NPL
National Physical Laboratory

NPL REPORT IEA 4

A NET PRESENT VALUE ASSESSMENT OF NPL'S SUPPORT TO UK BUSINESSES

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JUNE 2020

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ISSN 2633-4194

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EXECUTIVE SUMMARY

The National Physical Laboratory (NPL) has a long history of evaluating the economic effect of its programmes, demonstrating a strong connection between firms' growth and past use of NPL's services. This evidence has been used to populate parameters in a model that connects public funding from BEIS to employment and productivity growth among firms that received support from NPL.

This report is organised as follows: Sections 1 and 2 provide context by introducing NPL and the National Measurement System (NMS), and outline the rationale for the existence of NMS public funding. Section 3 explains the sources of impact resulting from NPL's collaboration with the UK's private sector. Section 4 summarises the impact evidence produced by NPL which is then used to populate some parameters in the model in section 5 that assesses value for money. Lastly, section 6 concludes.

CONTENTS

1 THE NATIONAL PHYSICAL LABORATORY

NPL is a government owned and funded national laboratory that specialises in metrology (the science of measurement). NPL's goal is to generate welfare for the UK's society. To that end, NPL carries out a multitude of activities across a wide range of areas – from quantum sensing and composite materials, to radiotherapy and emissions monitoring. In a nutshell, the way NPL creates value for the UK can be summarised as follows. Firstly, NPL conducts fundamental research and performs international measurement comparisons that generate articles in peer-reviewed scientific journals. This enables the development of cutting-edge measurement capabilities that support the creation of primary standards and state-of-the-art instrumentation. This expertise is then used to deliver calibration, testing, and training services to private businesses, hospitals, and universities. In addition, NPL works closely with Innovate UK to offer grant-funded collaborative R&D projects which involve many firms and research organisations.

NPL is part of the National Measurement System (NMS). The NMS is the technical and organisation infrastructure which ensures a consistent and internationally recognised basis for measurement in the UK. It has two central objectives:

1	To enable individuals and organisations in the UK to make measurements competently and accurately and to demonstrate the validity of such measurement
2	To coordinate the UK's measurement system with the measurement systems of other countries.

The following figures give a clearer picture of NPL[1]:

NPL at a glance	NPL has 820 scientific and technical staff and 200 PhD researchers.
	It has turnover of around £90m; £57m of that revenue in annual NMS funding.
	It generates £13m of revenue from sales of measurement services. The R&D performed by NPL supports the introduction of new and improved calibration services, whose benefits fan-out down the calibration chain.
	NPL publishes around 350 articles in peer reviewed journals each year and its scientists perform around £30m of public research work each year.
	It partners with or otherwise provides services to around 500 UK-based firms each year; the lab's scientists collaborate on R&D projects with around 200 UK-based firms each year.

[1] These figures are as of 2019.

2 RATIONALE FOR PUBLIC FUNDING OF NPL

The economic rationale for the existence of a publicly funded organisation like NPL is that measurement R&D is subject to market failure. Indeed, the private investment needed to generate innovative measurement capabilities will always be below the socially optimal level. This occurs because the benefits that measurement R&D generates will always spill over to firms who did not contribute, and this creates a strong incentive to free-ride (Arrow, 1962). The problem is particularly acute in the case of the R&D that the NPL undertakes, because advances in metrology tend to have applications across many sectors. It is this wide applicability that makes the development of these new tools and techniques particularly susceptible to free riding. Consequently, it is argued that measurement should really be seen as a public *infratechnology* (Tassey, 2004), that is, a technology that provides tools and techniques which can be widely applied across a number of sectors to enable further innovation.

In short, NPL and its partners' scientific work generates a pool of knowledge that can be accessed and used by any firm. This fact carries a strong incentive to free ride, and thus, there is a clear need for public funding to complement measurement R&D funded through private spending.

Another key argument for publicly supporting a specialist laboratory like NPL is that the kind of metrology research it conducts requires the setting up of large facilities. In such cases, the fixed costs could be so high that they exceed the private gains to any one company. Therefore, the facility would never be developed on the basis of individual private funds alone, despite the total benefits from the capability outweighing the cost.

Lastly, there is an efficiency justification that supports the idea of a publicly funded metrology laboratory like NPL. Indeed, the high cost and difficulty of maintaining primary standards makes the calibration chain very efficient. NPL supplies a costly high-level calibration service to a commercial laboratory, which then calibrates the instruments of a vast number of users without the need for the calibration laboratory to establish their own primary standard.

Although NPL's portfolio is quite varied, roughly speaking it can be considered to offer one unique good: the time and the expertise of highly trained scientists and engineers. In that regard, NPL can be thought to operate much like a professional services firm which sells the time and the knowledge of its workforce. However, other aspects NPL are far from resembling a typical professional services firm. In particular, there is a fundamental difference when comparing both business models – say between a law firm and NPL. For the former's core business consists of one sole activity: representing its clients in court and providing them with legal advice. For NPL it is not as straightforward because NPL staff need to maintain the measurement capabilities required to deliver high-accuracy measurement services and engage in cutting-edge collaborative R&D projects.

Hence, unlike a law firm, NPL must preserve a knowledge stock that depreciates over time in order to meet the requirements of its users. To do so, NPL's staff carry out a wide variety of activities. These include conducting international key comparisons, participating in proficiency testing schemes, maintaining UKAS accreditation for calibration and testing services, running audits, contributing to standards and protocols, and performing research that generates articles in peer-reviewed scientific journals. This knowledge is then used to meet the needs of beneficiaries, whether they are users of measurement services or R&D collaborative partners. In this sense, NPL could be considered to resemble strongly an orchestra for which the day of the concert is only the tip of an iceberg of constant work over months and years of practice. The show would not be possible without the previous effort put into practice. Similarly, for NPL both activities (the maintenance of capabilities and the delivery of services) are deeply entwined.

Greater public funding allows NPL to hire more scientific staff, which leads to a greater number of UK companies receiving support. NPL's staff help users to either develop new products, design and implement new processes, or prevent their skills and knowledge base to become obsolete. New products enable the supported businesses to increase their market power and command a price premium. New processes enhance their productivity and competitiveness. In any of these two cases, innovative activities supported by NPL lead to additional earnings, either through increased sales or costs savings. Conversely, NPL also helps its users to safeguard their capabilities by transferring valuable knowledge. This is done in a variety of ways such as events, conferences or one-to-one consultancy and training services.

NPL's services lead to increased future earnings or can safeguard the current level of income. In this sense, companies regard NPL's services as investment projects that generate profits over time. A rational consumer would prioritise projects with a higher payoff and, if no budget constraint is in place, would buy NPL's services to the point that the marginal benefit equals the marginal cost. This suggests a downward sloping aggregate demand curve for NPL's services: more profitable projects yield higher future earnings which makes customers more willing to pay for them. This situation is depicted in Figure 1. The horizontal axis shows NPL's number of scientific staff which is a proxy for the volume of services supplied. The vertical axis of Figure 1 (a) is the net present value of the investment projects supported by NPL, whereas in Figure 1 (b), the vertical axis is money measured in pounds:

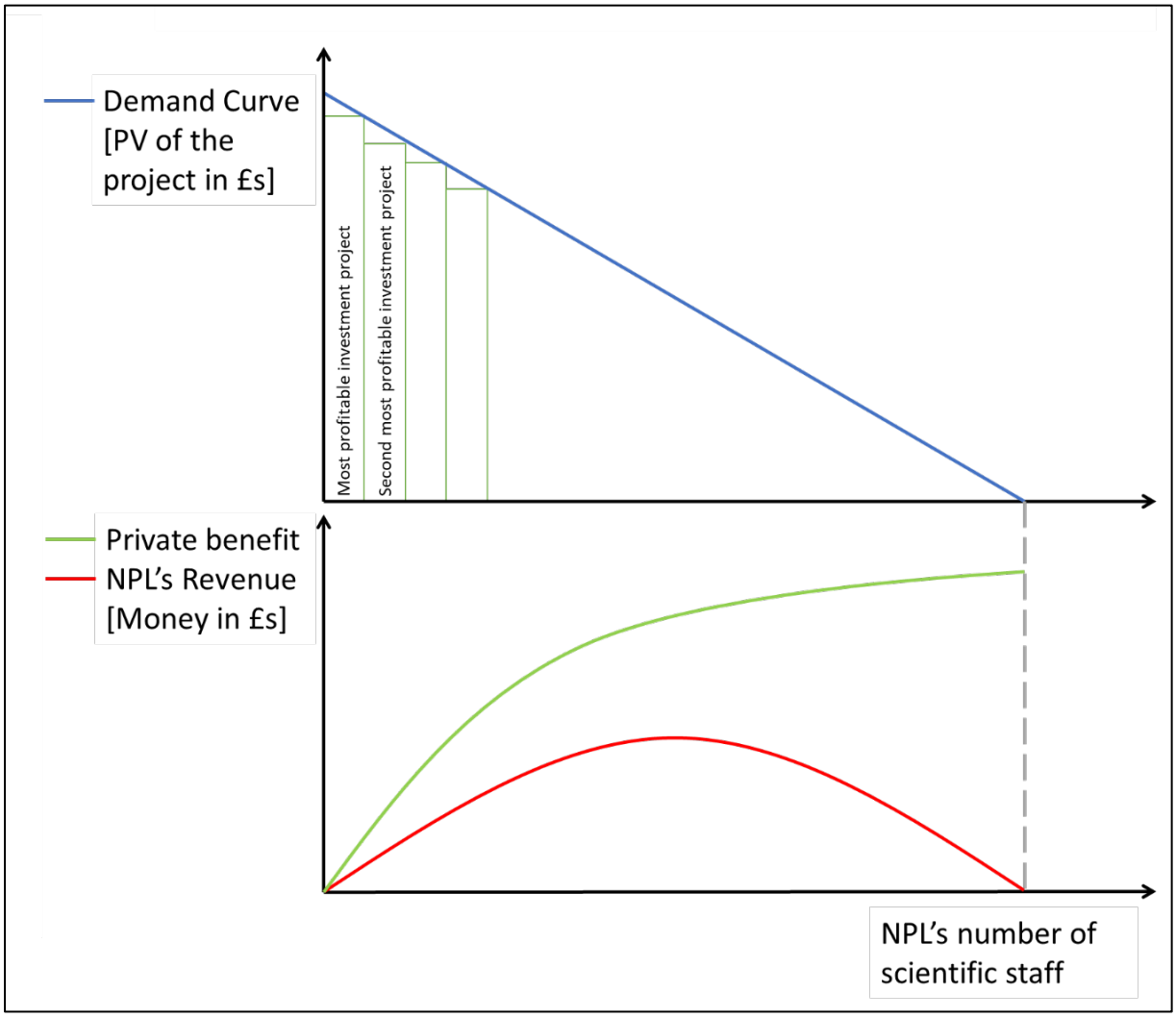

Figure 1: (a) Top: NPL's services demand curve. (b) Bottom: NPL's revenue and private benefit.

Figure 1 (a) considers the demand curve for NPL's services. Naturally, as any other normal good, as the price increases, the quantity demanded decreases. The negative slope of the demand curve reflects the fact that NPL holds a certain level of market power. This is consistent with NPL being a highly-specialised producer. As with any downward sloping demand, there is a point where NPL makes optimal use of its market power and maximises its income. This leads to a bell-shaped curve for NPL's revenue which is outlined in Figure 1(b).

Figure 1(b) can lead to confusion if not interpreted correctly. The reader might wonder how it is possible that NPL's revenue diminishes beyond a certain level of sales – even reaching a point where no income is generated. This may seem counterintuitive. However, note that NPL affects prices indirectly through the number of scientific staff it hires. That is, the more scientists and engineers working at NPL, the more services are provided to UK businesses, and thus, the lower the market clearing price. Hence, this could get to the point whereby the price is so low that it would not matter how much time it sells; income would be minimal (the limiting case being when the price is zero and therefore no income is generated)[2].

On the other hand, from the customer's perspective, there must be a benefit associated with NPL's services. Moreover, we know this benefit should be greater than NPL's income; otherwise the transaction would not take place. However, we also know that any benefits that NPL's customers get must show some diminishing returns, since not all projects carry the same payoff, and in fact, the most profitable projects are prioritised. For that reason, the private benefit curve in the second chart consists of an increasing concave function. Indeed, the private benefit function plateaus at a certain level because there is a finite number of potential users within the UK's private sector.

Up to this point, we have addressed one side of the market, that is, the demand for NPL's services. In order to get a complete picture of the implications for welfare, the supply side must be analysed too. NPL incurs two types of costs. On the one hand, NPL has to cover fixed costs such as the rental of the facilities where it carries out its activity. On the other hand, NPL faces variable costs which are mainly the wages of its scientists and engineers. Hence, it is expected that the total cost is an increasing function of the number of scientific staff with a positive intercept at origin (F). Furthermore, this curve is likely to show some convexity because there is a limited pool of scientists and engineers with the specific knowledge required to work in NPL. The more NPL hires, the more it has to compete with other laboratories within the UK and in the rest of Europe. Therefore, costs (wages) tend to increase more than proportionally. Figure 2 adds the costs curve to the previous set up and focuses on the region of interest.

[2] Formally, this can be seen by considering revenue generated. This is given by $R = P \cdot Q$. Now, if we consider a linear demand curve, price is given by $P = A - BQ$, where A and B are parameters. Hence, combining both expressions we get a quadratic expression for revenue: $R = (A - BQ)Q = AQ - BQ^2$. This parabola has two roots: $Q = 0$ and $Q = A/B$.

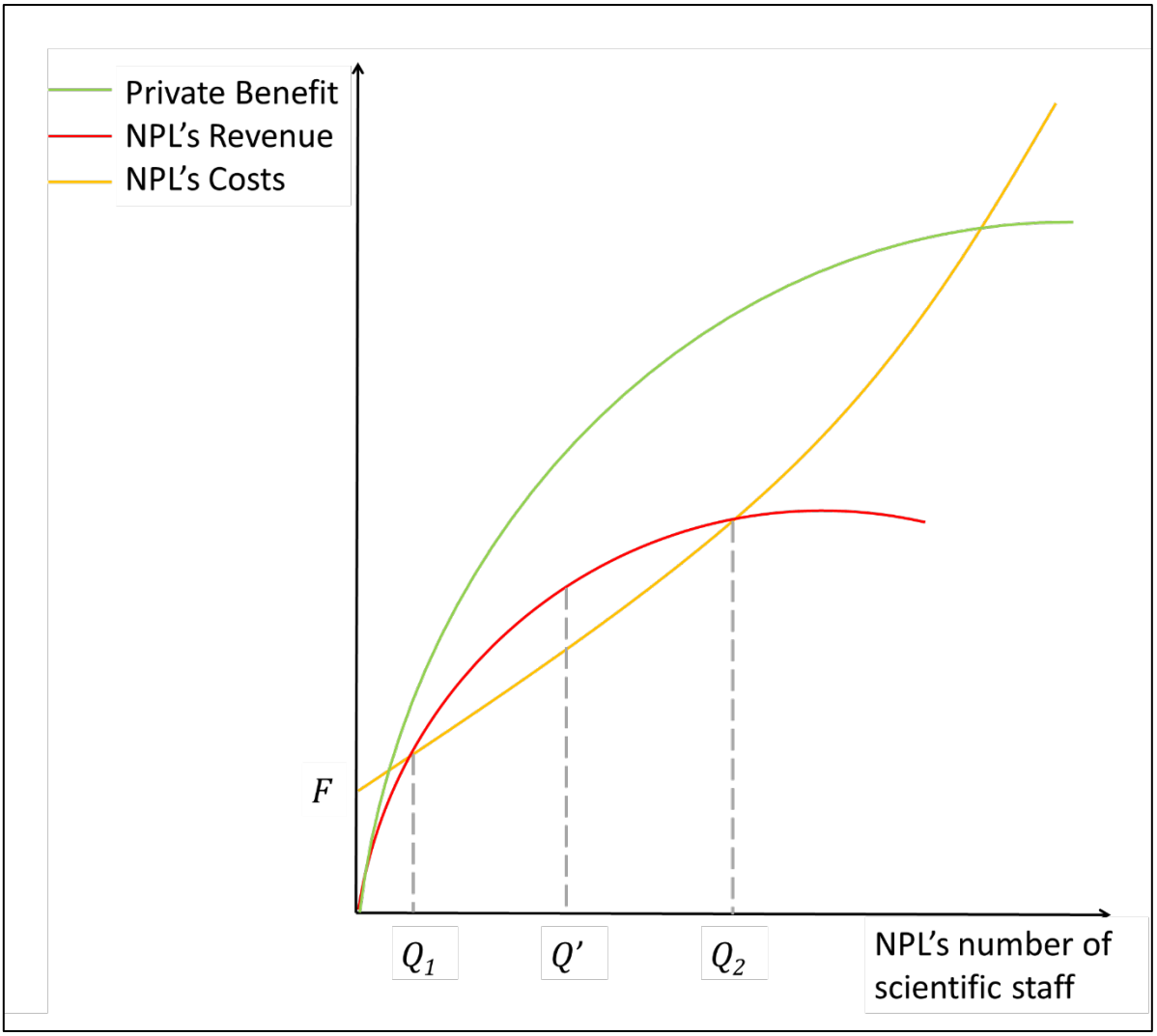

Figure 2: Private benefit and NPL's revenue and costs.

NPL's objective is to generate welfare for the UK (whilst being financially sustainable), rather than maximise its profit. Without public support, it could generate welfare up to the level where revenue equals costs. These are given by Q_1 and Q_2. Q_1 represents the minimum scale that allows NPL to make a profit. Hence, NPL would always seek to expand its production beyond this point. If NPL were an organisation that seeks to maximise its profit, it would make use of its monopoly position by supplying Q'. However, since NPL pursues maximum social welfare, with no public support, it would supply Q_2.

Everything depicted until this point refers to the monetary flows *within* the transaction; in other words, we have only addressed the value for both parties involved, that is, NPL and its customers. Nonetheless, there are wider social benefits from NPL's activity. This suggests that, even if NPL supplies the market with as many services as possible without incurring losses (Q_2), the socially optimal level of output is not achieved. In other words, public intervention is needed to get the maximum value from NPL's capabilities. In the context of Figure 2, this positive externality implies that there is a social benefit curve which is above the private benefit curve. Thus, social benefits consist of a private and a public component which combine to give the social benefit curve. The private component corresponds to the increase in profits by companies supported by NPL. The public component comes from firms that do not directly access NPL's services, but who benefit from NPL because of spillovers. In any case, the optimal level of output is achieved when the vertical distance between the social benefit curve and NPL's cost is maximal (Q_3). To reach this point, a subsidy is needed. This

subsidy would reduce NPL's marginal cost, effectively covering part of the wages of the scientific staff. Figure 3 shows the optimal scale of activity which accounts for public-sector intervention in the form of a subsidy.

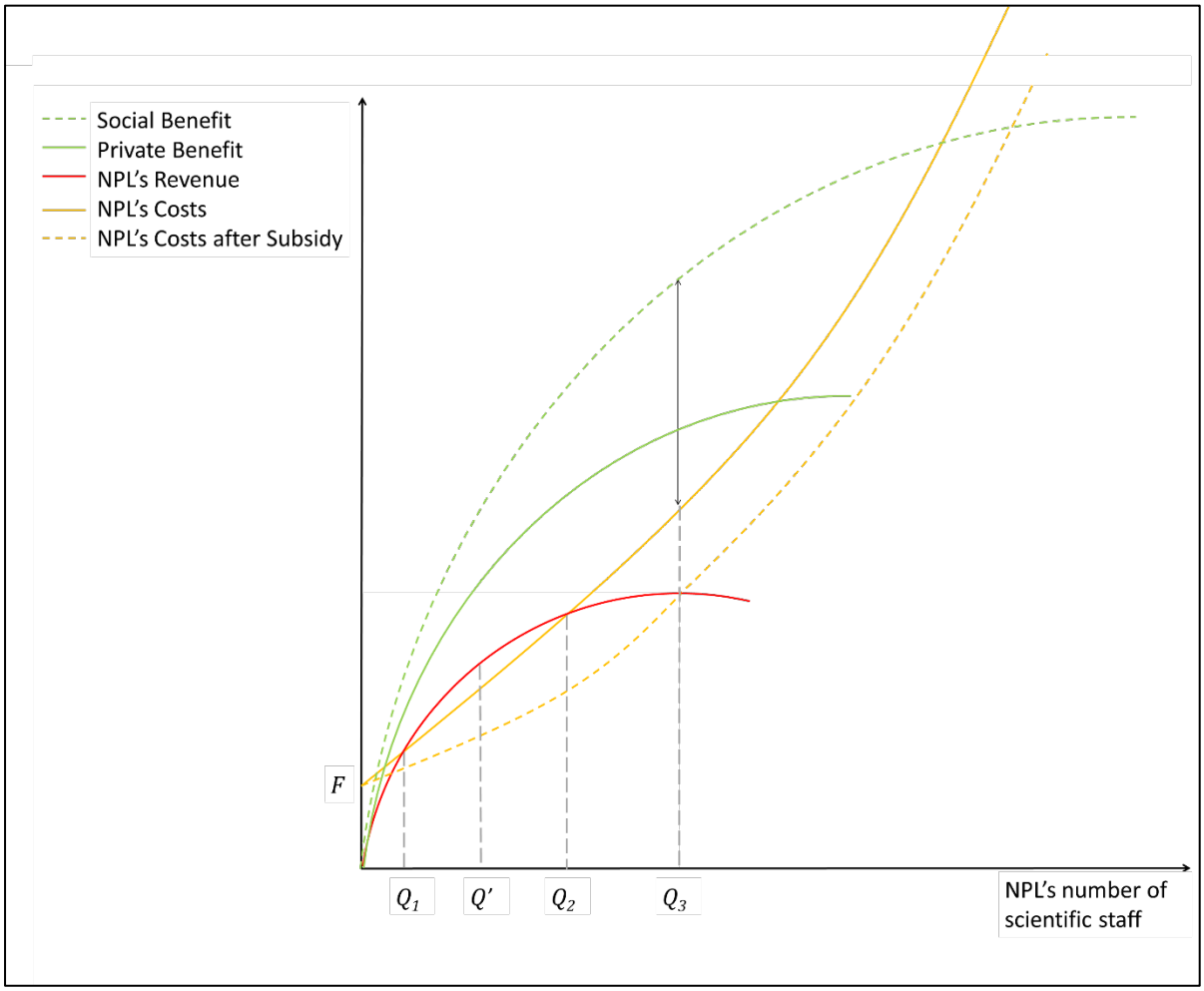

Figure 3: Socially optimal production of NPL's services.

Therefore, the free market outcome does not reflect all the benefits of NPL's services. Public intervention is needed to internalise this positive effect. However, unsurprisingly, users are only willing to pay for the work pertaining to the services they receive. Hence, the way to secure these wider benefits is by subsidising NPL's services. Public funding pays for the maintenance of measurement capabilities that grow with the number of scientific staff. Therefore, NMS funding operates according to a cost-sharing formula that allows scientists to bill the NMS for work performed to maintain their measurement capabilities that are then drawn on to generate competitively won work. In fact, a substantial part of NMS funding is dedicated to this. Therefore, NMS funding is not used to pay for the work done to support private companies, nor it is given to R&D partners in the form of grants. NMS funding pays for the development and maintenance of measurement capabilities which are needed to support UK businesses. Maintenance activities contribute to retain customers, but will not bring in new ones. Conversely, increasing a groups funding allows it to develop new measurement capabilities or to improve existing ones, which in turn helps to attract new customers.

The fact that NPL has commercial income indicates that it is generating value for its users. NPL's customers either pay for commercial services (the mean measurement invoice is around £3,800), or engage in collaborative R&D (typically with a several tens of thousands of pounds private spending). However, although NPL generates revenue from both activities, the market failure that motivates its existence prevents it of being a self-financing organisation. In

other words, although competitively won work creates revenue that helps to cover some of the cost of maintaining NPL's measurement capabilities, it is not enough to repay all of it. Therefore, NPL needs the cost-sharing agreement it has with the NMS to ensure that its scientists and engineers develop and maintain the cutting-edge capabilities needed to serve its customers. Yet the NMS budget is fixed, which means this cost-sharing only operates up to a certain limit[3]. Beyond this point, it would be necessary for any additional scientific staff to bring in enough competitively won work to cover the full cost of their activities. Experience has found that this is close to impossible in practice; which means the size of NPL is effectively set by the NMS resource, which in 2018 was over £56.8 million.

Figure 4 consists of a chart that shows all the sources of government money received by NPL on 2018.

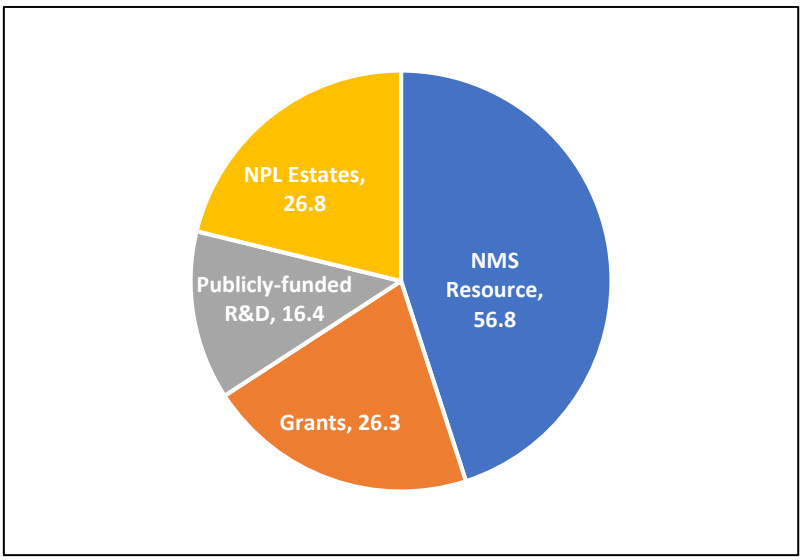

Figure 4: Money received from government by NPL in 2018 (£m).

However, not all of these sources of government money should be considered public funding, in the sense of being state aid. In the case of NPL Estates, this money is received to cover the maintenance and improvement of the facilities in which NPL carries out its activity. But since the government owns the premises, these funds follow from the rental agreement, for which NPL pays an annual rent. With regard to 'publicly-funded R&D', this also should not be considered public funding. The reason being that, though this income is generated through research work that NPL performs for the government (defence and health), NPL is providing a service as it would for any business in the UK.

[3] The kink point Q_3 in Figure 3 reflects the fact that the NMS budget is fixed. Beyond this point, the marginal cost is the same as in the unsubsidised cost curve.

3 IMPACT OF PUBLIC INVESTMENT

NPL's goal is to generate welfare for the UK. There are two types of benefits: direct and indirect benefits. Direct benefits are those that occur *within* supported companies, whereas indirect benefits are those arising *beyond* the supported firm (i.e. typically in competing or vertically linked firms).

3.1 Direct benefits

NPL's staff help users to either develop new **products**, design and implement new **processes**, or prevent their **skills and knowledge** base to become obsolete.

	New products enable the supported businesses to increase their market power and command a price premium.
	New processes enhance their productivity and competitiveness.

In any of these two cases, innovative activities supported by NPL lead to additional earnings, either through increased sales or costs savings.

NPL also helps its users to safeguard their capabilities by transferring valuable knowledge. This is done in a variety of ways such as events, conferences or one-to-one consultancy and training services.

These different effects can be better understood in terms of a generic production function considering capital (K), labour (L) and human capital (H):

$$Y = AK^{1-\alpha-\beta}H^{\alpha}L^{\beta}$$

Where A is the level of technology.

Technology is nothing more than a stock of knowledge that may grow over time thanks to the generation of new ideas through innovative activities and research. This stock also depreciates over time when knowledge becomes obsolete. NPL's support to the UK's private sector innovative activities has a positive effect on the level of technology. Whether through the development of new products or new processes, the knowledge stock expands allowing new production to take place. NPL supports innovation mainly through collaborative R&D projects.

Equally, human capital is also a key input in the production function on which NPL can have a remarkable effect. Human capital can be seen as the skills, knowledge, and experience possessed by individuals. This stock of capabilities also tends to depreciate over time. Technical progress makes certain skills of workers obsolete (e.g. automation in assembly lines). NPL helps its users to maintain and update the necessary skills of their workforce. This is achieved through a variety of services such as training, events or free downloads.

Therefore, NPL generates direct benefits for its users via supporting innovation (which leads to new products of processes being developed) or safeguarding already existing capabilities.

3.2 Indirect benefits

There are two classes of indirect benefits arising from NPL's work with UK businesses: knowledge spillovers that benefit non-users and the so-called *calibration fanout.*

As mentioned in section 2, measurement R&D is subject to market failure because it has the characteristics of a public good. In short, NPL and its partners' scientific work generates a pool of knowledge that may be accessed by other firms. The way this knowledge spills over to non-users is typically through job switchers that move into unsupported companies. These workers may have acquired some skills during the collaboration of their previous employer with NPL, and can now apply those capabilities in their new position. Also, some research is impossible to patent and / or keep secret, and thus, normally generates articles in peer-reviewed journals. In any case there is a clear benefit for companies that did not spend any resources in the R&D activities that led to the new development.

Indirect benefits also exist in cases where NPL generates benefits for firms that are not even competing with NPL's users and are not aware of NPL's role in the measurement infrastructure of the UK. For example, suppose that NPL extends the range of one of its calibration services, which enables the calibration labs who take traceability from them to pass on this extension of the range to their customers. Initially, only a few calibration labs might offer calibrations in this range which could allow them to charge a premium to firms who benefit from this new capability. However, as more calibration labs update the service they offer, this price premium will be eroded by competition and the full benefit of the new service will be passed on to the customers of the calibration labs.

4 EVIDENCE

4.1 NPL's support increases employment growth

In 2016, Frontier Economics analysed the impact of NPL's support on the performance of UK companies. This report found that NPL's support had a positive effect on survival rates and employment growth[4]. This study was a major contribution that constitutes a first attempt to make use of micro econometric methods to assess the impact of the NMS. Based on firm-level data, it analysed the effect on survival and employment up to four years after the receipt of support. To do so, Companies House reference numbers were used to link internal administrative records of invoices for paid services from 2008 to 2012, to annual data collected by the ONS (Office of National Statistics) on all UK companies with more than ten employees. The resulting dataset contained a mixture of customers and non-users that provided information on whether these companies had been R&D active or had received other types of public support.

This dataset was used to estimate the likelihood (*i.e.* propensity score) that a firm with certain characteristics would become a customer of the NMS laboratories. Each customer was matched to a set of non-customers who shared the same characteristics and propensity score. Hence, each customer was associated with a control group of non-users. The average outcome (employment growth and survival up to four years after using a service) for customers of the NMS laboratories was compared to the average outcome for their matched controls. The study argues that the difference between the average performance of customers and their matched controls can be attributed to the support, since three years prior to using the NMS services both had similar growth rates. This indicates that the divergence in performance starts after the customers received support and not beforehand. Therefore, the results of the study show that **companies who use NPL services have higher survival rates and experience an average employment growth of 20 employees within 2 to 4 years.**

4.2 Firms that work with NPL pay higher wages than their comparators

Since wages are the main component of value added[5], it follows that wages are a reasonable approximation to GVA and thus reasonable proxy for economic benefit. If one supposes that the people filling the additional jobs would have been unemployed, then an estimate of the economic benefit is the job-years multiplied by the wage rate. However, the type of jobs being created at firms working with NPL will largely go to people who won't struggle to find a job (e.g. technicians and engineers). And, in the situation where the labour market is tight, the expansion of one firm is likely to come at the expense of other firms – both domestic and overseas. Due to the displacement of market share from one firm to another, the employment effects discussed above cannot really be treated net additional job-years.

However, the companies that engage with NPL tend to pay higher wages to joiners than firms in the control group of non-users. A forthcoming econometric study run in collaboration with Innovate UK and Belmana Consulting (which has already gone through BEIS' peer-review process), finds that;

- Over 80% of job growth seen in NPL supported firms is not seen in comparator businesses.

[4] (Frontier Economics, 2016)
[5] Wages have been estimated to amount around three quarters of total value added.

- Employees moving into NPL supported businesses receive a £2,600 annual wage premium (which remains significant after controlling for age and occupation of earners).

This suggests that the **NPL's support helps create the conditions for these job-switchers to make better use of their capabilities, thus increasing their productivity.** This translates into the wage premium observed by the study. This is based on analysis of data from the Annual Survey of Hours and Earnings (ASHE), which shows the change in wage that occurs when someone joins or leaves a firm supported by NPL. In the current analysis we have used the estimate of the wage premium given by this work.

As this analysis is empirical, there is not yet a settled understanding of what's causing this increase (decrease) in wages that occurs when someone joins (leaves) a firm that works with NPL. However, a plausible explanation is based on the idea that some people possess certain technical skills and that these are highly prized by employers recruiting people for certain specific jobs. However, there may be a limited demand for such skills and so sometimes people with such skills work in jobs where a more generic skill-set is sufficient. These people tend to earn reasonable wages but are nonetheless underemployed because they could be more productive in other roles, i.e. they are not using their full abilities. Thus, support from NPL may enable certain types of firm to expand and, in so doing, help to create jobs that require the specific technical skills that this group of people possess. In short, NPL may be helping to create or sustain roles that allow certain types of human capital to be properly employed.

4.3 Non-users also benefit from NPL

A survey of users performed 2017 found that **38% of NPL's private sector users[6], that report an innovation, said the impact of their innovation has reach beyond direct users.** These users claim that there are benefits going to partners, suppliers and customers that are not monetised. It is difficult to use this to infer the scale of these spillovers but it does provide evidence that such benefits exist.

At the aggregate level, R&D investment generates strong positive economic impacts. For private sector R&D investments, (Frontier Economics, 2014) found that existing literature estimates private rates of return to R&D investments of around 20-30%. Social returns, based on spill-over benefits from R&D, are typically 2 to 3 times larger than private returns. Therefore, our analysis estimates the indirect benefits by doubling the direct benefits, while applying a two-year time lag to allow time for the diffusion of new knowledge to take place.

[6] (Winning Moves, 2017).

5 ASSESSING VALUE FOR MONEY

This section quantifies the impact of NPL. The model is based on the Green Book's established economic guidelines for assessing the economic impact of public programmes (HM Treasury, 2018). The goal of the present analysis is to compute the Net Present Value (NPV) and the NPV-to-DEL ratio for NPL. The NPV is calculated as the difference between the present value of streams of costs and benefits, which are obtained using a discount rate to convert all future deflated figures to values that can be compared across years.

5.1 Public and private costs

The costs to both UK public and private sector are:

- **Exchequer costs** to resource NPL.
- **Direct private sector costs** by those who pay for NPL's services or work on collaborative projects.
- The **private opportunity cost** of not allocating those resources to other profitable activities.

Research by Winning Moves (Winning Moves, 2017) shows that there is a 1:2 ratio between the amount of effort that NPL and the supported firm put into a project. That is, if a project costs £90k in total, then NPL would do £30k of the work (e.g. research) and the firm would do £60k of the work (e.g. development). Thus, NPL's UK commercial income must be multiply by three to account for all the private spending.

Hence, considering both the public and private resources spent in those projects, the total expected real discounted cost is £114m. (Note that this includes the opportunity cost of the private spending.)

5.2 Monetised benefits to UK society

Funding NPL essentially carries two types of benefits:

Direct benefits flow to firms who engage with NPL either paying for measurement services or through their participation in collaborative projects. These benefits are assumed to incur a 2-year time lag before the benefit materialises – observed as employment growth. This assumes that any innovation needs some time to get implemented, that is, the firm's operations require an adaptation period.

Indirect benefits spill over to firms that did not engage with NPL but share the same environment (e.g. market) as the supported firms. In this case, there is an additional 2-year time lag, so that it takes four years for the indirect benefits to materialise in the form of employment growth. This assumes that it takes two years for the knowledge acquired by NPL supported firms to flow to competitors, customers, or suppliers. (The idea is that over this two-year period some knowledgeable employees leave the supported firms and are then employed elsewhere.)

5.3 The model

The assumptions made in this analysis are:

- NPV has been assessed over a 15-year horizon.
- Discounted figures have been computed using the factor indicated by the Green Book. For the appraisal horizon considered this discount factor is 3.5%.
- Adjustments to inflation have been made using ONS deflators forecast (these are estimated by the Office for Budget Responsibility).
- A 5% return has been used to account for the opportunity cost of capital invested.
- A 14-year period is used to account for the duration of the opportunity cost of capital invested[7].
- The average lifetime of an innovation is expected to be 10 years.
- Wages account for three quarters of gross value added (GVA). Hence, any wage premium estimated by the model needs to be scaled up to account for profits[8].

Along with these assumptions, the following pieces of information will now be combined so as to infer the effect on employment growth among supported firms:

- NPL receives £83.1m of public funding; £56.8m of that revenue is NMS funding, and £26.3m are grants to engage in R&D[9].
- NPL invoices records show over 500 distinct paying customers per year.
- The expected impact on a supported firm amounts to around 20 additional employees 2 years after working with NPL (because direct benefits take some time to realise). As mentioned above, the innovation enabling this growth is expected to last for 10 years. Therefore, since NPL works with around 500 companies per year, this support is expected to generate a total of 10,000 additional jobs per annum in 2 years. It has become traditional to talk about additional job-years rather than of jobs being created or saved. The idea is that one job running for one year is “one job-year”. If that job continues for another year, then its two “job-years.” This concept is meant to make it easier to talk about cumulative employment effects taking place over a number of years. Hence, NPL’s support is expected to generate 100,000 job-years within the 15-year appraisal horizon considered[10].
- Employees moving into NPL supported businesses receive a £2,600 annual wage premium. The idea is that the new jobs created following support from NPL, generate opportunities for people with specific technical skills. Hence, people who were previously in less demanding jobs now get to use their full abilities, which creates value as people are employed more productively.

The current analysis assumes that NPL helps to shift jobs in the direction of innovative firms who build human capital and retain staff by paying a wage premium. The following table presents the direct economic benefit in nominal undiscounted terms, to give a sense of the value added by NPL:

Wage Premium Analysis	
Average wage premium per annum (£)	2,600
Total full-time-equivalent job years (000s)	100
Cumulative wage premium (£m)	260

[7] The duration of the perturbation is calculated as the time taken for the private investment to make back the principal invested plus any returns earned in the counterfactual situation of a non-sunk investment.
[8] Effectively by multiplying the resulting estimated cumulative wage premium by $4/3$.
[9] Arguably, NPL receives an additional £16.4m of public funding in the form of publicly-funded R&D. This money pays for the building-up of measurement capabilities that are later drawn on to provide services to the public sector. However, these wider social benefits have not been assessed by the model, and therefore the associated cost should not be considered either.
[10] Note that the appraisal horizon set allows for benefits to completely taper. That means that no benefits are left over because the horizon not being long enough.

5.4 Final Results

In order to assess value for money, both the Net Present Value (NPV) and the NPV-to-DEL ratio must be computed. The following table summarises the outcome of the NPV analysis:

NPV Analysis	
DEL (£m)	83
Economics Costs (£m)	114
Total Economic Benefits (£m)	691
NPV (£m)	578
NPV-to-DEL ratio	6.95

The NPV is calculated as the difference between the present value of streams of costs and benefits. The first two rows in the table constitute the present value of the costs: a direct cost to the exchequer (DEL) of £83m (the public funding received by NPL) and a total cost of £114m once the private costs (direct and opportunity) are considered.

The present value of the benefits is estimated at £691m. Considering both figures, a net present value of £578m is computed as the difference of both. Lastly, the NPV-to-DEL ratio is obtained by dividing the NPV by DEL. This ratio shows that a net benefit of almost £7 is expected for every pound invested by the public sector. If private sector resources and opportunity costs are taken into account, this net yield is a 4:1 ratio (5:1 benefit to cost ratio).

6 CONCLUSION

This report makes use of impact evidence produced by NPL to generate a model that assesses the net present value of funding NPL; the evidence used shows that:

	Businesses supported by NPL grow more rapidly than unsupported comparators - on average, supported companies have around 20 additional employees 2-3 years after working with NPL, when compared to a matched control group of similar unsupported ones.
	Companies with a propensity to engage with NPL pay higher wages (£2.6k premium) than the typical firm, because of the knowledge and experience needed to work with NPL.

The analysis based on these pieces of evidence finds an expected gross benefit of £691m, which leads to a net present value of **£578m** and a 7:1 NPV-to-DEL ratio, once investment costs are deducted over a 15-year appraisal horizon.

REFERENCES

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In R. R. Nelson, *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609-625). NJ: Press: Princeton.

Frontier Economics. (2014). *Rates of return to investment in science and innovation.* London.

Frontier Economics. (2016). *The Impact of Public Support for Innovation on Firm Outcomes.*

HM Treasury. (2018). *The Green Book: Central Government Guidance on Appraisal and Evaluation.*

Tassey, G. (2004). Underinvestment in public good technologies. *The Journal of Technology Transfer, 3*(1-2), 89-113.

Winning Moves. (2017). *National Measurement System: Customer Needs and Impact Survey.* NMS.