

The D2N2 Productivity Gap: Summary

1. Productivity, the ratio of output to the inputs used in production, matters for living standards over the long-run and has been found to explain more of the variation in income levels between economies than differences in skills or differences in capital (machinery, ICT etc.).
2. According to ONS data D2N2 productivity is about 88% of the rest of the UK. In 2015 this meant that an average worker in D2N2 produced around £10,700 less in gross value added (GVA) than an average worker in England. Aggregating across all employees in D2N2 this amounts to a productivity gap of more than £8.2 billion.
3. Aggregate productivity can be calculated as the weighted sum of each individual businesses within an economy, where these weights are measured by the relative size (sales) of each firm. Productivity within the D2N2 region therefore depends both on the productivity of each individual business and the weights assigned to each firm. Regions with high productivity are typically characterised as having many productive firms that are large and unproductive ones that are small. Unproductive regions have more productive firms that are small and unproductive ones that are large! This correlation between size and productivity is known as allocative efficiency.
4. Using a dataset on businesses in D2N2 and the rest of the UK allows us to consider whether the D2N2 economy is held back by the sectoral-mix of its economy, by the productivity of the average firm, or by low allocative efficiency. The answer would appear to be that all three act to lower aggregate D2N2 productivity. Ranking them we find the negative effect of low allocative efficiency to be stronger than the effect from the lower productivity of the average firm, with both of these having a much stronger effect than the industrial composition. As productive firms can be found in all industries, industrial composition matters much less than is commonly thought.
5. Further investigation of the data reveals that the lower productivity of the average firm in the D2N2 region is not explained by a long tail of very unproductive firms. Nor is it because there are too few exceptionally productive firms (although the best D2N2 firms are below the best UK firms). That is good news and shows both that the D2N2 economy is capable of producing exceptional firms and those firms can thrive here. It also shows that whatever allows unproductive firms to survive is no worse in this region than elsewhere in the UK.

- 6. More important for the productivity gap are the differences in the middle, where a greater proportion of firms in D2N2 are to the left of the average productivity of the UK firm. D2N2 has too many 'below average but not very weak' firms and too few of the 'above average but not exceptional' firms.
- 7. Allocative efficiency of the D2N2 economy is also below that of the rest of the UK, although the reason also seems to be the gap between the average D2N2 and the average UK firm.
- 8. Productivity enhancing policy for the D2N2 economy would ideally seek to raise productivity of the below average productivity performers and ensure that low productivity firms do not grow at the expense of high productivity firms. The 'small & productive' firms are an obvious target group for support to achieve such an outcome.
- 9. Productivity enhancing policies often include the following list

Policy	Comment
R&D	Evidence shows that this makes firms more productive and grow. However tends to be undertaken by the most productive firms and D2N2 under-performance is not of those firms.
Skills	The evidence indicates only a small causal improvement in productivity from this. However, as D2N2 scores poorly on these measures, closing this gap would have an important effect on aggregate productivity.
Investment	Strong evidence that this matters for productivity. Investment includes all types of capital, but investment in productivity enhancing effects from ICT have been shown to be complementary to changes in organisation and skills. No evidence on D2N2 performance on these measures.
International Trade	Firms that export or are multinational are more productive than non-exporters. The literature concludes this is mostly due to self-selection. There is evidence of only a small causal impact of starting to export, with a stronger effect on the growth of firms. There is also evidence that being acquired by a foreign multinational increases productivity. Some indication that exporting from D2N2 is lower than rest of the UK.
Management	Differences in managerial quality matters for productivity. Some indicators suggest that D2N2 firms perform poorly here.
Infrastructure	There is evidence that infrastructure matters for both market access and competition, both of which have been associated with higher productivity and higher growth.

- 10. Policies targeted specifically at improvements in productivity are rare. This suggests that knowledge of 'what works' is relatively limited, and will remain so unless robust policy

evaluation exercises are conducted. That would ideally include both past and future policy interventions, in which case it needs to be built into the design-phase of policy making.

11. Policies targeted at the growth of firms are common, but are not necessarily productivity enhancing. Evidence from a past UK-wide policy of this type found that they were successful at increasing in employment. However, there was no evidence that they led to any increase in productivity. In addition, the firms that received support had on average lower productivity, such that their employment growth came at the expense of high-productivity firms, thereby lowering aggregate productivity.

The D2N2 Productivity Gap

It is often said that productivity, the ratio of output of an economy to the inputs used in production, is easier to define than it is to measure. The effort to generate such measures is worthwhile, and we should be concerned when we observe obvious and persistent productivity gaps for two reasons. Firstly, productivity is the driver of living standards over the long-run. While investment in new capital (machinery, computers etc.) or in skills (human capital) is valuable in increasing the growth rate of income per capita, eventually this growth will be constrained by the rate of productivity growth. Secondly, productivity is the key reason behind differences in income gaps across economies. To put this differently; when comparing the gap in income levels it has been found that the differences in the type of machines, computers etc. that are available, or in the skills of workers, are much smaller than the differences in productivity. Income gaps are therefore not solved solely by accumulating more objects (investment) or education, and policy solutions that are focused on increasing productivity are warranted.

Labour productivity is calculated as the ratio of output to employment, while total factor productivity (TFP) accounts for the other inputs used. Labour productivity is the simplest measure of productivity to calculate and is typically the most commonly used measure. Calculating total factor productivity requires knowledge of all of the inputs that are used to produce a unit of output, but also the precise way that they are combined. For an individual product that can be quite straightforward, but given the thousands of products that are produced and the myriad of ways that they might be produced, for the aggregate economy that is a more complex matter. In this report we focus on labour productivity, although where possible we try to verify whether TFP estimates are likely to differ from this. Typically we find that they do not.

As shown in Figure 1, according to ONS data the labour productivity of the D2N2 economy is about 88% of that of the UK as a whole (about 95% when excluding London). In 2015 this meant that an average worker in D2N2 produced around £10,700 less in gross value added (GVA) than an average worker in the UK as a whole. Aggregating across all employees in D2N2 this amounts to a productivity gap of more than £8.2 billion.

This productivity gap has been a persistent feature of the D2N2 economy for a long period of time, although the precise estimate has drifted upwards and downwards slightly (see Figure 1). To understand why it exists, and therefore what policy levers might be targeted to remove it, requires an investigation of its causes.

Figure 1: Value Added per hour



Source: ONS

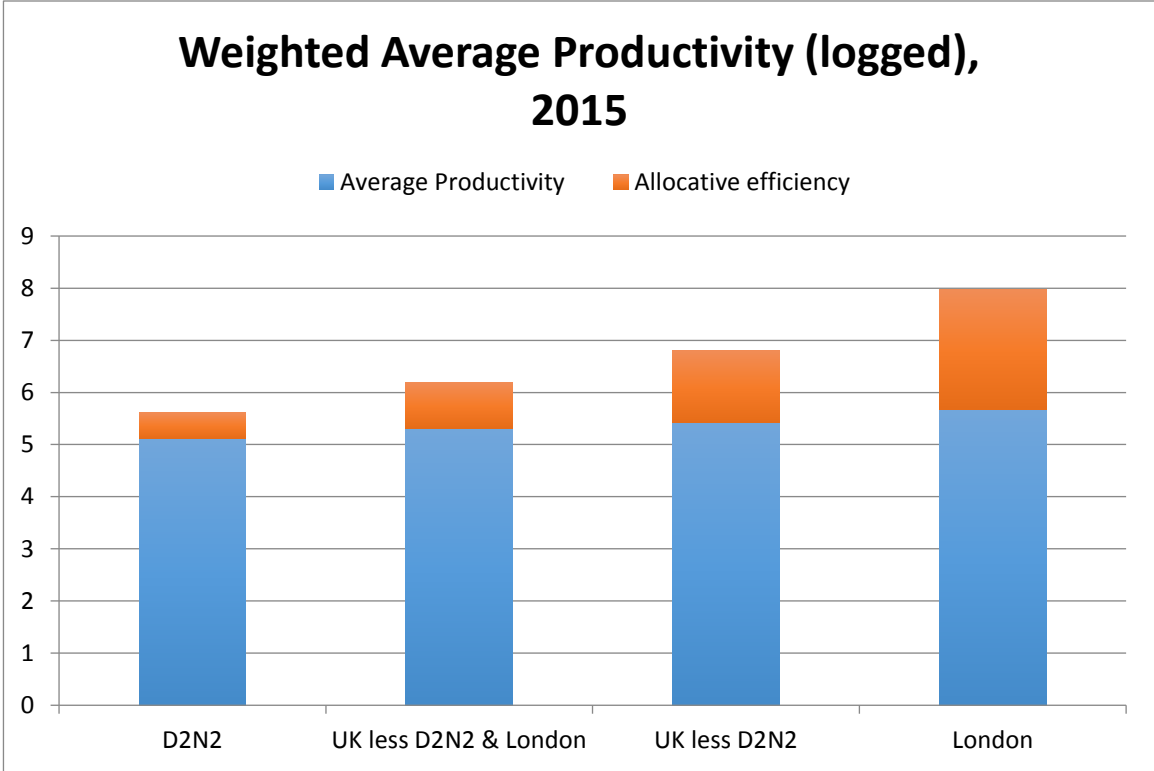
To enable a more granular analysis of the D2N2 productivity gap, we use firm level data on financial statements from a commercial data provider (Bureau Van Dijk). There are advantages and disadvantages of this data, the main disadvantage being one of coverage. The data includes sufficient information to construct productivity estimates for a sub-set of firms, where these tend to be larger firms on average (the sample includes 911 companies in D2N2 and a further 35,368 for the rest of the UK). Given the relatively small sample of firms for D2N2 we concentrate on analysis at the aggregate level and provide little discussion of particular local authorities or industrial sectors. Despite these data limitations we estimate D2N2 productivity to be 83% of the UK value using this data, close to the estimate of the productivity gap found from ONS data.

Using this data we can re-calculate aggregate labour productivity as the sum of the productivity of each individual business, weighting each business by its overall importance to output or employment (we use output). Under this measure productivity depends both on the productivity of each individual business but also the weights assigned to each firm. Regions with high productivity are typically characterised as having more productive firms that are large, while the unproductive firms are small. Unproductive regions have productive firms that are small and unproductive firms that are large! The correlation between size and productivity is known as allocative efficiency.

The micro level data allow us to consider if the D2N2 productivity gap is characterised as a problem with the productivity of firms, how big they are, or if they are in the wrong sectors. In practice all three play some role, but the allocative efficiency and the productivity of individuals businesses are much more important. Evidence on the productivity of the average firm and the benefit of allocative

efficiency are shown in Figure 2 below where we calculate aggregate productivity along with that total broken down into average productivity and allocative efficiency for D2N2, the UK less D2N2 and London, UK less D2N2 and London. The figure shows that D2N2 underperforms on this aggregate as well as each component. It also shows that allocative efficiency, while a relatively small share of the total, has an important role in explaining the productivity gap between these various regions.

Figure 2



To push at this further we consider what would happen to aggregate D2N2 productivity if:

1. we changed the industrial composition to match the rest of the UK
2. increased the average firm productivity to that of the rest of the UK
3. increased allocative efficiency to the rest of the UK.

As already mentioned the effect of changing the industrial composition is relatively small. According to our data the productivity of the D2N2 economy would reach 84%, up from 83%, if we change it to match the UK’s industrial structure. The effect is small because while D2N2 has relatively little employment in a high labour productivity sector such as finance, it has relatively more in high labour productivity manufacturing. Therefore the productivity boost brought about by increasing finance is to a large extent offset by the productivity decline brought about by decreasing

manufacturing employment to match the UK average. That the industrial composition plays relatively little role in explaining productivity differences is a point also made by CBI (2016).

Aggregate productivity also depends on the productivity of the individual firms in the economy. On average firms in D2N2 have lower productivity than those in the rest of the UK; the efficiency of the average firm is about 94% of that of the average firm in the rest of the UK. Closing this gap to the average UK firm would clearly help reduce the aggregate productivity gap. We calculate that increasing productivity in the average D2N2 firm to that of the average UK firm would boost overall productivity to 88%. This suggests that, if successful, a strategy of improving the productivity of D2N2 firms to the UK average would have an effect on aggregate productivity about 5 times larger than a strategy of matching the industrial composition of the UK.

Finally, we find calculate that for both the UK and for D2N2 allocative efficiency is positive, meaning that employment shares are usually bigger for the more productive firms in both regions. However, the value of this allocative efficiency is smaller for D2N2 than it is for the rest of the UK, again implying a potential productivity boost if this could be altered. According to the data improving this feature of the D2N2 economy to match the rest of the UK would suggest that D2N2 productivity would reach 95% of the UK value. This allocative efficiency term, along with firm productivity, are therefore the most important explanations for the D2N2 productivity gap and are worthy of further analysis.

Before turning to this task we consider whether these productivity gaps exist for all of the sectors that make up the D2N2 or whether there are some that buck this trend. The gap does differ across sectors and there is one sector, real estate activities (105%), for which weighted labour productivity is higher than for the rest of the UK. In other sectors, such as construction (94%), accommodation and food (93%) and manufacturing (92%), the gap is small, whereas it is large in finance and insurance (87%) and particularly in administrative and support services (57%). This result for admin and support services is important as these firms account for a large percentage of sales in the data (12%) and is explained by both lower productivity for the average firm and a negative allocative efficiency value.

The Productivity of Firms

As already noted the data indicate that the productivity of the average firm is below that of the average UK firm. That average arises of course from comparing across lots of different firms. In both regions we find that the best firms outperform the worst firms by a long way. In D2N2 firms at the 90th percentile of the distribution have a value of labour productivity some 10 times that of firms at the 10th percentile. In the UK as a whole the comparison suggests the best firms produce 19 times

more revenue per employee. Even when we focus within industries significant heterogeneity remains: for example in wholesale and retail the best firms in D2N2 (UK) produce 9 times more revenue per employee than firms at the bottom of the distribution (a multiple of 13 in the UK as a whole) and in manufacturing the figure is close to 5 times (a multiple of 6 in the UK as a whole). Those differences are typical and have been found using other data sets on UK firms, or indeed other country settings and even when very narrowly defined industries are used.

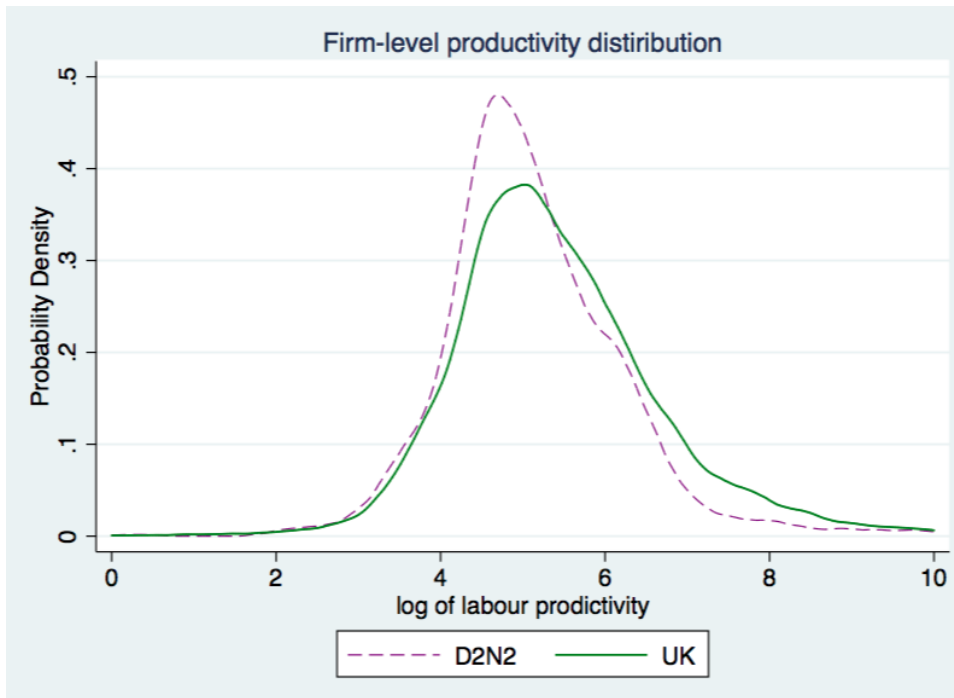
Three other notable features of the productivity distribution are:

1. the performance of D2N2 firms and other UK firms at the bottom of the productivity distribution is similar, indicating that the minimum productivity required to survive in both regions is also similar.
2. as in the rest of the UK, the D2N2 economy also has a small number of firms with very high labour productivity. These high productivity firms are spread across all industries and can also be found in every local authority. The best D2N2 firms are however some way short of the very best in the UK.
3. the differences between the D2N2 region and the rest of the UK are instead more apparent in the middle of the distribution. The D2N2 economy has too many firms that are to the left of the average productivity of the UK firm and too few that are at or above this average.

These key patterns are neatly summarised in Figure 3 below. Starting from the left tail of the distribution it is evident from this figure that the productivity distributions of D2N2 and the rest of the UK overlap; the productivity of the weakest firms is similar. Differences in performance then appear just below the peak of the distribution, where this peak for D2N2 is to the left of that for the UK as a whole, indicating that average productivity is lower. The peak for D2N2 is also noticeably higher indicating that there are more D2N2 firms clustered around this mean value. Moving to the right of this peak point is where firms outside of the D2N2 region really begin to outperform those inside. These are above average but not exceptional firms. At the extreme right hand tail there are some D2N2 firms as well as UK firms.

We are also able to demonstrate that this difference is statistically significant. This pattern repeats itself when we consider this at the industry level and we again find statistically significant differences for manufacturing; administrative & support services; Professional, scientific & technical; and Transportation & storage.

Figure 3



Having identified large differences in productivity between firms and also between D2N2 and the rest of the UK a natural question to ask is how much of this is explained by the characteristics of industries and the regions in which they reside and how much is explained by differences in the characteristics of the firms themselves. Unfortunately the data do not allow us to answer this second question and we are left to appeal to the academic literature to identify potential explanations.

We can get a limited sense of the first question with the data we do have available. To study this point we regress the productivity of firms in the UK, including those in D2N2, against the industry and the local authority of the firm. We focus on these regional characteristics and benchmark everything against Derby. The results are displayed in Table 1. They indicate that within the D2N2 region there is evidence of a significant positive effect on productivity from the agglomeration within Amber Valley, Erewash, High Peak, South Derbyshire and North East Derbyshire. Negative effects of location on labour productivity are found for Bolsover and Nottingham. For everywhere else we find from a statistical perspective at least, that the productivity of firms in those local authorities is at the same level as in Derby.

But how important are these regional characteristics? The answer is not very. Using these local authority dummies we can explain a little over 3% of the variation in productivity across firms. It is worth noting that by adding industry dummies we can do a little better, such that with both industry and region dummies together we can explain just over 13% of the variation in the data.

Table 1

Productivity is significantly lower than Derby	Productivity is the same as in than Derby	Productivity is significantly higher than Derby
Bolsover Nottingham	Chesterfield Derbyshire Dales Ashfield Bassetlaw Broxtowe Gedling Mansfield Newark and Sherwood Rushcliffe	Amber Valley Erewash High Peak North East Derbyshire South Derbyshire

We next consider whether there are measurable characteristics of these regions which leads to high productivity. We include here measures of education attainment, entrepreneurship (entry and survival), agglomeration (persons per sq km), broadband infrastructure and occupation. In these regressions we can explain 20% of the variation in productivity across firms. Still much remains unexplained and most of the action is what is happening within the firm!

Considering the variables individually, we find that local authorities in which more of the population has qualifications at NVQ4+, a faster rate of enterprise births and occupations at management level tend to have higher productivity. Broadband speed and agglomeration appear to have no consistent role. Before moving on to consider by how much these factors matter it is worth noting that none of these factors explain the tendency for firms in the different local authorities in Table 1 to have above or below average productivity. To put that differently; the differences in Table 1 are not explained by differences in the availability of skilled workers, broadband, the types of occupations etc.

Again, the ability of these variables to explain variations in productivity is quite limited, although for skills as the gap to the rest of the UK is big this has a larger impact. The proportion of the workforce with NVQ level 4+ is 43.66% in the UK versus 30.04% for D2N2. According to the regression results increasing the skills of D2N2 workers to the UK average would add 0.18 log points to the productivity of the average firm. This represents 3.6% of an increase in the productivity of the average (median) firm. For the other variables the effect is even smaller: increasing the rate of enterprise births in D2N2 to the UK average would add 0.03 log points and increasing the proportion of senior managers would add 0.04 log points (an increase of less than 1% for the average firm).

Given the absence of data we answer the question on what makes firms' more productive by appealing to academic research on this topic. We might split these factors into those that are internal and those that are external to the firm. The most often researched internal factors are management, investment, skilled labour, R&D and globalisation. The external factors include market access, competition and agglomeration (including spillovers).

An important note to point out before discussing this evidence is that the volume of research that has found a correlation between these various factors and productivity is much greater than the volume of evidence that has reliably demonstrated causation. As an example, a large number of academics have researched the question whether being an exporter leads to higher productivity. These two variables are positively correlated as one would expect, but when we follow firms that start to export we find that they were already amongst the best non-exporters. This indicates the causation may in fact go in the opposite direction: there is the self-selection of the best firms into exporting. Untangling this inter-relationship is not easy but a few studies have successfully done so and have been able to conclude that exporting also brings a productivity benefit to the firm of about 1-3%. This is a little smaller than the productivity gain that research has found on the benefits from being acquired by a foreign multinational firm.

The benefits to exporting and FDI accrue in particular when the firm is encouraged to invest and adopts improved technology into its production process, or is able to upgrade the quality of its products. Exports and FDI increase productivity because they incentivise firms to invest through access to larger markets and access to better technologies. A point worth highlighting for a post-Brexit UK. This result mirrors the evidence of capital investment more generally, where there is strong evidence that this matters for productivity.

Perhaps the most studied type of investment in capital has been in ICT. Here again, it is typical to find that the most productive firms are the quickest adopters of new types of ICT, but there is some evidence of small additional productivity gains from this investment. These effects are typically unevenly felt across firms and accrue in particular to those firms that improve in staff training (or employ higher skilled workers) or alter the way they manage and organise themselves. This type of complementarity between investment in new improved capital and skills is typical in the literature, where there is little evidence of a direct productivity pay-off skill upgrading. For productivity, improved training and education appears to matter instead when performed in conjunction with some other activity.

The economics literature has made rather large strides in the last few years in trying to quantify how much management matters for productivity. Again, disentangling causality is rather difficult here, in particular separating the difficult to replicate characteristics of the manager, their x-factor

if you like, from the aspects of management science which are. The most reliable estimates from the literature indicate that improving the management of a firm at the 25th percentile of the management quality distribution up to that of a firm at the 75th would increase its productivity by about 3-7.5%, which is about 10-23% of the productivity gap between those two firms. Clearly management matters, but it is not everything

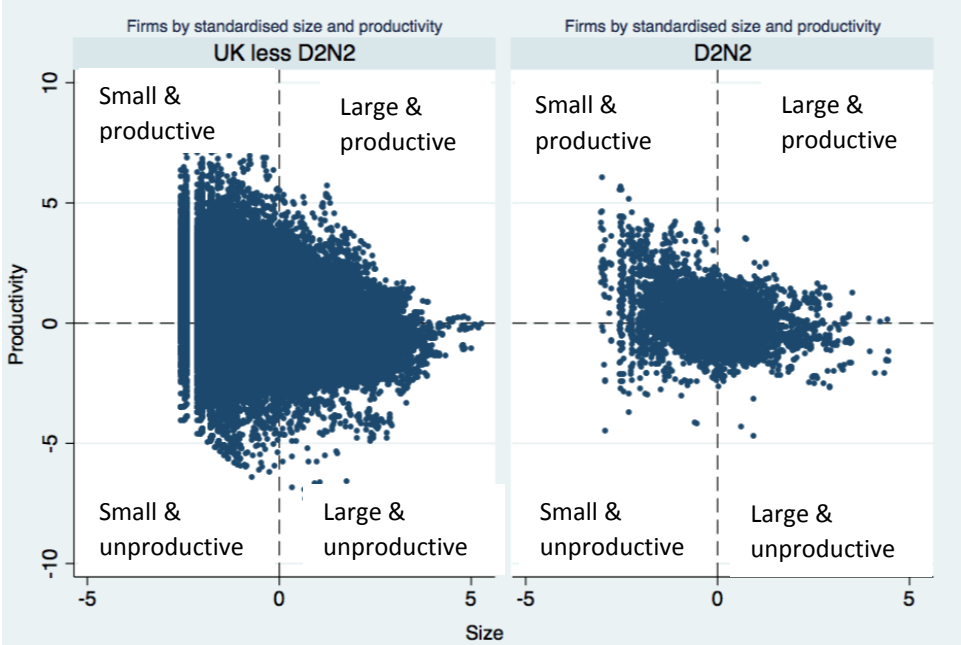
Finally, many discussions of productivity usually start with a discussion about R&D and technological progress. The underlying basis for this is a top-down approach to the productivity problem and a theoretical model, the Solow model, that underlies this. Bottom-up approaches to productivity such as this one, tend to view R&D as one factor amongst many others. This largely stems from the realisation that the by far the majority of firms don't undertake any formal R&D, and that the firms that do are already the most productive firms. The OECD has a useful characterisation of firms at various points in productivity distributions of the type shown in Figure 2. They label the best firms as 'frontier firms', those above the mean but below this as 'national champions' and those below the mean as 'productivity laggards'. Innovation matters at the top, for the frontier firms. For the majority, for the national champions and the laggards, innovation is less important than investment in new advanced types of capital that embodies the R&D and management innovations of these frontier firms or imitation of their management and other organisational practices. That is not to suggest that product and process innovation are not important for aggregate productivity, but the evidence presented here does suggest it is not the root of the D2N2 productivity gap.

Economic research has found it easier to demonstrate that external factors, in particular those around competition and market access matter for the productivity of firms. Weaker competition and limited market access tend to be associated with lower productivity, in part because they discourage investment in new types of capital and in R&D. Disentangling the effects of agglomeration has proved more difficult, although cities with better transport infrastructure (including road, rail, airports and information highways) have been found to grow more quickly than those with weaker access.

Allocative Efficiency

To understand differences in the efficiency with which the market allocates resources across firms in the D2N2 region versus the UK average we plot the market share of firms (relative to the industry average) against their labour productivity (relative to the industry average) in Figure 4.

Figure 4



In Figure 4 we then separate the four quadrants of the diagram and label the firms in those quadrants as ‘small & productive’, ‘large & productive’, ‘large & unproductive’ and ‘small & unproductive’. To a large extent the patterns for the UK and D2N2 appear similar, notwithstanding the fact that there are more firms in the rest of the UK. This is borne out by the number of firms in each of these quadrants reported in Table 2. Comparatively the UK has more firms in the ‘small & productive’ and ‘unproductive and large’ quadrants, whereas D2N2 has a relatively greater share of firms in the ‘large & productive quadrant’ and ‘unproductive and small’. This is of interest, as that pattern would tend to be associated with D2N2 having higher, not lower allocative efficiency.

Further investigation suggests that this comes because the gap in productivity to the average is bigger than for the rest of the UK. To put this differently, the low allocative efficiency of D2N2 stems from the gap in firm productivity evident from Figure 2, and closing that gap would help to improve allocative efficiency also.

Table 2

Percentage of companies in the sample falling within each quadrant of the Productivity-Size plot

Productivity/Size	D2N2	UK (less D2N2)
Productive/Large	19%	17%
Productive/Small	31%	33%
Unproductive/Large	31%	33%
Unproductive/Small	19%	17%

What are the determinants of allocative efficiency? That is a difficult question to answer as it requires us to model the many institutional features of an economy all at once. The economics literature has only recently begun to develop those models, although an early conclusion would be that distortions, including policy distortions, to market access, competition, access to finance, the allocation of inputs (including labour) generate effects on aggregate productivity that are large.

A greater volume of research has considered the determinants of firm growth for the type of internal (management, investment, skilled labour, R&D and globalisation) and external factors (market access, competition and agglomeration) discussed above. To generalise from this literature, it is often much easier to find effects on the size of the firm (employment and sales) than it is productivity. For example, while it appears to be the case that the best firms simply self-select into becoming exporters and there is little productivity benefit from doing so, it has been consistently found that these firms grow more quickly than they would otherwise have done. Higher productivity firms growing more quickly implies higher allocative efficiency and therefore higher aggregate productivity. Similar results have been found for a number of other variables including R&D, FDI and investment.

Policy

Two perhaps obvious guiding principles for productivity policy that might be drawn from the above analysis would be that:

1. Firms at the top, middle and bottom of the productivity distribution are different and their productivity determinants also differ. Innovation matters more for productivity at the top of the distribution and imitation and investment are more important at the middle and bottom. To the extent that the determinants of innovation are different from those of investing and imitating in order to catch-up, any policy actions should also differ. A factor common to both would be the size of the market firms' can access. Better access to larger markets increases innovation and investment.
2. Aggregate productivity is also determined by allocative efficiency. Productivity enhancing policy for the D2N2 economy would also ideally give thought to the effect on allocative efficiency and ensure that policies do not support growth of low productivity firms at the expense of high productivity firms. The 'small & productive' firms are an obvious target group that would support increases in aggregate productivity through increases in allocative efficiency. While this would seem obvious, evidence of past UK-wide policies indicates that employment promoting policies led to the growth of low-productivity firms at the expense of high-productivity firms, lowering aggregate productivity.

The evidence also indicates that the productivity gap between the D2N2 region and the rest of the UK is explained in part by an under-performance in the middle of the productivity distribution and low allocative efficiency. There are too many 'below-average but not very weak' productivity firms and not enough 'above average but not exceptional' firms. Low allocative efficiency seems to occur from the same reason.

The D2N2 productivity gap has much less to do with the sectoral composition of the economy; because of a long tail of underperforming firms; or because the best firms in D2N2 are not amongst the best nationally or internationally. That is good news as it shows both that the D2N2 economy is capable of producing exceptional firms; that those firms can thrive there; and that whatever allows unproductive firms to survive is no worse in this region than elsewhere in the UK. This suggests that to address the D2N2 productivity gap policy actions would not be targeted at those groups of firms. The evidence also indicates that they should not be targeted at particular industries, at the cost of productive firms in other, less fashionable ones.

Unfortunately, data limitations prevent us from providing further diagnosis of the reasons for the productivity gap amongst middle productivity firms and therefore our ability to offer a more detailed policy description. From the academic evidence we do know that firms in this part of the distribution are more likely to be non-exporters than exporters (or export relatively little), to have lower management scores and use more recent technologies less intensively. That might be a useful starting point for thinking about appropriate support for these firms.

The academic literature suggests that the direct effect of improvement in education and training on productivity is small, although these do appear to help leverage the effects of ICT and management. However, because the increase in education necessary to bring D2N2 back to the UK average would be large, this could generate a productivity impact of some importance.

Policies targeted at improving productivity are rare. This suggests that knowledge of 'what works' is relatively limited and will remain so unless a robust policy evaluation exercise is conducted. The methodologies required to achieve such a robust evidence base are well-understood and have been applied in many settings including those around firms. Evaluations of policy would ideally include all future policy interventions, in which case it needs to be built into the design-phase of policy making, but could also include past-interventions (in particular those designed to support the growth of firms).

*Professor Richard Kneller
University of Nottingham*