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Linking Industry to Neutrons and X-rays

ESTIMATING THE VALUE OF LINX

Thoughts at the halfway point

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Revision Record

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Executive summary

We were tasked by Innovation Fund Denmark (IFD) to evaluate the LINX Partnership's impact on job creation and (revenue) growth - both phenomena directly tied to companies. We therefore gathered publicly available financial data for the last five years for all the LINX partnership companies. We utilized the historical R&D performance of each company to predict the impact of their participation in LINX. We introduced the LINX multiplier to reflect the nature of the specific LINX projects each company was engaged in and how the project might affect the company going forward.

As at July 31, 2018, DKK 15.5 million had been spent in 15 LINX Focus Projects, 12 of which were still ongoing. In the mid- to long term, LINX research will arguably impact company revenue and jobs much the same way internal R&D does. Our model showed a positive revenue impact of > DKK 400 million and a positive job creation impact of > 300 jobs.

So far, participating companies have used LINX to pursue new research avenues and/or to complement existing R&D. We see no signs of LINX crowding out internal research.

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1. Background

In 2016 Innovation Fund Denmark (IFD) announced that it would support the LINX Partnership (LINX) with DKK 50 million out of a total five-year budget of DKK 78 million. LINX is a societal partnership (or industry portal) the objective of which is to facilitate and enable Danish industry's use of and access to, the large-scale X-Ray and neutron facilities ESS and MAX IV now under construction in Lund, Sweden.

In a wider sense, LINX' ambition is to bridge the traditional gap between industry and academia and it is based on industry pull. Individual focus projects under the program take the problems as identified by participating companies themselves as their starting point. The companies then work closely together with one or more of the three participating universities to find a solution.

In the traditional terminology, the IFD's support of LINX would therefore fall under the heading of applied rather than basic research.[1] A large number of LINX projects in the areas of materials science, non-destructive testing, biotechnology and others are currently in progress or have been completed (please see www.linxproject.dk for more details).

Innovation Fund Denmark is a public tax-funded entity which supports Danish R&D to create new knowledge, jobs and growth in Denmark. Funded projects are expected to demonstrate that they indeed do fulfill these objectives.

The objective of this note is to discuss the value created by IFD's investment in LINX at a time where the program is approximately halfway through its projected five-year period.

[1] Applied research is scientific research designed to solve problems in the modern world as opposed to basic research which is driven by scientific curiosity. However, a small portion of the LINX budget has been set aside for Global Development Activities which may be considered basic research.

2. The LINX Value Proposition

A fundamental objective of the LINX program has been and continue to be to facilitate industry engagement and lowering entry barriers to the maximal extent possible. Both large and small companies are invited to participate in LINX through various means and in various ways.

It has already been established that companies collaborating with academia gain a productivity advantage: In the total group of R&D active companies in Denmark, those companies which collaborated with a university or a GTS (Godkendt Teknologisk Institut) enjoyed significantly higher productivity gains than those which did not.[2]

However, in LINX this fundamental industry-academia collaboration idea is taken a step further to include collaborations between companies that share an interest in the same topic and between universities which offer different approaches to these topics. As opposed to a traditional contract research collaboration a LINX project frequently has more than one industry partner and more than one university engaged. This greatly increases innovation. Several LINX companies report that they have come to see their development or quality issues in an entire new light after joining the collaboration and that this eye-opening effect primarily was a result of discussions with other companies in the same project.

In the academic literature this would be known as network benefits. Companies get to discuss the implications of what they have learned with academic experts and other partner companies in the project (if they so desire). They become acquainted with state-of-the art techniques and are pointed in new directions and to other networks. These benefits may be intangible and hard to measure but that does not mean they are not real.

To make such wide-ranging collaborations work in practice, LINX has developed a number of new tools, such as multiparty collaboration agreements that handle potential IPR, confidentiality and conflict of interest issues, as well as new project management processes and reporting tools that bridge the gaps in objectives and traditions that undoubtedly - and understandably - exist between the industrial and the academic worlds. By its support of this mutual learning process, the IFD effectively facilitates future industry-academia collaboration both outside and beyond LINX.

[2] Uddannelses og Forskningsministeriet, December 2017: *Erhvervslivets investering i Forskning og Udvikling i 2017.*

Through conferences, workshops, industry meetings and other means LINX actively work to create awareness among Danish companies of the possibilities created by existing and emerging technologies in the X-ray and neutron field. Scientifically, Denmark has long been at the forefront when it comes to the application of advanced X-ray, neutron and imaging technologies in applied research. An important part of LINX' role is to promote this strength position both in Denmark and neighboring countries as an industrial asset on which future industrial competitiveness will rest.

LINX lowers the companies' cost of R&D, not just because of the IFD financial contribution but as an integral part of the collaborative nature of the entire program. When two or more companies share resources to address a topic, say, can a computer model to describe fiber orientation be developed, everybody benefits. If the R&D is sufficiently basic, issues related to confidentiality and the granting of commercial rights to any inventions can usually be handled.

Hence it may be argued that LINX creates more value for projects that operate at an earlier TRL level, not just because the individual participant company gets more bang for its buck but also because the results can branch out to more downstream applications in more companies.[3] Early research is risky but participation as a project partner in LINX greatly reduces this risk, much more so than would be the case for late stage development projects.

The partner companies sometimes use LINX to answer questions they would not otherwise have sought answers to, i.e. to obtain information they have hitherto rightly or wrongly considered nice to know rather than need to know. In contrast, the scope of a company's own R&D will usually be closely linked to its current products and processes. Several LINX projects appear to be aimed at widening the companies' knowledge and capabilities outside their current scope. Such external scope-enhancing R&D has a value beyond the company's internal R&D but is difficult to quantify.

In a similar vein, the information sought in LINX projects often relates to a longer term, something which the partnering companies suspect or already know will be important in the future. The LINX R&D may very well be considered applied research but at times it has a probing, almost basic character to it. As such, the LINX R&D may be less commercially valuable than the company's own R&D in the short term but more valuable in the long term.

[3] The LINX projects launched so far have had TRLs (Technology Readiness Level) between three and five

Having said all that there are also LINX projects (perhaps particularly among the smaller participating companies) which have the appearance of R&D projects the companies could and probably would have conducted in-house had they been in possession of the financial and organizational muscle to do so. They appear to be aimed at issues that are essential to the company's business. In some instance this even applies to larger companies, inasmuch the research although essential could not ever have been performed in-house because it requires technology and expertise that only resides in an academic setting.

The LINX partner Rockwool exemplifies several of these themes. The company is a world leader in fibre based building materials. It would benefit enormously from being able to describe exactly how the properties of its products relate to the length, width and orientation of the fibres inside the material, and then being able to predict and control these parameters. But on a much shorter term, this knowledge is also a simple quality control tool with an immediate ability to save costly test runs of Rockwool's furnaces.

3. Why Companies Invest in R&D

3.1 R&D seen from the companies' perspective

Companies invest in R&D to develop and/or improve their services and products. A good deal of evidence supports the notion that R&D helps companies increase their productivity.[4] There is also evidence that companies which invest in R&D consistently perform better than companies that do not (i.e. it is not just the *how much* but also the *how often* that matters).[5]

3.2 What determines how much companies spend?

The factors that determine R&D spending include but are not limited to:[6]

- Cash flow and sales. This relationship has been strongly supported in multiple investigations. The correlation is particularly strong for smaller and younger companies. Companies with strong cash flows and growing top lines are more likely to invest in R&D[7]

- Competition. The more competitive an industry is, the more its companies invest in R&D

- The availability of public subsidies and tax credits. The correlation seems particularly strong for smaller companies

- Proximity to sector relevant academic research institutions. This includes substantial empirical evidence that joint ventures with academia increases private R&D spending

All the above are described as one-way causal relationships but particularly the first – cash flow and sales - goes both ways: Companies invest in R&D when they have strong cash flows and sales. But they also have strong cash flows and sales because they invest in R&D.

[4] See Zvi Griliches: *R&D and productivity. The econometric evidence*. University of Chicago Press, 1998.
[5] Börje Johansson and Hans Lööf: *The Impact of Firm's R&D Strategy on Profit and Productivity*. CESIS Electronic Working Paper Series, no. 156, 2008
[6] This overview draws on Bettina Becker: *The Determinants of R&D Investment. A survey of the empirical research*. Loughborough University, 2013
[7] Some of this evidence is Danish. See Carter Bloch: *R&D investment and internal finance: The cash flow effect*. Economics of Innovation and New Technology, 2004. Block concludes that capital market imperfections in Denmark's predominantly debt-based system means that particularly smaller firms only invest in R&D when they can effort to, i.e. when their cash flows are good

Perhaps not surprising, there is therefore also a well-documented causal relationship between company R&D spending and company market value. This is because the financial markets look at a company's reported spending on R&D and makes a judgment of its merits. In some countries and in some industries, the correlation is stronger than in others. For instance, a 2004 paper showed that the correlation is equally strong in France and Germany but almost absent in Italy.[8]

3.3 Danish R&D spending

Denmark spends around DKK 60 billion on R&D per year. Most, i.e. around two thirds of the R&D spending is private. The remaining third is publicly funded, a small part of it from outside Denmark, such as the EU's Horizon 2020 program.[9] Danish companies' R&D spending has been relatively constant around DKK 40 billion per year (around 2% of BNP) since 2008.

There is some evidence that Danish industrial R&D is increasingly concentrated on fewer and larger companies and that the total number of Danish companies with R&D activities is in decline. In 2015, 187 Danish companies with more than 250 employees (less than 10 per cent of the entire group of Danish companies with R&D activities) accounted for 73 per cent of all private R&D investments in Denmark.[10] This development is a result of both a decline in the R&D intensity in the group of smaller companies and a significant increase in the R&D intensity in the group of large companies.

If R&D is indeed becoming an activity for the few, lowering barriers to entry and facilitating access to the academic world particularly for the smaller companies should continue to be an important government goal.

The two LINX partner companies Novo Nordisk and Novozymes together stood for 40 per cent of all private R&D investment in Denmark in 2017. For other, perhaps smaller companies which may not be known for their R&D intensity or scientific excellence, participation in LINX and its various network activities has proven to be a highly effective employer branding tool.

[8] Bronwyn H. Hall and Raffaele Oriani: *Does the Market Value R&D Investment by European Firms? Evidence from a Panel of Manufacturing Firms in France, Germany, and Italy*. NBER Working Paper, 2004

[9] The distribution changes marginally depending on whether one looks at where the money came from or where it was spent. As a rule, funding is spent in the sector where it originates

[10] Uddannelses og Forskningsministeriet, December 2017: *Erhvervslivets investering i Forskning og Udvikling i 2017.* The report makes no secret of the fact that the statistical material concerning the number of companies with R&D activities is questionable

4. Why Governments Support Private R&D

4.1 The classical case

In the classical micro-economic model, companies are assumed to be faced with a high number of R&D project opportunities for which they consider the costs and benefits to calculate the rate of return. The company – assuming no capital constraints – then prioritize the opportunities and finance all those projects whose rates of return exceed its cost of capital.

It follows that some worthwhile R&D projects are not funded. To increase the number of funded projects the government may; a) attempt to increase the marginal return on the project opportunities themselves and/or; b) reduce the marginal cost of capital.

In this model, the IFD's support of LINX would be an example of b) whereas the building of ESS and MAX IV is an example of a).

In the classical model the R&D investments whose productivity or product enhancing returns are immediately obvious will have already been undertaken by the private sector itself without support from the government. It therefore follows that publicly funded R&D will - and indeed should - have a lower company return on investment compared to the R&D funded by the companies themselves.

If not, publicly funded R&D could in fact be substituting or crowding out private R&D instead of complementing it.[11] If real, this substitution effect would add to the difficulty of measuring the impact of the public funding.

4.2 Newer arguments and research

More recent arguments take the case for public R&D support beyond the classical model. A well-known argument is that government has a longer-term objective and is more interested in even incremental productivity improvements than industry. This is because long term industry productivity growth matters enormously to society. As pointed out by Ben Bernanke, a growth rate of 1.5% in output per person doubles living standards in two generations (i.e. approximately 47 years). Add a percentage point and it

[11] For a discussion, see Paul A. David, Bronwyn H. Hall and Andrew A. Toole: *Is public R&D a complement or substitute for private R&D? A review of the econometric evidence*. NBER Working paper 7373, 1999.

takes only one generation (28 years).[12] This type of long term thinking is and probably should be beyond most companies.

Another line of arguments has focused on the so-called positive externalities to knowledge. Even if companies were not capital constrained and were in fact able to fund all the R&D they desire, society would still have an interest in spending more than the sum of the companies' private R&D spending. This is because knowledge, a scientific infrastructure and an educated workforce are all public goods. Investing in them carries a return to society over and above the returns required and received by company shareholders.[13]

Knowledge resides in individuals and networks. A society's and indeed a company's continued access to these individuals and networks may be as important as the knowledge itself. Access is an intangible benefit often taken for granted. Its value is impossible to quantify. But it is nevertheless a vital part of the framework government creates within which industry can thrive and compete.

4.3 Public and private R&D is intertwined

Government support will have an indirect effect on the marginal returns of the companies' own private R&D. For instance, large government funded R&D infrastructure projects such as ESS and MAX IV will lower the cost of conducting private R&D, hence increasing such R&D investments' returns. And there may be informational spillover effects where the knowledge which industry gains from a government sponsored activity in time allows them to make better decisions about their own private R&D.

In this way, public funding of R&D stimulates further private R&D activity down the line. Indeed, this is a key finding in the Novo Nordisk Fonden study highlighted in section 4.5 below.

4.4 Measuring the impact of public R&D funding is inherently difficult

Given the discussion above, it should come as no surprise that measuring the impact of the governments support is inherently difficult. The list of problems includes but is not limited to:

[12] Ben Bernanke: *Promoting Research and Development. The Government's Role*. Issues in Science and Technology, Volume XXVII Issue 4, 2011

[13] A reference discussion is Ben Martin and Ammon Salter: *The relationship between publicly funded basic research and economic performance*. SPRU Review, 1996

- We do not know and cannot know what would have happened without the public support

- The impact may lie far into the future or be most profound in unexpected areas. We may be looking for the impact in the wrong time and in the wrong place

- Data - especially consistent data - may not (read: Will hardly ever) be obtainable from the various companies and academic institutions effected

- A plethora of other factors will be at play during the measurement period. Causal relationships will be blurred

These challenges are well known among policy makers, policy implementers and academic researchers. Indeed, a generally accepted formula for calculating the social economic return on public R&D funding does not exist. Furthermore, any method by which one tries to approach such a value creation estimation is subject to very relevant criticisms.

4.5 Recent Danish research

An overview of the "*What-is-the-impact?*" field seen from a Danish point of view can be found in a 2012 report from Ministeriet for Forskning, Innovation og Videregående Uddannelser.[14] The report references a long list of previous academic research in the field and concludes that public funding of R&D leads to productivity gains and carries an overall social economic rate of return of 20 to 40 per cent.

Another noteworthy recent Danish study is Novo Nordisk Fonden's 2016 study of the impact of public R&D funding on the Danish life sciences industry.[15] The study is based on econometric studies of data from over 400 Danish companies in the life sciences industry, scenario runs on the ADAM macroeconomic model and interviews with experts and industry participants. The study concludes that every DKK 1 the Danish government spends on life sciences R&D leads to an additional DKK 4 to 11 spent in the private sector, and that increased public R&D spending in Denmark generally leads to significant BNP growth.

[14] *Offentlig Forskning – effekter på Innovation og økonomisk vækst*. Ministeriet for Forskning, Innovation og Videregående Uddannelse, 2012

[15] Novo Nordisk Fonden, 2016: *Forskningsøkonomi. Samfundsøkonomisk effektanalyse af finansiering af offentlig forskning*. This study also contains a good review of the literature and findings to date.

5. Measuring the Value of LINX

5.1 How effective is LINX in creating jobs and growth?

In industry, there is a big difference between "R" and "D", even if they do feature in the same line in the annual report. A company may be able to calculate the return on an investment in Development but that will hardly ever be the case for Research.

Companies cannot reliably predict the outcome and calculate the return of their research investments, but they nevertheless continue to make these investments. In the company accounts research is treated as a cost, i.e. the expense is carried to the profit/loss statement and is not capitalized and depreciated. In contrast, large near-market development projects will be capitalized and subsequently depreciated in the company's books. A calculation (often based on discounted cash flows) will have been made of the value of the project and this calculation is revisited and the book value adjusted from time to time.

LINX is usually more "R" than "D". It is therefore unrealistic to expect that the participating companies would (or could) have calculated the return on their commitments before they entered the program.[16] Hence, to arrive at an estimate of the value of LINX we cannot just ask each of the companies to present their NPV calculations and then add the values up.[17]

Fortunately, the IFD focusses on jobs and (revenue) growth, both of which are phenomena which can in fact be tied to companies: The LINX participant companies employ people and sell products and services. This is therefore where we will look.

Below we suggest a crude assessment method which has the benefit of being based on mostly readily available company data while taking into consideration the R&D profiles of each of the companies participating in LINX. This method relies on three assumptions:

- LINX R&D is correlated with company revenue in the same way as the company's own internal R&D
- LINX R&D does not crowd out a participating company's own internal R&D

[16] Indeed, we asked and none of them have

[17] Even if we could, these calculations would fail to capture the additional social returns discussed elsewhere in this note

- Time is not a factor. LINX R&D adds value when the expense is incurred

5.2 Calculating a value of the LINX R&D

We gathered publicly available financial data for the last five years for all the LINX partnership companies. If five-year data were not available, we included data since the company's inception. For those companies that do not disclose revenue and/or R&D cost data we either received the data directly from the company under a Non-Disclosure Agreement or we made estimates based on peer companies, industry characteristics, previous reporting and similar.

We can now tie LINX value to the company's own R&D: If a company participates in a LINX project that has a total budget of, say, DKK 2 million, our assumption is that this project will have the same kind of impact on the company's performance and job creation as DKK 2 million spent on R&D in-house. To determine exactly how much of an impact, we introduce the LINX multiplier. If LINX R&D and own R&D are equally effective in creating new revenue and jobs, the LINX multiplier is 1. If LINX R&D is more effective, the multiplier is greater than 1, and vice versa. The LINX multiplier is further explained in section 5.3 below.

Let us consider two examples:

The Small Company invests DKK 5 million in R&D every year and has annual sales of DKK 200 million. It has 200 employees. Its Sales-to-R&D and Employees-to-Sales ratios are thus 40/1 and 1/1, respectively (i.e. DKK 1 spent on R&D led to DKK 40 million in new sales and each DKK 1 million in new sales led to 1 new job).

The Small Company participates in LINX project XYZ that has a budget of DKK 2 million. The DKK 2 million LINX R&D spend has the same effect as the company's own R&D (i.e. the LINX multiplier is 1). If so, DKK 80 million in new sales is created (DKK 2 million x 40), leading to 80 new jobs (DKK 80 million/1 million).

The Big Company invests DKK 200 million in R&D every year and has annual sales of DKK 15,000 million. It has 10,000 employees. Its Sales-to-R&D and Employees-to-Sales ratios are 75/1 and 0.67/1 million, respectively. If The Big Company participates in LINX project XYZ, also with a DKK 2 million budget, DKK 150 million in new sales is created, leading to 100 new jobs.

Thus, if The Small Company and The Big Company both participate in LINX Project XYZ, DKK 230 million in new sales is created, leading to 180 new jobs. Some of these jobs will be in Denmark, some will not. The jobs created in The Small Company are more likely to be in Denmark.[18]

It would appear the LINX R&D creates more value in The Big Company, which on the surface would seem logical since large companies can apply new knowledge on a larger base whether in the form of product improvements leading to new global sales or cost reductions leading to increased profits and company value. However, the difference in the example above actually stems from the rate at which the two companies turn R&D into additional revenue. Two companies spending, say 2.5%, of their annual revenue on R&D will create the same amount of additional revenue from one extra million DKK of R&D, namely DKK 40 million. How many jobs the two companies create likewise depends on the relationship between revenue and employees, not their size.

In our example, the benefit derived from LINX in a small company is just as large in nominal terms but may be much more significant in relative terms. DKK 40 million in additional revenue would be significant if not downright crucial for The Small Company but hardly noticed in The Big Company.

5.3 The LINX Multiplier

Is LINX R&D more or less impactful than internal R&D? We assume the multiplier is greater than 1 when the project:

- Could have a profound impact on the company's market position (e.g. BioModics).
- Is "easily" implemented in the company's processes upon successful completion (ROCKWOOL).

We assume the multiplier is smaller than 1 when the project:

- Is in a very early stage, exploratory in nature, high risk (low TRL).

[18] Danmarks Statistik: *Virksomhedsgiganter eller gazeller. Hvor skabes størst vækst?* DST Analyse 2018:9, June 6, 2018. The analysis shows that from 2009 to 2016 the growth in the number of full time Danish jobs was highest in companies with less than 50 employees. One reason is that many of the largest Danish companies moved manufacturing and support operations to foreign subsidiaries during this period.

- Only relevant for a small subset of the company's activities (Novo Nordisk).

We always keep the multiplier between 0.5 and 2 (half as impactful to twice as impactful). There is no particular reason for this, other than the fact that estimated deviations measured in orders of magnitude become harder to explain. Why would LINX R&D be ten times more impactful than internal R&D? Or ten times less?

We generally assume the multiplier is below 1 for the larger companies and greater than 1 for the smaller companies unless there are specific reasons this would not be the case. Large companies are more likely to use LINX on lower impact projects they would not otherwise themselves have financed. Hence, these projects would *a priori* be thought to have a lower impact. In any event the LINX multiplier is set specifically for each of the participating companies and the particular project(s) they have engaged in and were based on input from the company in question: How did the company rate the LINX project along a number of dimensions (not shown) and how impactful compared to own R&D did the company think the project would turn out to be.

5.4 Large LINX companies

The large LINX partnership companies are Rockwool, Velux, Grundfos, Novo Nordisk, Novozymes, LM Wind Power and Tetra Pak. The relevant combined five-year key figures of these companies are depicted in table 1 below:

Table 1: Large LINX company data

TOTAL, LARGE LINX COMPANIES (mDKK)	2017	2016	2015	2014	2013
Revenue	260.452	256.912	252.796	223.603	215.426
R&D expenses	19.851	20.282	19.362	19.460	17.108
R&D % of revenue	*7,6%*	*7,9%*	*7,7%*	*8,7%*	*7,9%*
Employees	128.668	122.397	118.599	119.016	116.495

The seven large LINX companies had combined revenues of DKK 260 billion in 2017 and employed more than 125 thousand people. They spent an average of 8% of annual revenues on R&D, however with significant variation. Novo Nordisk and Novozymes spent considerably more (> 10%) the remainder considerably less (< 5%).

An analysis of individual company data (not shown for confidentiality reasons) gives rise to the following total job and growth creation in the group of large LINX companies.

Table 2: Large LINX company revenue and job creation

LINX participation, all projects (mDKK)	10,45
Average LINX multiplier	0,9
Revenue created (mDKK)	405
Per cent of 2017 revenue	0,16%
Number of jobs created	322

Based on an average LINX multiplier of just below one, the estimated impact of LINX for the large companies would be > DKK 400 million in new revenue and > 300 new jobs. Although seemingly large, please note that these revenue and job numbers are a tiny fraction of the 2017 levels exhibited by this group of companies.

5.5 Small LINX companies

The small LINX companies are BioModics, Frichs Ecotech, Tegnology, Xnovotech and Exruptive. The combined five-year financials (or financials since inception) of these companies are depicted in table 3 below:

Table 3: Small LINX company data

TOTAL, SMALL LINX COMPANIES (mDKK)	2017	2016	2015	2014	2013
Revenue	20	14	15	13	11
R&D expenses	16	14	14	12	9
R&D % of revenue	*79,2%*	*101,7%*	*93,5%*	*98,3%*	*86,3%*
Employees	34	30	20	19	18

The five small LINX companies had combined revenues of DKK 20 million in 2017 and employed more than 30 people. They spent an average of 92 % of annual revenues on R&D although for some of the companies this figure is meaningless since they had no revenue for all or parts of this period.

An analysis of individual company data (not shown for confidentiality reasons) gives rise to the following total job and growth creation in the group of small LINX companies.

Table 4: Small LINX company revenue and job creation

LINX participation, all projects (mDKK)	5,00
Average LINX multiplier	1,3
Revenue created (mDKK)	10
Per cent of 2017 revenue	50,0%
Number of jobs created	16

Based on an average LINX multiplier of 1.3, the estimated impact of LINX for the small companies would be DKK 10 million in new revenue and 16 new jobs. It is worth noting though, that the small LINX companies display a much less robust relationship between R&D investments, revenue and job creation. Several have only recently been founded and/or have not yet commercialized their first product. However, they all invest aggressively in R&D (ie. R&D expenses constitute a high proportion of their total fixed cost base). For these companies, participation in LINX is not necessarily about creating jobs and new revenue in the short to medium term but based on a wish to cost reduce and de-risk crucial R&D activities.

A good example is LINX partner BioModics (< 10 employees). They have developed a silicone-based material with the potential to become an important novel drug delivery technology. However, because of the extensive regulatory requirements surrounding such products, BioModics must develop an extremely detailed understanding of the fundamental properties of their material, all the way down to a nano-scale level. The prize is an equal place among other successful Danish medtech companies like Ambu and Coloplast (2,500 and 10,400 employees, respectively).

6. Critique and Conclusion

We believe it is reasonable to discuss LINX in the context of the participating companies' internal R&D efforts. There are two reasons for this:

- Our task was to evaluate LINX on its ability to support growth and job creation in the companies. We note that all partnering LINX companies have taken an active decision to participate and commit resources and continue to engage. Access to LINX resources is not free.

- It is reasonable to assume that a company's decision to participate in LINX is somehow linked to its other R&D decisions and that the LINX activities are somehow tied in with - or evaluated in the light of - its other R&D activities.

Furthermore, even if a company presently does not calculate expected returns on its early stage research activities, it still prioritizes and makes decisions about the benefits of those activities. It is reasonable to assume that the company reached its decision to participate in LINX in a similar manner, whatever that manner was.

We know from countless econometric studies that R&D, revenue and job creation in companies are connected and correlated. Our method, however, reduces what is a very complex picture into a straightforward causal relationship: We assume that R&D activities lead to immediate top-line and job growth. If only the world was that simple! No doubt more companies would invest everything they had into R&D. At this time, we can point to only two specific instances where LINX has had a direct tangible effect on a sale or a new job in any of the participating companies. However, that is to a large extent the nature of early research. If the government wants immediate "bang for its buck", the alternative is to support late stage development. But that is really just subsidizing an activity the company would have carried out anyway. The benefits of LINX may - is actually highly likely to - accrue unevenly. Some companies will benefit a lot. Some not. Those latter companies might look back on LINX as a waste of resources. But that should not matter to the government if it was LINX that helped BioModics become the next Coloplast.

We have shown that measured purely on job creation and revenue growth, there are good reasons to believe LINX creates value for the participants. However, the result of our method very much depends on the choice of LINX Multiplier. The question then becomes: Are the resources committed to LINX for a

particular focus project likely to generate more or less of an impact than the resources the participating company already commits to R&D internally? In this respect we note that:

- We can discuss the LINX multiplier in each case, but we cannot ever know the "true" multiplier, *a priori* or *a posteriori*.

- We can however tie the multiplier to other measures, such as TRL or different types of RISK matrices. Furthermore, we could ask companies to rate them and adjust them as the project in question advance.

This is something we plan to pursue further.

Last but not least: In addition to the value created in participating companies, we believe the LINX Project create value in at least three other ways:

- Creating an industry-academia network in the field of neutron, X-ray and imaging technologies. This benefits not just industry but also the participating academic institutions.

- Training employees to collaborate with the other side and providing them with the tools to do so. This in turn will lower the entry barriers for future industry-academia societal partnerships. This point is particularly important to all the Danish SME's that are not part of LINX today. If an when these companies approach a university sometime in the future, they will meet an institution which knows what collaborating with a small company entails and may find that the barriers to such collaboration were not as insurmountable as they thought they were.

- Creating awareness of the unique position Denmark holds in the field and the possibilities created by the ESS and MAX IV. This in turn supports increased foreign R&D investments in Denmark as a country where access to large scale facilities is well organized and facilitated under the LINX Portal.

We have not sought to quantify the value of any of these positive externalities.

7. Acknowledgements

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