Machinery and equipment 0.08 to 0.19 (7 years), Electric and electronic equipment and components 0.04 to 0.20 (7 years), Transportation 0.07 to 0.17 (7 years), Scientific instruments 0.13 to 0.24 (5 years), All industries 0.11 to 0.20 (5 years)
Bosworth, D. and Jobome, G.	2001	Estimates of hazard rate from cohorts of patent renewal data	USPTO patents data on UK patent renewals for patents granted 1950 to 1975	Average depreciation rates between 12% and 16%, but changing over time
Bitzer, Jurgen and Stephan, Andreas	2002	Econometric estimation of a production function, assumption of creative destruction.	Data for 12 OECD countries, 2-digit SIC, with 9 manufacturing sectors, 1973-1997	A displacement rate of 0.94.
Ballester, M., M. Garcia-Ayuso and J. Livnat	2000	Econometric estimation of a simultaneous system of equations. Variant of Lev and Sougiannis (1996) but not assuming that percent of R&D expenditures and amortization rates are constant for all firms in the same industry	Sample 1: Annual Industrial data for 365 firms (18 years); Sample 2: Quarterly Industrial data for 350 firms;	Amortization rate for Chemical and Pharmaceuticals 12%, Machinery and equipment 17%, Electric and electronic equipment and components 18%, Transportation 20%, Scientific instruments 15%, Others 15%
Bernstein, Jeffrey I. and Theofanis P. Mamuneas	2004	Econometric estimation. R&D depreciation within the context of intertemporal cost minimization, where depreciation rates are estimated simultaneously with other parameters characterizing the overall structure of production.	US data on 4 R&D intensive industries (covering 78% of R&D expenditure in manufacturing) 1954 to 2000	Depreciation rate: Chemical products 18%, non-electrical machinery 26%, electrical products 29%, transportation equipment 21%.
Bronwyn H. Hall	2006	Econometric estimation of private returns to R&D using two different methodologies: one based on the production function and another that uses firm market value to infer returns. Derives an implied depreciation rate for R&D capital	An unbalanced panel of publicly traded U.S. manufacturing firms observed from 1974 to 2003, a thirty year period - approximately 60,000 observations (6,000 firms)	Inconsistent results: with use of production function near zero or negative for all industries. With use of market value median depreciation rate: Chemicals 22.2%, Drugs and medical instruments 16.1%, Electrical equipment 52.1%, Computers and scientific instruments 42.0%, Metals and machinery 43.0%, Miscellaneous 24.1%
van Rooijen-Horsten, Myriam, Murat Tanriseven and Mark de Haan	2008	Distribution of patent values is used to estimate mortality probabilities	Data on use of patents and estimates of values from surveys in the framework of the PatVal EU 2005 project covering inventors of 9017 EPO patents in Germany, France, UK, Italy, Netherlands, Spain	Mortality probabilities between zero to 21 years, highest probabilities in the range of 2 to 8 years

II. THE PILOT SURVEY ON SERVICE LIVES OF R&D

10. When planning the pilot survey a number of peculiarities of R&D capital formation were taken into account:

(a) There is usually a time lag between the start and completion of R&D projects, called the gestation lag. This time lag will probably vary according to type of R&D, but is expected to be longer than a year for almost all R&D. The information on this time lag is important, if one wants to distinguish between expenditure on work in progress and expenditure on finalized R&D in the national accounts, and include the work in progress in inventories similar to the recommendations for software development.

(b) There may also be a time lag between the end of development and the beginning of use of the R&D in production – this lag is usually called the application lag.

(c) The length of the stage when R&D is used in production should be the most important question in the questionnaire – and for R&D that is acquired from other R&D producers, this is the only information needed for estimating the service life of R&D.

11. However, since most R&D is produced on own account and it may not be possible to separate the 3 stages in the national accounts, the length of all 3 stages will have to be taken into account, when preparing estimates.

12. The pilot survey has had 2 stages. In the first stage the survey was conducted using personal interviews, mostly with the participation of one or two representatives from the survey department and a representative from the national accounts unit. The questionnaire used at this stage was quite long (see questionnaire 1 in the annex) in order to determine how to pose the shorter questions in a regular survey. The terms used in the questions were chosen by the representatives from the Survey Department, and were based on their experience from the R&D survey.

13. In the second stage a shorter questionnaire was composed (see questionnaire 2 in the annex) to be sent by mail to the firms. For the first batch sent, a personal interview was conducted following the delivery of the mail – respondents were asked about their opinion about the questionnaire, and reported any difficulties in filling it out. The second batch will only be sent by mail.

14. Until now a small number of businesses have been covered, representing the important industries engaging in R&D in Israel. Representatives of venture capital funds were also interviewed.

15. Important parts of the information obtained during the interviews concerned the ways to collect data, the relevant contact persons etc. After the pilot survey has been concluded, the final decision on the framework for the collection of data and on the method, may be made on the basis of this information.

A. The feasibility of obtaining data on average service lives

16. In the enterprises visited so far, in almost all cases, the respondents were able to give firm estimates of the average length of service lives of R&D, and when data for more than one enterprise in a certain industry were collected, the length reported was similar for R&D of a similar kind.

17. But in almost all cases the respondents explained that they used more than one kind of R&D, each kind with its special length of service life. For example, in the semiconductor industry the service life of R&D destined for applications in the communication industry are very different from the service life of R&D destined for applications in the transportation industry. Or in the pharmaceutical industry the service lives of R&D for new medicine are quite different from the ones of R&D for generic medicine.

18. One of the experts on capital venture funds interviewed also explained that the length of service lives is different for R&D, which involves major innovation, and R&D involving minor innovation. In her opinion the enterprises distinguish mainly between those two kinds of R&D, and she gave examples from the software industry, which is very prominent in Israel.

19. This means that it may be important to collect data on the composition of R&D in some industries. The impression is that in most cases there are 2 main kinds of R&D within an industry, and that it will not be a problem to obtain data on the composition of R&D - often there are separate units within an enterprise, each one concentrating on a different kind of R&D.

20. Some respondents also explained that the length of service lives has changed in recent years, and for some industries they have become shorter. This implies that data on length of service lives need to be collected at least every few years.

B. The duration of the R&D project, the application lag and the period of use in production

21. The length of service lives appears partly to be connected to the duration and difficulty of R&D projects. If R&D projects are very expensive and have a very long duration, then the service lives are usually longer. For example the explanation for differences in service lives in the semiconductor industry was that R&D projects for applications in the transportation industry usually take much longer than projects for communication and are checked much more in depth due to the risks to lives involved. Another example was the pharmaceutical industry, where the explanation given was that the R&D projects for new medicine take much longer than projects for generic medicine – among other things due to the large amount of clinical trials that have to be made.
Data on the duration of R&D projects were easy to obtain – the enterprises had structured working programmes for R&D projects.

22. The length of the application lag seems to be quite short in many cases. Due to the fierce competition, the enterprises reported that they work simultaneously on the R&D and on the designs for use of the R&D in production, so that the implementation can take place almost

immediately. The enterprises seem to have very tight work programmes for a number of years ahead, and are well able to respond on questions on gestation periods.

23. As said above, since R&D is mainly performed on own account in most countries, the duration of the R&D project and the length of the application lag need to be added to the service lives in production, since the own-account R&D will be included as fixed capital in the national accounts from the beginning. The data on the duration of the R&D project and the application period are also needed for enterprises that sell their R&D, since it may be used to estimate the parts of R&D that is work in progress.

24. An interesting information collected during the first round of the pilot survey concerned the various stages of the R&D projects. The stages involve varying amounts of researchers – in some stages only a few are involved, and in others many may collaborate. Similarly the service lives are also sometimes described as having various stages. For example, the main income from R&D on an original medicine may be generated in the first years until the patent expires, and then after generic medicine is developed by competitors, the income may be much smaller, although it does not stop. Such information could perhaps be used to refine the profiles of the R&D used in the estimations.

25. Table 2 below presents some preliminary information from the pilot survey for selected industries is given. The lengths given are un-weighted averages for the few enterprises examined in the industries. Although the responses were similar within industries, since only a few cases were checked, the information may of course not be representative for the relevant industries.

Table 2. Average service lives reported by enterprises in selected industries in the pilot survey*

Industry	Type of R&D	Length of gestation lag in years	Length of application lag in years	Length of use in production in years	Total length in years
Pharmaceuticals	Major improvement - unique, original medicine	15	1	5	21
	Generic medicine	2	1	10	13
Chemicals	Major development	9	1	50	60
	Development on existing product	1	1	10	12
Semiconductors	For use in communication - appliances	2	0 to 1	3	5
	For use in communication - equipment for infrastructure	2	0 to 1	6	8
	For use in transportation equipment	2	1	10	13
Monitoring equipment	Original product	4	1	15	20
	Development on existing product	2	1	10	13
Software	Major improvement	3	Up to a year	5	9
	Minor improvement	2	Up to a year	2 to 3	5
Fabricated metal products, except machinery and equipment	Major development	2	1	15	18
	Development on existing product	Less than a year	1	10	12

* Since only a few enterprises in each industry were covered in the pilot survey, the length may not be representative, although the responses within industries were similar

C. Successful and unsuccessful R&D

26. In the interviews the question about the success of R&D was brought up. Respondents from the enterprises were aware of the amount of success, and the fact that part of the R&D is unsuccessful was taken into account in the work programmes. There are time schedules for the

decisions - milestones when unsuccessful projects are to be abandoned. On the other hand, the respondents said that the revenues on successful R&D covered all R&D, also the unsuccessful attempts. The plan is to bring the issue up in a future meeting with experts on venture capital.

D. The reason for ceasing to use the R&D

27. The reason for ceasing to use an R&D asset given by the respondents was the use of new R&D, which replaced and improved upon the former R&D. In most cases the old R&D asset is entirely abandoned, once a replacement is introduced, but in some cases it may be used in production on a minor scale to reap some remaining benefits from it. In some industries the competition is not such an important issue as in others – some enterprises have found a niche, where they don't have many competitors, and then the service life may be quite long. This seems to be the case for some enterprises producing chemical products. When the R&D is embedded in large-scale products, the service life is also longer – the price of a large product may be significant, and buyers may be hesitant to exchange one model for another due to the price.

E. The framework for collection of data

28. The pilot survey has been conducted among important R&D performers. However, in the case of Israel such performers often develop R&D used by enterprises abroad – either because they sell it to abroad or because they function as R&D centers for multi-nationals. The respondents even reported that R&D may first be produced within the country, then sent to abroad to a world distribution center, and afterwards sold back to the domestic country by this distribution center to be used in the production of another enterprise. The data on service lives obtained from such enterprises may be less relevant for the capital stock within the country (even if some of it may later end up in domestic enterprises), so that one should perhaps concentrate on enterprises that produce R&D for own use. But representatives from such R&D centers may have much more experience and information on average service lives than smaller R&D performers, since they are active in the world market, so they may be used to obtain expert opinions. If it turns out that service lives are uniform across countries due to world-wide competition, it might be possible to use international figures for R&D service lives.

29. If imports of R&D are very common, the collection of data should perhaps be made in the framework of a regular business survey, and not only in the R&D survey. The CBS of Israel has started performing a survey on exports and imports of services by enterprises to improve the classification of balance of payments estimates. The first results of this survey are now available, and from these results it appears that imports of R&D are important in some industries. It should be possible to link questions on service lives to this survey in the relevant cases – but if it is decided to use expert opinions, adding questions may not be necessary.

30. Responses to the pilot survey so far seem to indicate that using expert opinions on survey lives may be a satisfactory solution, since the respondents come up with consistent answers on length of R&D projects, application lags and service lives. In the most recent interviews respondents were also asked if they thought that service lives were similar for types of R&D, and in all cases the answer was that in their opinion the length was similar for specific types. But before more responses from enterprises have been received (responses to the mail questionnaire), such a conclusion should not be made. On the other hand, questions on composition of R&D

according to kind, as indicated above, seem to be extremely important, and have to be added to the R&D surveys.

F. Contact persons

31. The choice of contact persons within the enterprise seems to be important. According to one of the experts from venture capital funds the preferred respondents to the questionnaire are the Vice President of R&D and the CTO (Chief Technical Officer), or if it is an R&D enterprise, the Product Manager. She also explained that representatives for marketing or financial managers mostly will not provide the relevant information.

32. During the pilot survey a number of representatives for each enterprise were interviewed. Financial managers in some cases were a bit hesitant in their responses to the questions on service lives. It should be mentioned that the Israeli tax authorities currently allow expensing R&D costs, and this is often cited as one of the benefits to encourage R&D in the business sector. Financial managers will, of course, be more alert to any implications for tax purposes, and it had to be explained that the issue was of interest for national accounts purposes, and not anything else. On the other hand R&D managers understood the questions well, supplied all information asked for, and often added important information that could improve the survey such as suggestions of changes to the questionnaire, explanations of terms used in the enterprises etc.

G. Conclusion

33. Since R&D by definition is unique and the major parts of R&D are produced on own account, the estimation of R&D stocks will have to be done through PIM or other methods based on accumulated expenditure assuming a finite service life of R&D and patterns of depreciation or obsolescence of the assets over time.

34. Service lives and depreciation patterns for R&D has been estimated in the past in academic research using various models, but the methods used have been criticized by experts in econometrics, and ways to improve the quality of such estimates are still sought.

35. This paper has described a preliminary examination of the possibility of measuring service lives of R&D using enterprise surveys or expert consultations in the same way that service lives of tangible assets are frequently measured.

36. The results from the first stages of the pilot survey performed among a few major R&D performers in Israel and from interviews with experts on capital venture funds and R&D financing are promising. The impression is that it is possible to obtain relatively firm and consistent responses in a business survey on the duration of R&D projects, length of application lags and length of use in production. However, it appears that in order to estimate R&D capital stocks, it is also important to obtain information on the composition of R&D by main type within the enterprises.

37. The pilot survey has also provided information on the appropriate person to contact within the enterprise. It turns out that staff in financial or marketing units may not be able to provide the necessary information, and it is important to interview technical or R&D managers.

After more information is gathered, one possible conclusion could be that collection of expert opinions on length of the R&D project, application lags and use in production for each type of R&D may be sufficient in order to prepare reasonably reliable estimates of R&D capital stocks. The service lives of specific types of R&D could even be identical at the global level, so that international figures for length of service lives could be used. To reach such a decision, it is important that additional countries collect similar information from performers and users of R&D.

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ANNEX

Questionnaire 1:

Expenditure on research and development may be registered in the business accounts as expenditure or as an investment.
Recently the important international statistics organizations approved the registration of research and development as fixed assets in the national accounts.
In order to enable the national accountants to estimate the depreciation of research and development (as is done for other fixed assets), information on the length of the service life of R&D is needed.

One may observe 3 periods in the life of R&D produced:

Stage	Information needed	
The development stage	1. What is the average time needed to develop a project? That is, how much time pases between the start of the project until the the development is finalized?	
	2. Is it possible to identify sub-stages in the development stage?	
	3. What is the variability of the time needed for development between various projects?	
The stage between development and production	1. Is there a time lag between the end of development and the start of use of the development?	
	2. If yes, what is the average time lag?	
	3. What is the variability of such time lags between various projects?	
The production stage	1. What is the average length of time the development is used in production? That is, how long time passes on average between the start of the use of the development until it is decided to stop the use and go on to using another development (a new version)?	
	2. Is it possible to identify sub-stages in the production stage?	
	3. What is the variability of the time of use between various projects?	
	What is the reason/reasons for stopping to use a development?	

Questionnaire 2:

Recently the important international statistics organizations approved the registration of research and development (R&D) as fixed assets in the national accounts.
In order to register R&D as a fixed asset we need information on the length of life of the R&D. The Central Bureau of Statistics is making preparations for a survey on "the Length of Life of Research and Development". To help us with these preparations we ask you to provide us with information on typical R&D projects in your company by filling out the following tables:

R&D projects for own use

No.	Description/name of the type of project describe also in what way such R&D projects are innovative.	Details on stages in the "life" of R&D			Comments
		Stage	**Information needed**	**Time in years**	
1		Development	Average time of development		
		Transition from development to production/operation	Average timegap between end of development to start of use of R&D in production/operation		
		Use in production/operation	Average length of time from start of use of the R&D developed until end of use		
2		Development	Average time of development		
		Transition from development to production/operation	Average timegap between end of development to start of use of R&D in production/operation		
		Use in production/operation	Average length of time from start of use of the R&D developed until end of use		
3		Development	Average time of development		
		Transition from development to production/operation	Average timegap between end of development to start of use of R&D in production/operation		
		Use in production/operation	Average length of time from start of use of the R&D developed until end of use		

R&D purchased from others

No.	Description/name of the type projects describe also in what way such R&D projects are innovative.	Details on stages in the "life" of R&D			Comments
		Stage	**Information needed**	**Time in years**	
1		Use in production/operation	Average length of time from start of use of the R&D purchased until end of use		
2		Use in production/operation	Average length of time from start of use of the R&D purchased until end of use		
3		Use in production/operation	Average length of time from start of use of the R&D purchased until end of use		

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