National Physical Laboratory

NPL REPORT IEA 15

NMS BUSINESS CASE MODEL: AN EXPLANATORY NOTE

DR MIKE KING, SOLOMON OLAKOJO

MARCH 2023

NMS Business Case Model: an explanatory note

Mike King, Solomon Olakojo
Analysis and Evaluation, Partnerships Directorate

ABSTRACT

This note presents the NMS business case model focusing on estimating the costs and benefits associated with funding the programme. All monetary values that feature in the analysis are in real values by adjusting for the effects of inflation on prices using 2022/23 as the base year. Economic direct benefits are derived from jobs created by firms supported by NMS and the wage premium (which tracks changes in workers' productivity) earned by job-switchers into those businesses. The present value of the total benefits (direct and indirect) was calculated using the 3.5% conventional discount rate from *HMT's Green Book*. The social cost includes the public investment made from the BEIS' R&D budget to resource the NMS (DEL), private direct and indirect cost respectively to those businesses who engage with the NMS and second-round innovators, and private opportunity cost of not allocating those resources to other profitable activities. The net present value (NPV) of the programme (£255.83 million) is found by subtracting the present value of total benefits (£425.19 million) from the social cost (£172 million) to arrive at NPV-to-DEL of approximately 2.7. This shows that NMS programme produces net benefits that are more than double of the value of the public investment of about £94 million. These results, however, only cover quantifiable benefits to the private sector. There exist a host of non-market benefits that didn't feature in this analysis.

ISSN 2633-4194

https://doi.org/10.47120/npl.IEA15

National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

Approved on behalf of NPLML by
David Skelton, Strategic Programme Leader.

CONTENTS

1. INTRODUCTION

This document is a note on the business case model which is an estimate of the value-for-money of the NMS programme. The estimate is based on considering what would happen to future costs and benefits if the NMS programme operates at its current scale in the following year. To that end, estimation of the costs and benefits associated with funding the programme for a single year was based on the business-as-usual basis. On one hand, the benefits are based on the empirical evidence generated by the impact studies on how NMS supported businesses expand their output through the sales of new products, which requires the company to hire more staff and pay premium wages. This expansion in output would not have occurred without the support from the NMS laboratories. This is regarded as direct benefit. The indirect benefits are spill over to firms that did not engage with the NMS labs, but share the same environment (e.g., market) as the supported firms. On the other hand, the activity of the NMS also involves costs both for the public sector and for the supported companies. The model considers three types of costs:

- The public investment made from the BEIS' R&D budget to resource the NMS.
- A private direct cost to those businesses who engage with the NMS.
- The private opportunity cost of not allocating those resources to other profitable activities.

All monetary values that feature in the calculations of Net Present Value (NPV)/Departmental Spending (DEL) are in real values, which account for the effects of inflation on prices using 2022/23 as the base year.

1.1 NARRATIVE BEHIND THE MODEL

The analysis (Belmana, 2020) on which benefits are derived used Propensity Score Matching (PSM) and Difference-in-Differences (DiD). These are quasi-experimental approach that compares the changes in outcomes over time between supported firms (the treatment group) and firms that are not supported (the comparison group). PSM ensures that the control group is similar to supported firms in terms of observable characterises and past behaviour. The DiD technique accounts for the influence of unobservable fixed effects. Robustness was explored by checking for common growth tends prior to support and running balancing tests to check comparability of the control group.

Our model focuses on the benefits of creating opportunities for labour to move into better paid jobs. Our inability to determine how many of the new jobs created by supported businesses are truly additional to the UK's economy means that the economic benefits are best measured as the wage premium earned by job-switchers rather than the jobs created. The idea is that wages should track and reflect underlying changes in workers' labour productivity (output per worker) – that is, the NMS support helps create the conditions for job-switchers to make better use of their capabilities, thus increasing their productivity.

Using the Annual Respondents Database (ARD), the Belmana study made use of very detailed data on the operations of individual business units run by large manufacturing companies to perform a productivity decomposition. It was possible to disaggregate the change in a company's productivity over the period 2010-16 into its constituent components: changes in the productivity of individual plants; shifting resources from less productive plants to more productive plants; and the entry and exit or more of less productive units.

Our model used turnover per employee to measure labour productivity. This measure has the advantage of being easy to compute for all firms using basic data from the Business Structure Database. However, the preferred measure of labour productivity is based on Gross Value Added (GVA) as opposed to alternative approaches based on changes in turnover per

employee. This is based approach developed by Foster, Haltiwanger and Krizan (FHK) (2001). Sadly, data limitations means that this can only be computed for large firms in the Annual Respondents Database.

NMS funding is the primary input in the model. It is used to estimate both the costs incurred by the supported companies, as well as the direct benefits they receive and the indirect benefits that spill over to other non-supported firms. The rest of this subsection explains how NMS funding is used to estimate costs and benefits, and the considerations made to properly discount both to arrive at the Net Present Value of the programme.

2. BENEFITS

2.1 DIRECT BENEFITS

It's unlikely that the benefits of R&D could so rapidly be translated into growth, given the time it takes to develop and introduce a new-to-market product. That is, economic studies have consistently found that it takes about two to three years before even successful innovation projects start to generate benefits that show-up in a business's performance.

The calculation of the benefits is made through the connection between the NMS funding and the number of supported companies. An econometric analysis conducted by Belmana's analysis shows that the attributable increase in jobs only takes place among the 358 regularly supported firms. Since each of these firms grew by 6.31 employees per year, it follows that the attributable increase in employment among the supported firms amounts to around 2,259 (358X6.31) new jobs each year (Please see Annex 1 for further details.). Belmana used longitudinal micro data on individual employees from the Annual Survey of Hours and Earnings (ASHE) to estimate a wage premium for employees switching to firms supported by the NMS laboratories. Belmana's analysis found that the weekly wages of new staff joining an NMS supported firm increase by around £78.30 which translates into an annual wage premium of £4,083 since there are 52 weeks in a year. Moreover, this wage premium persists even after controlling for the age, skills and fixed characteristics of these job-switchers (Belmana, 2020).

Gross Value Added

We have found that a wage premium of £4,083 is acquired by employees switching to NMS supported firms. This increase in wages can only be sustained by an underlying increase in productivity, brought about by successful innovations among the regularly supported firms.

However, only part of the surplus created by a productivity shock will be passed-on to employees in the form of high earnings; the rest is retained by the owners of the firms' capital or taken in by the government in the form of additional tax revenue. The proportion passed to employees in higher wages depends on employees' bargaining power and ability to use the threat of outside job options to force wage renegotiation (Postel-Vinay and Turon, 2010).

This analysis should focus carefully on how the increased economic surplus from successful innovations are split between a firm's employees and its owners. Estimation of the benefits that go with innovation support is presented as follow:

- The benefits associated to innovation support that go to labour is £4,083. This is the annual wage premium received by employees switching to NMS supported businesses.
- Dearden et al (2005) suggests that the increase in a firm's profits is roughly equal to the increase in wages. Hence, a wage premium of £4,083 translates into a similar sized increase in profits. Compared to the benchmark for the split between capital and labour of 1:3, Dearden et al (2005) suggests that when it comes to splitting the proceeds of innovation, capital gets relatively higher share because of high risks associated with innovation activities.

- Wages and profits account for only two of the three components of Gross Value-Added (GVA) - the remaining component being taxes collected by the government to fund public spending. The UK has a tax-to-GDP ratio of around 33%. That is, two-thirds of the total benefits goes to labour and capital, while the remaining one-third is taxes.

It follows that to find the total benefit we need divide the sum of benefits going to capital and labour by 2/3. That is, the total benefit is (£4,083 + £4,083)/(1 – 1/3) = £12,249. Since the tax-to-GDP ratio is 33%, the increase in taxes can be calculated as £12,249 × 1/3 = £4,083.

Together the points detailed above suggest that the surplus can be breakdown as follows:

- The increase in wages is £4,083.
- The increase in profit is £4,083.
- The increase in taxes is £4,083.

This implies that a wage premium of £4,083 translates into an increase in GVA of around £12,249.

We have already seen that among the regularly supported firms the attributable increase in employment amounts to around 2,258.98 (i.e., 358x6.31) new jobs each year; each of these jobs command a wage premium of £4,083, which translates into an increase in GVA of £12,188. Multiplying these quantities together gives a flow of benefits contributing £27.67 million (i.e., 2,258.98 x12,249) each year to GVA; and using the results listed above this surplus will be split as follows between the interested parties:

- The flow of wages is £9.22 million each year
- The flow of profits is £9.22 million each year
- The flow of taxes is £9.22 million each year

This flow of benefits lasts for around 6 years, but future incomes is slightly discounted. Hence, flows of future costs and benefits should be assessed in terms of '*present values.*' Because people tend to discount the future, future benefits (costs) are worth less than present benefits (costs). A time lag of T years means discounting the benefits (costs) by $1/(1+\rho)^T$, where the conventional discount rate from *HMT's Green Book* is ρ = 3.5%. For instance, £100 next year is equivalent to £96.62 today, because T = 1 and 1/1.035 = 0.9662.

Using 3.5% as the rate of time preference, the present-value (PV) of £27.67 million annual flow of benefits is £152.60 million1. However, there's known to be a two-year lag before the benefits materialise, and so the previous value is further discounted to £142.46 million. That is, if the project takes place in year 1, then benefits are accrued between year 2 and year 7.

Year	Discount factor	PV (£ mill)	Cumulative PV (£ mill)	Cumulative PV with 2-year lag (£ mill)
0	1.000	27.67	27.67	0
1	1.035	26.73	54.40	0
2	1.071	25.83	80.23	25.83
3	1.109	24.96	105.19	50.79
4	1.148	24.11	129.30	74.90
5	1.188	23.30	**152.60**	98.20
6	1.229	22.51	175.11	120.71
7	1.272	21.75	196.86	**142.46**
8	1.317	21.01	217.87	163.47

1 Note that the first-year flow of benefits does require discounting. Hence, the discount periods start from 1 to 5.

This is a significant benefit, nonetheless, it's important to keep in mind that it's only the direct benefit to firms using the NMS labs. The indirect benefit is presented in what follows.

2.2 INDIRECT BENEFITS

Creating value through innovation does not entail having the ability to capture much of the value that's being created (hence, the need for public support). That is, much of the value created by innovation does not go the innovators but rather to the imitators who manage to supply generic versions of once novel products at a more competitive price (e.g., those firms playing a 'fast second' strategy and who don't need to recoup the large R&D costs of the original innovators). Hence, much of the benefits of innovation show-up at the aggregate level in form of spillovers that benefit competitors, as well as benefiting the wider society and consumers.

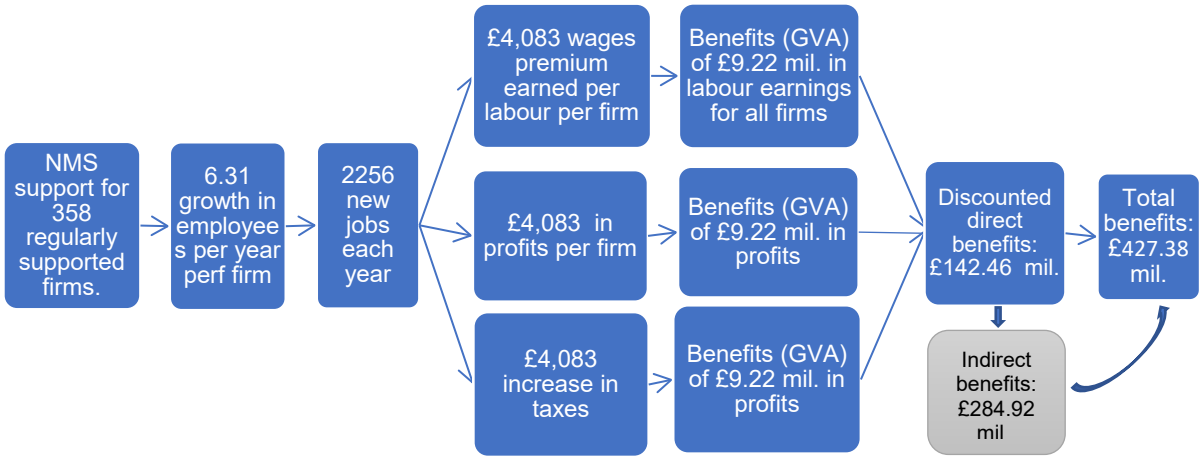
- A meta-analysis by Frontier Economics carried out in 2014 found that the existing literature estimates private rates of return to R&D of around 16% (Frontier Economics, 2014). However, the social rates of return to R&D are around 50% - three times larger than the private rate of return. This suggests that if direct benefits correspond to a social return of 16.6%, then the indirect benefits correspond to a rate of return of around 33.2%. Together these benefits give a social rate of return of around 50%.
- A citation analysis by Belmana found that the supported firms generate patents with markedly higher knowledge spillovers than typical patents (Belmana, 2020). This analysis of the spillovers was done by matching citation data for all patents in the PATSTAT database to patent data for the supported firms. The citation data used in this analysis had previously been prepared by Dr Ralf Martin (a data scientist at Imperial College London) to develop sophisticated measures for the importance of each individual patent based on its location in the overall network of citations. Ralf Matin's network analysis is based on the idea that the importance of a patent is not just the number of citations it gets, but also depends on the citations of any citing patent. This insight was used to create a metric he called Patent-Rank which is analogous to the Page-Rank developed by Larry Page for measuring the importance of websites based on pattern of outgoing and incoming links. Based on this Patent-Rank metric, the patents generated by the regularly supported firms are much more important than patents produced by other firms.

Since knowledge spillovers generated by inventions from NMS supported businesses exceed that of typical inventions, the 1:2 ratio of direct-to-indirect benefits from the meta-analysis (Frontier Economics, 2014) can be considered a lower bound. Based on this, we assume that the indirect benefits are twice the size of the direct benefits.

Based on these assumptions we arrive at the following estimates:

- The present-value of this annual flow of indirect benefits is £284.92 million.

The following diagram summarises the steps to arrive at the total benefits of £427.38 million:



3. COSTS

3.1 PRIVATE COSTS

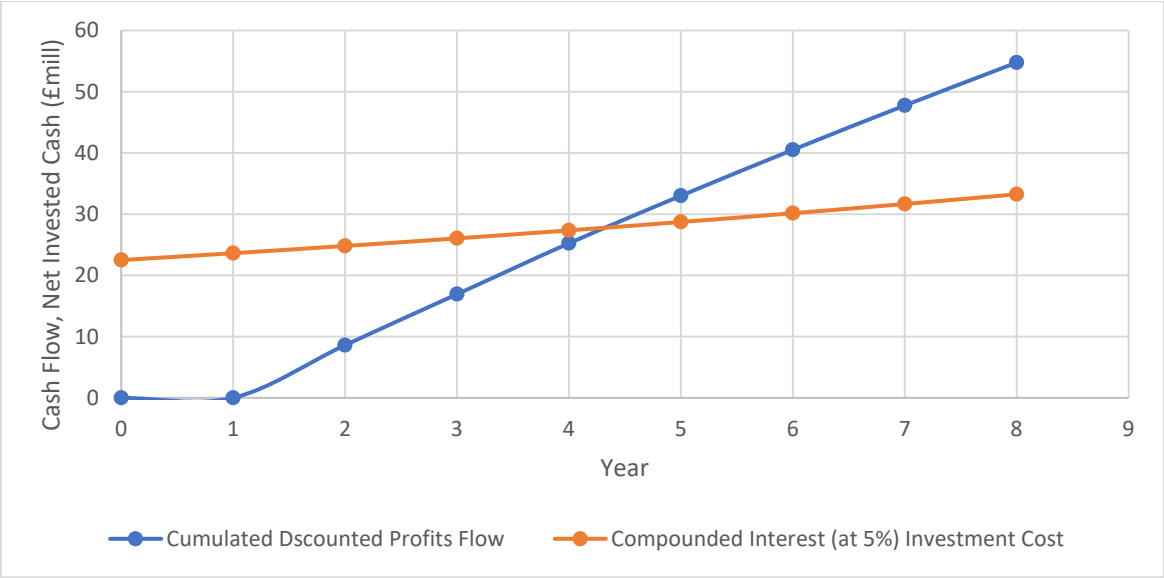
The private costs are the sum of direct cost and private opportunity costs of not allocating those resources to other profitable activities by innovators engaging with NMS, as well as costs to the second-round innovators.

The benefits discussed above are generated by innovation projects that take place partly in the NMS labs and partly in the firms themselves. UK-based firms supported by the NMS laboratories pay around £7.5 million each year for the services they receive. Moreover, the NMS customer survey found that users believe that for every £1,000 spent on innovation activities carried out by the NMS labs, a further £2,000 is spent by the firms on in-house innovation activities (King and Tellett, 2020). (That is, if a project cost £60k in total, then £20k would be paid to cover work done by one of the NMS labs, and a further £40k would be spent by the firm on its in-house innovation activities.) Together these results suggest that working with the NMS labs costs the supported firms around £22.5 million (£7.5 million x3) each year.

The full cost of this investment includes the opportunity cost of foregoing some other investment or buying back shares. The opportunity cost is based on the conventional rate of 5% per year and lasts for as many years as it takes to pay back both the principal and the interest.

The private opportunity cost of not allocating those resources to the R&D projects is investing in the stock market. Over the last 35 years, the FTSE-100 has, on average, comfortably provided investors with inflation-beating returns: Nominal returns have averaged 7.75% while RPI inflation has averaged 2.70%, implying that the average real return over this period was 5.05%.

With an interest rate of 5%, taking out a loan of £22.5 million in year 1 means paying back £27.3 million in year 5. With annual gross profit flows of £9.22 million, it would take a regularly supported firm about 3 years to pay back both principal and interest. Allowing for two years before benefits start accruing, it would take a regularly supported firm about 5 years to recoup both principal and intertest.

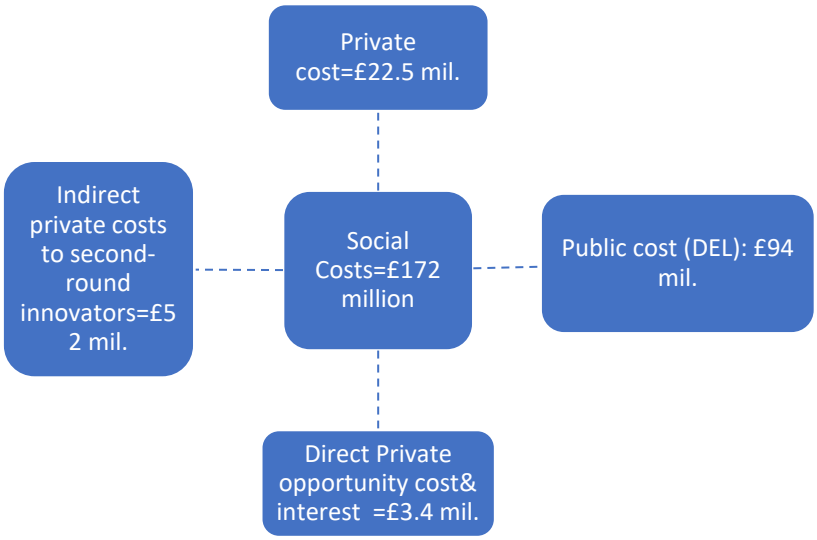


Combining the principal with the interest accrued, and discounting for the rate of time preference, gives a total discounted cost of around £25.9 million. It is probably less costly to make use of a new piece of knowledge than it is to generate it in the first place. However, in the absence of specific evidence, it will cautiously be assumed that the costs scale proportionally with the benefits. That is, if we double the benefits to account for adoption and diffusion, then we should also double the private costs incurred by firms. (The indirect benefits don't come for free – second-round innovators and adopters need to make investments so that they can exploit the new knowledge being generated by the regularly supported firms.) Hence, the cost of these second-round innovation is £52 million.

Since the costs borne by the second-round innovators were assumed to be twice the costs incurred by the supported firms, the private cost is given by 3 x £26 million = £78 million.

3.2 SOCIAL COSTS

In 2020/2021, NMS receives about £94 million as public investment from the BEIS' R&D budget. To find the social cost we need to add the public funding received by the NMS to the private cost. Thus, the social cost is given by £94 million + £78 million = £172 million. The following diagram summarises the steps to arrive at the social costs:



4. NET PRESENT VALUE

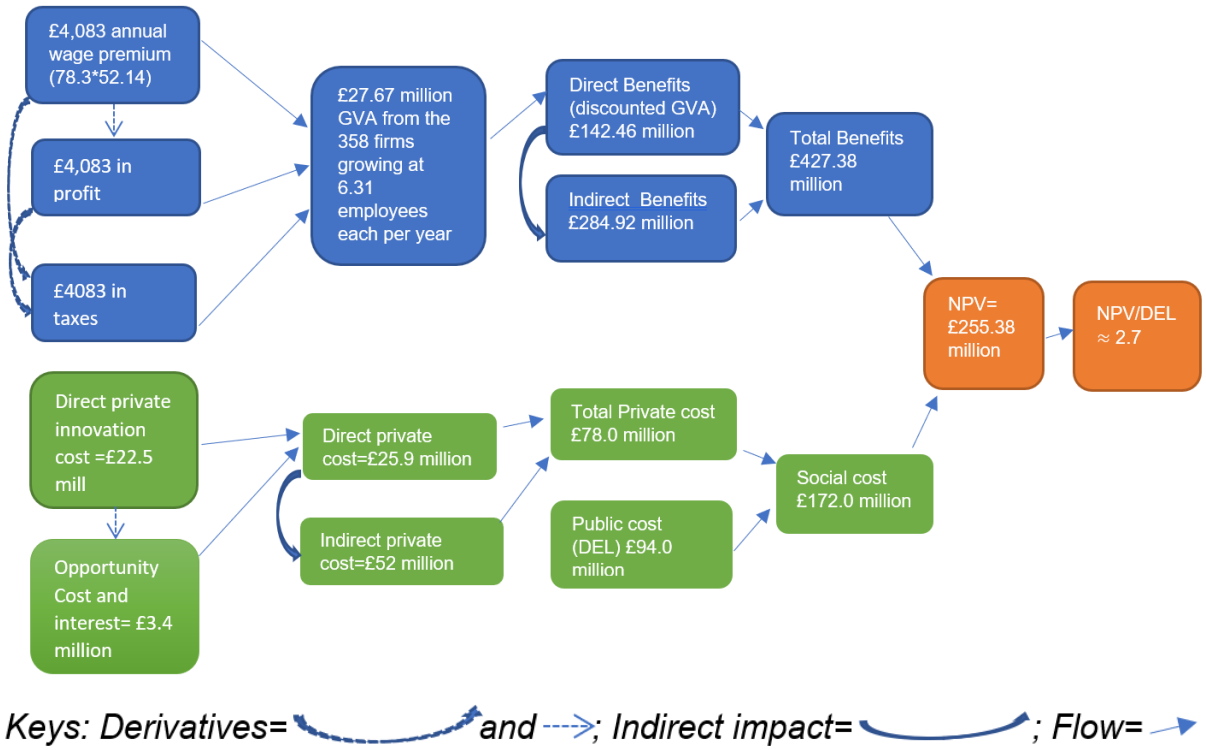
The present value of the benefits is the sum of the direct benefits and the indirect benefits. Since the indirect benefits were assumed to be twice the direct benefits, the gross benefit is given by 3 x £142.46 million = £427.38 million.

The net present value (NPV) of the programme is found by subtracting the present value of the benefits from the social cost. Thus, the NPV of the programme is given by £427.38 million − £172 million = **£255.38 million**; and the NPV-to-DEL ratio is given by (£255.38 million / £94 million) = **2.7**.

The headline results of this value-for-money analysis are that the programme has an NPV of £254.9 million, and an NPV-to-DEL ratio of 2.7. However, these results only cover quantifiable benefits to the private sector. It's important to keep in mind that there exist a host of non-market benefits that didn't feature in this analysis.

The economic business case model is summarized as follow:

NMS Economic Business Case Model



5. CONCLUSION

The NPV-to-DEL ratio provided above explained our NPV model. However, it is made artificially low by the inability to quantify some of the benefits generated by the NMS laboratories. While full cost was considered, economic quantification of around half the benefits is extremely difficult because these are non-market benefits created by supporting public goods. Hence, the analysis table above significantly underestimate the ratio of benefits to costs. The full picture of the impact of NMS covers a range of unmonetizable benefits including maintaining the UK's Quality Infrastructure, public health, environmental, and security/defence benefits.

References

Belmana. (2020). *Public Support for Innovation and Business Outcomes.* London.
Dearden, L., H. Reed and J. van Reenen (2005). The impact of training on productivity and wages: Evidence from British panel data. CEP Discussion Paper no. 674.

Foster, L., J. C. Haltiwanger, and C. J. Krizan (2001). Aggregate Productivity Growth: Lessons from Microeconomic Evidence. In Charles R. Hulten, Edwin R. Dean and Michael J. Harper, editors New Developments in Productivity Analysis. University of Chicago Press. Page 303 – 372. http://www.nber.org/chapters/c10129
Frontier Economics (2014). *Rates of return to investment in science and innovation.* London.
King, M., and G. Tellett, (2020). A Customer Survey for Three of the Core Labs in the National Measurement System. NPL, Teddington. https://eprintspublications.npl.co.uk/8655/

Postel-Vinay, FYB., and H. Turon (2010). On-the-job Search, Productivity Shocks and the Individual Earnings Process. *International Economic Review*, 51(3): 599 - 629. https://doi.org/10.1111/j.1468-2354.2010.00594.x

ANNEX: CREATION OF NEW JOBS WITHIN THE REGULARLY SUPPORTED FIRMS

A crucial claim made in the main body of the document was that each regularly supported firms adds 6.31 new employees to their staff each year due to growth attributed to support from the NMS labs. This annex explains how this estimate was arrived at using estimates from Belmana's econometric study.

Table 4.7 of the Belmana report details the additional jobs for the 175 regularly supported firms used for the main analysis. (This is a sub-sample of the regularly supported firms - trimmed on the propensity score and excluding any firms in receipt of grants from Innovate-UK.) The base-year is 2009 and then there are six treatment years (from 2010 to 2015). The cumulative job years added during the six treatment years was 23,573. The econometric analysis (e.g., DiD) found that 80% of the employment growth was net-additional in the sense that it isn't seen in the matched controls. Thus, there are 18,809 net-additional jobs years among the sub-sample of 175 regularly supported firms. However, we also need to account for significant survival effects attributed to NMS support which have the effect of increasing the attributable jobs years by 4,404. Putting these two numbers together gives us 23,213 additional jobs years among our sample of 175 regularly supported firms.

In the base-year (2009), the sample of 175 regularly supported firms had 58,160 employees. To get the average number of new jobs added each year we could model this as the result of an arithmetic series. (This abstracts from variation across years occurring due to with random noise.) The sum of an arithmetic series is given by:

$$S_n = a + (a + d) + \cdots + (a + (n-1)d) = \frac{1}{2}n(2a + (n-1)d).$$

Hence, the sum of the additional jobs years is given by:

$$S_n - na = d + 2d + \cdots + (n-1)d = \frac{1}{2}n(n-1)d,$$

where in this instance: S = 58,160 + 22,892; a = 58,160; and n = 7. Thus, the expression for the additional job years becomes:

$$\frac{1}{2}.7.(7-1).d = 23{,}213.$$

Solving for 'd' gives us d = (23213 / 21) = 1,105.38. On a per firm basis, this means that each of the 175 regularly supported firms creates about 6.3 new jobs each year.

Table 4.7: Additional jobs in NMS supported businesses

Regularly Supported	2009	2010	2011	2012	2013	2014	2015	Job Years
Gross employment for NMS supported trimmed	58,160	57,622	59,554	61,693	62,684	66,019	64,961	430,693
Job years added each year		-538	1,932	2,139	991	3,335	-1,058	23,573
Additional job years		-429	1,542	1,707	791	2,661	-844	18,809
Sometimes Supported	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Job years**
Gross employment for NMS supported trimmed	145,565	142,241	150,503	149,886	143,720	143,559	139,623	1,015,097
Job years added each year		2,076	-12669	-6624	1188	-1472	-3416	-80181

Analysing impacts beyond increases in economic activity has become a focus for evaluations, with appraisal highlighting the importance of productivity impacts. HMT Green Book (HMT, 2019) notes the importance of looking at evidence about productivity using earnings as a proxy.

The higher wages paid by NPL supported businesses generated job switching to or from a supported business. The impact is stronger for labour switching to a business supported by the NMS. Figure 5.10 shows that employees gain £78.3 in weekly wages after switching to an NMS supported business. Since there are 52 weeks in a year, this translates into an annual wage premium of £4,083.

It was shown above that 6.23 new jobs are created each year at the 175 regularly supported firms. Since the new employees receive a wage premium of £4,083, it follows those wages ('earning power') increase by £25,722.9 (i.e., 6.3*4083) each year for the new employees at each regularly supported firm.

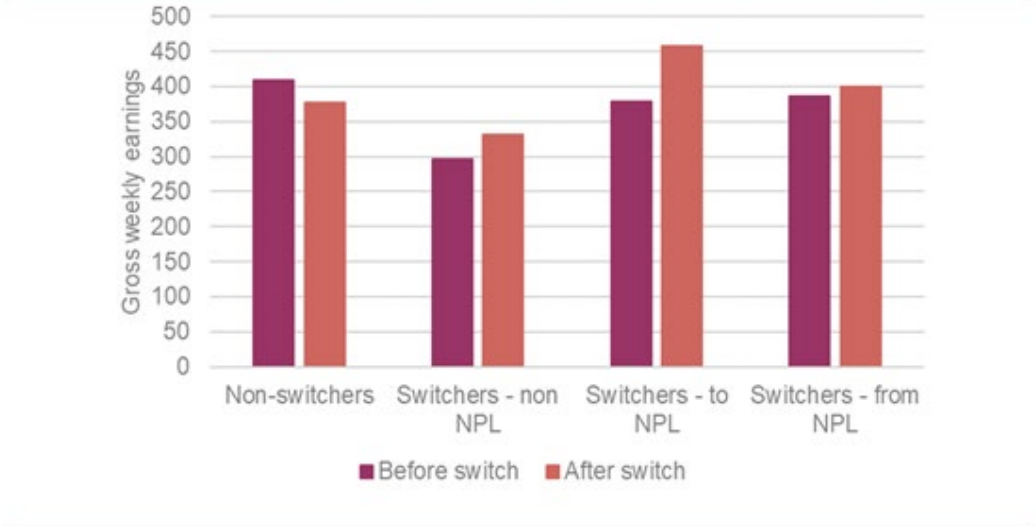
However, wages are only one component of Gross Value Added (GVA) – the other components are profits and taxes. Moreover, page 73 of the Belmana's report says that only half the productivity effects is passed on two a firm's employees:

There is a recognition that only about half of the productivity effect is passed on to workers in the form of higher earnings (Dearden et al., 2005). Firms pass productivity shocks through to employees if employees can use the threat of outside job options to force a renegotiation of their wage (Postel-Vinay and Turon, 2010).

Dearden, L., H. Reed and John van Reenen (2005). The impact of training on productivity and wages: Evidence from British panel data. CEP Discussion Paper no. 674.

The study be Dearden et al suggests that the increase in a firm's profits is roughly equal the increase in wages. Hence, there's an additional £25,722.9 of profits going to each regularly supported firm each year - this gives us £51,445.8 in profits and wages. However, we also need to account for taxation; and in 2019 the tax-to-GDP ratio in the UK was 33%. This suggest that the full increase in GVA was around £76,784.8 per firm per year. (The calculation is: GVA = (Profits + Wages)/(1 – 0.33) = (£51,445.8 / 0.67) = £76,784.8.)

Figure 5.10: Earnings of NMS job switchers



The headline analysis in the Belmana's study focussed on the 175 regularly supported firms for which there's a strong matched control, and for which the growth effects can't be attributed to grants from Innovate UK. However, there are actually 358 regularly supported firms in the population, and so grossing up these average treatment effects to all regularly supported firms gives us around £27 million of additional GVA per year going to all the 358 regularly supported firms; and 2,258.98 new jobs (6.31 x 358 = 2258.98) each year created by these regularly supported firms.