AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Dairy Productivity Growth in Northern Ireland

Summary Report

Kehinde Oluseyi Olagunju, Aurelia Samuel and Erin Sherry

21 June 2021

Summary

Understanding the components of productivity and what has been driving productivity change in Northern Ireland (NI) can help identify ways to accentuate the positive and address weaknesses at farm level. Higher year on year productivity will improve the competitiveness of the NI dairy sector in UK and international markets.

Total Factor Productivity (TFP), a measure of productivity, is the ratio of total outputs to total inputs used in production. The TFP was computed for NI's dairy sector using an approach called the *transitive fisher index*. The approach is similar to the methodologies used by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and the Organisation for Economic Co-operation and Development (OECD) for computation of TFP measure.

Using the dynamic Olley-Pakes approach, the sector- level TFP was decomposed into three components: productivity growth within farms; resource reallocation between farms; and all remaining factors (such as farm entry and exit). Finally, econometric analysis was employed to identify factors influencing productivity at farm-level.

The main findings are:

- TFP improved (growth averaging 0.5% a year) between 2005 and 2016 due to outputs, primarily milk, increasing relative to inputs
- NI's average yearly productivity growth during the period 2005-2016 was larger than England's (0.2%) and Australia's (-0.1%)
- Productivity growth within farms (in terms of technological progress and farm management practices) is the main contributor to sector-level productivity growth
- Resource reallocation has also made a positive contribution to sector-level productivity , but to a much smaller extent than productivity improvements within individual farms
- There is almost no measurable impact from remaining factors, such as farm entry and exit
- Herd size, stocking density, and educational attainment are related to higher productivity at farm-level, while labour input per cow and purchased feed input per cow tend to have a negative impact
- The relationship between age and productivity is negative, with the impact getting stronger as age increases
- Capital investment has a positive impact on farm-level productivity, and when combined with education the positive effect is even stronger

This report provides a summary of findings from a DAERA-funded project on trends and drivers of productivity in Northern Ireland's (NI) dairy farming sector[1] (project no. EI-17/2/04). The study computed an aggregate dairy sector productivity measure; decomposed aggregate productivity in different components, and identified significant factors impacting farm level productivity.

---

[1] The full project reports can be accessed through the following links –
https://www.afbini.gov.uk/publications/dairy-sector-productivity-growth-northern-ireland-trends-and-drivers
https://www.afbini.gov.uk/publications/decomposition-dairy-productivity-growth-northern-ireland
https://www.afbini.gov.uk/publications/literature-review-key-drivers-agricultural-productivity-growth

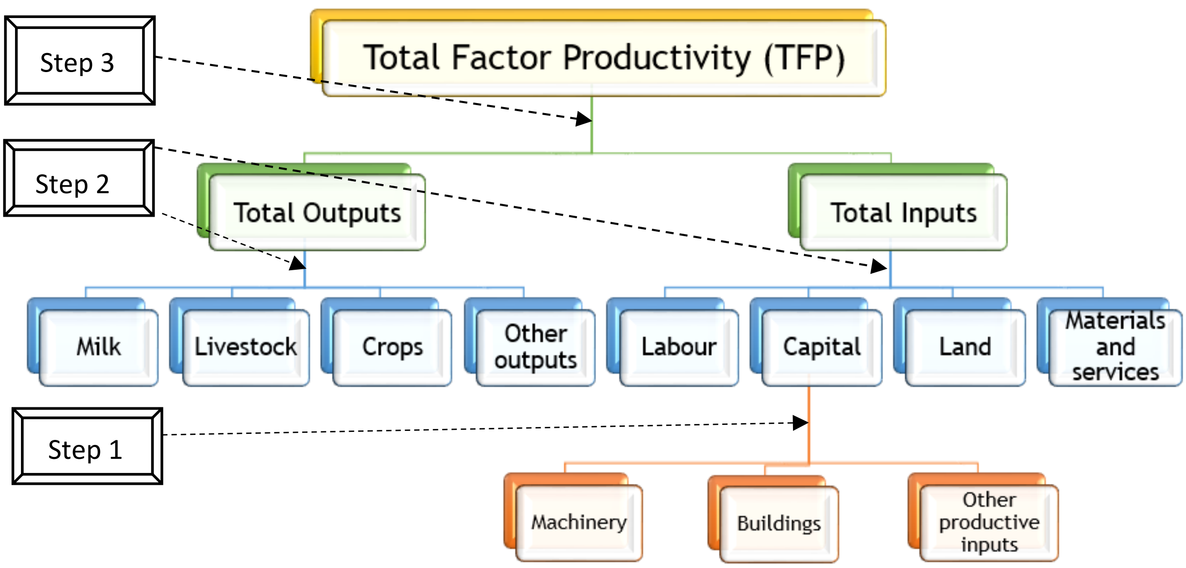
Total Factor Productivity

Total factor productivity (TFP) is the ratio of total outputs to inputs used in production. A farm that produces more output from the same level of inputs as another farm is more productive. Equally, a farm that produces the same amount of output using fewer inputs is also more productive. An increase in output/input ratios over time is referred to as productivity growth. Measuring productivity can be useful to evaluate the degree to which dairy farms have incorporated technological advances (e.g. through the adoption of new production practices and technologies such as modernising milking parlours). Productivity is also useful to assess the impact of wider factors such as policy, institutional, or market changes.

The TFP measure used in this study was guided by an extensive review of previous studies and reports on TFP measurements. In particular, an EKS-adjusted Fisher index (also referred to as *transitive fisher index)* was selected to compute dairy farm productivity in Northern Ireland (NI). This approach has been widely applied by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and the Organisation for Economic Cooperation and Development (OECD) for computation of aggregate productivity.

The aggregation procedure of NI's dairy sector TFP involves three main steps (as shown in Figure 1). First, aggregating specific items of outputs and inputs into broad types of outputs (milk, livestock, crops and other outputs) and inputs (labour, capital, land, and materials and services). Second, aggregating the broad types of outputs and inputs into total outputs and total inputs, respectively. The third step calculates a ratio of total outputs and total inputs to obtain the TFP measure. The procedure has been automated using computer programming code written in R-Studio, allowing for annual updating of the TFP index as new data becomes available from the Department of Agriculture, Environment and Rural Affairs (DAERA).

Figure 1. Aggregation of inputs and outputs to estimate TFP



Source: Zhao et al. (2012)

Dairy sector productivity

Table 1 and 2 present the average annual TFP growth, partial factor productivity, outputs, and inputs from the years 2005 to 2016. On average, the aggregate TFP growth is 0.5% a year per year over the period. This growth indicates an improvement in how efficiently inputs are used to produce milk and other dairy products. There is a structural break in the time period examined. The sector experienced negative annual TFP growth of 1.8% between 2005 and 2009, but starting from the year 2010 this reversed to positive growth at 1.8% a year. During the entire period covered, the annual growth rate of output increased by 4.6% and that of inputs increased by 4.2% implying that the annual growth rate of output marginally outpaced the growth of input.

The partial factor productivity growth for the four main factors of production used in the dairy farm sector is also reported in Table 1. Labour input increased the least (1.2% per year) compared to other inputs, making labour productivity growth (3.3% per annum) the most important partial factor productivity contributor to overall TFP growth. This may suggest gradual and partial replacement of labour inputs with capital over the years. The annual growth rate of output slightly exceeds that of capital input, resulting in moderate positive growth of capital productivity of 0.9%. This suggests that output from the dairy sector outpaced the level of investment in capital items between 2005 and 2016. Specifically, capital input increased by 3.9% between 2005 and 2016 which suggests that farmers are increasingly investing in capital inputs. The use of land inputs in the dairy sector experienced an increase of 2.8% per year between 2005 and 2016. The rate of growth per year of land input between 2005 and 2009 was higher than the growth rate after 2009. Overall, the growth rate of land input is outpaced by output growth leading to positive land productivity of 1.8% per annum.

Table 1. Average Annual Productivity Growth (Percentage) of the Dairy Farm Sector, 2005-2016

	2005– 2009	2010 - 2016	2005 -2016
Total Factor Productivity	-1.8	1.8	0.5
Partial Factor Productivity			
Labour	2.9	3.5	3.3
Land	0.7	2.5	1.8
Capital	-0.2	1.6	0.9
Material	-11.9	1.2	-3.6
Service	-3.0	0.6	-0.7

The results presented in Table 2 show that the largest component of material input in terms of cost share is feed/fodder which experienced annual average growth of 11.2%[2]. Similarly, the growth rate of fertilizer, chemical and fuel inputs was positive except for seed input. As a result, material input outpaced total output, thereby producing a negative annual material partial productivity growth rate (-3.6%) between 2005 and 2016.

While NI has performed well in productivity growth when compared with England and Australia during 2005 and 2016, the aggregate productivity growth level of 0.5% per annum is fairly modest,

[2] By definition, material input is same as variable costs which include feed/fodder, fertiliser, chemical, seeds and fuel.

suggesting that there is still room for improvement[3]. The negative partial productivity of the materials input component appears to be an area of concern, suggesting that better and efficient use of material inputs may be key in championing productivity improvement of the sector.

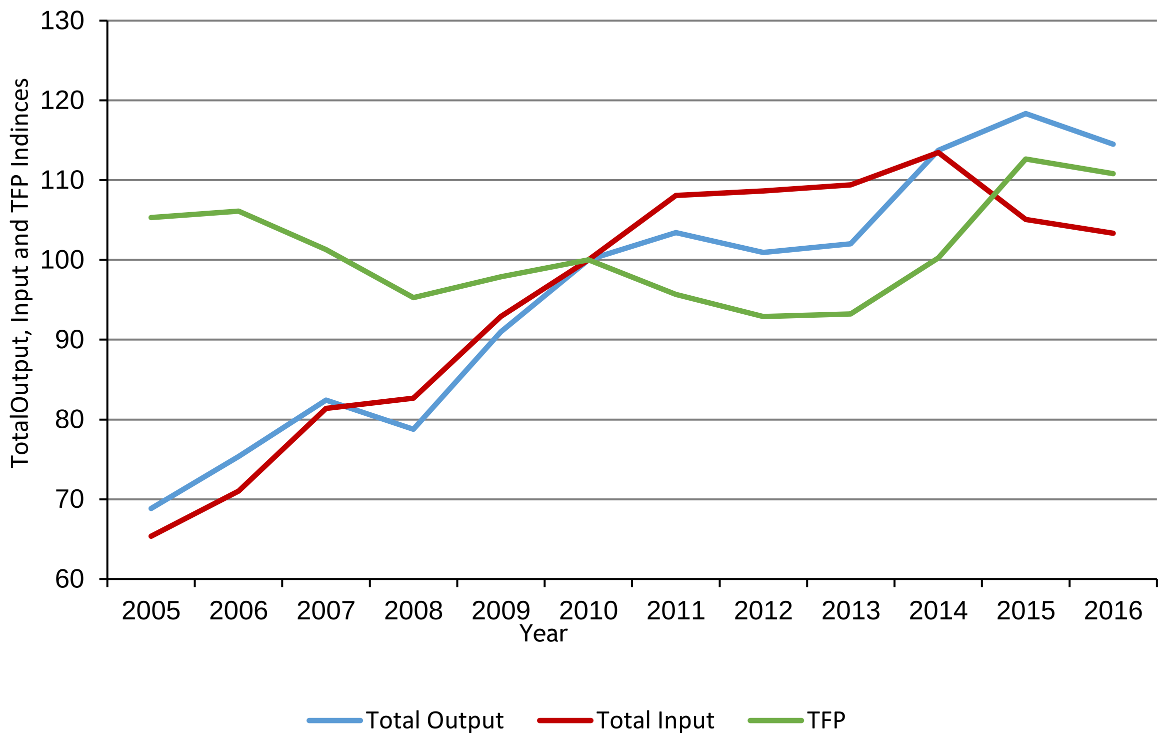
[3] Between 2005 and 2016, on average NI witnessed the highest TFP growth rate of 0.5% followed by England (0.1%), while the Australian dairy sector experienced a negative annual growth rate of -0.1%.

Table 2. Growth Rate of Dairy Farm Sector-level TFP, Outputs and Inputs, 2005-2016

	Average annual growth rate %	Average value or cost share %
Total outputs	4.6	100
Milk	3.9	73
Livestock	6.0	26
Total inputs	4.2	100
Labour	1.2	19.4
Land	2.8	7.2
Capital	3.9	22.8
Material	8.2	33.2
Feed/Fodder	11.2	77.7
Fertiliser	3.9	12.9
Chemical	5.3	0.9
Seeds	-1.8	0.9
Fuel	0.9	7.6
Services	5.4	17.4

Figure 2 shows the trends of TFP, total input and output during the period 2005 to 2016, making the level in 2010 a reference level of 100. The results show a downward trend of TFP until the year 2013, after which there is an upward trend, with a local peak in the year 2015. The peak in 2015 was mainly driven by growth in output and a decline in the growth of inputs, particularly material inputs such as feed, which lead to a reduction in total input growth.

Figure 2. Trends in Sector Total Factor Productivity, Total Output and Total Input Indices 2005 – 2016 (2010=100)



Decomposition of Dairy sector productivity

Productivity changes over time in the dairy farming sector[4] was decomposed using a methodology called the dynamic Olley-Pakes (OP) decomposition approach, that breaks down the change in sector-level productivity between two consecutive years into three main components. A *within-farm effect* captures productivity change that has been driven by a change in average farm-level productivity in the sector. This could be on-farm productivity gains due to innovation or adoption of new technology. A *resource reallocation effect* captures productivity change that has been driven by a change in the allocation of available resources across farms. This is captured by measuring the change in sector-level productivity explained by changes in the relative market share of more or less productive farms. Productivity growth, not attributable to within-farm productivity gains, can be associated with relatively more productive farms having access to a larger resource base, and therefore taking over more market share within the sector. A r*esidual effect* captures the net impact of all factors not included in the *within-farm* or *resource reallocation* effects, such as farm entry and exit.

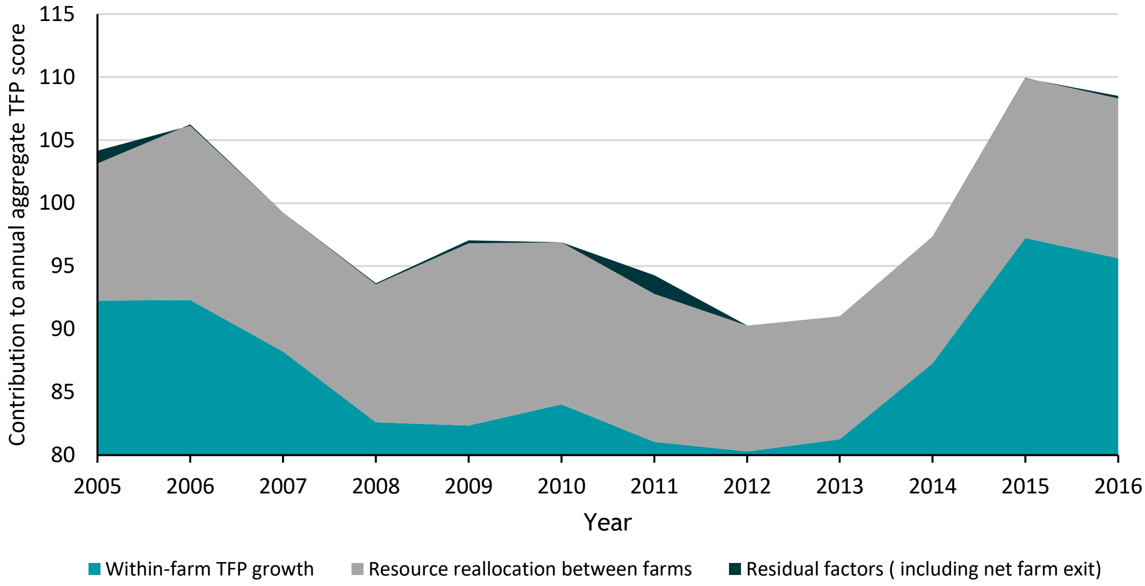
The results of TFP decomposition is presented in Figure 3. The *with-in farm effect* dominates, in terms of the proportionate contribution to changes in productivity over the period, and also exhibits the most volatility. This may reflect periods of above or below average weather conditions, having a wide-spread impact on farm-level productivity, or conditions of high milk prices triggering revenue increasing management decisions, that reduce efficiency of production, and therefore productivity. The net effect over the entire period is positive, averaging 0.31% productivity growth per year. This suggests that continuous uptake of new technologies and more efficient management of inputs at the farm level has enhanced productivity overall.

The *resource reallocation effect* has also made a net positive contribution to sector TFP over the period, averaging 0.16% growth each year. This finding suggests that on average, resource is moving from low productivity dairy farms to high performing dairy farms. This could be an indication that on average, relatively more productive dairy farms are more likely to be leasing in additional land. As more resources flow to relatively efficient farms, the overall efficiency of the industry increases. Worthy of note is that the decomposition results are specific to the time periods under consideration. Changes to barriers to resource reallocation in the future could potentially strengthen the importance of this source of productivity growth.

The *residual effect* is negligible between 2005 and 2016. On average, this component accounts for -0.08% of aggregate TFP. This category includes farm entry and exit, however, the structure of the dataset makes it impossible to measure this directly (more details are provided on this in the technical appendix).

[4] Sector-level productivity is defined as the sum of farm-level TFP weighted by each farm's share of total milk output

Figure 3. Decomposition of Sector Total Factor Productivity, 2005 -2016



Drivers of dairy farm-level productivity

A robust quantitative analysis of the factors that impact productivity at the farm-level was also carried out. The analysis specified three main model variations to accommodate different policy variables[5]. The first model specification contains net investment per cow variable at the current time (that is, at time *t*) while the second model incorporates the variable in its lagged form (three-year lag, that is, *t*-3)[6]. The third model includes some transformed versions of variables to try and capture non-linear relationships, such as with farmer age, and interaction effects, such as with education and investment. The results of the three models are presented in Table 3.

Findings suggest that herd size has a positive and significant impact on the productivity level, suggesting that larger farms are more competitive and have been able to take advantage of economies of scale. Higher milk yield is associated with higher farm productivity and is statistically significant, reflecting the importance of genetic improvement as an embodied technology in improving productivity. Higher stocking density has a positive and significant relationship with farm productivity. The finding suggests that dairy farms operating relatively more intensive systems are more productive. However, the analysis also shows that intensity of purchased feed input has a negative and significant impact on productivity. A possible explanation for this is that diminishing marginal returns to purchased feedstuffs may set in for some farmers, at which point higher feed input will not enhance productivity but rather constitute additional cost for the farmer.

The relationship between age and productivity is complex. Farmer age is positive, but statistically insignificant. The insignificance of the variable could reflect the multi-generational nature of many

[5] Two other supplementary models were specified. The first supplementary model includes agricultural college dummy variable as the only education variable and the other supplementary model controls for level of specialisation. The results of these two additional models are present in the full report.

[6] The main interest of the second model is to capture the impact of past farm capital investments on productivity.

dairy farms in NI and the need to know the role of all family members involved to better establish the influence of age on farm business performance. When age, as well as age-squared (quadratic form) is included in Model 3, age is positive and significant, and age-squared is negative and significant. On average, the effect of age on productivity is negative, and the negative impact increases in size as farmers get older.

The impact of education (defined as A levels, agricultural college or above) consistently has a positive impact on productivity across all the models. The interaction effect of age and education variable is negative suggesting that dairy farms with younger farmers that have attained at least A levels or agricultural college level qualifications tend to have greater productivity. This may imply that because younger farmers have completed agricultural education more recently, they may have access to more up to date information than a farmer with the same level of qualification, but at a time when industry standards and technological options were different.

The net investment variable was found to have a negative impact on productivity, reflecting a short term impact of farm-gate milk price movements on productivity level. This result also suggests that the productivity-enhancing effect of investment is likely to be delayed, which is in line with expectations. However, when the variable was lagged by 3-years, the relationship between investment and productivity turned positive. This affirms that the returns on capital investments in terms of productivity may not be immediate but may take some time before the impact may show, thereby reflecting a long-term impact of investment on productivity. The result of the interaction of capital investment and education is positive, suggesting that education has a complementary effect on net investment by increasing the positive effect of long term net investment on productivity.

Finally, the share of payments in total farm output has a significant and negative relationship with productivity. This could suggests that farms with higher share of payments in total output or those that are highly reliant on direct payment are less productive. This result may also indicate the level of specialisation of some dairy farms given that direct payments are based on historic activities, and farms with sizeable beef enterprises (mostly low productive) had larger payments, thereby suggesting that specialised dairy farms (compared to mixed farming activities) are more productive.

Table 3. Drivers of farm-level productivity – regression results across various models

Variables	Model 1 (contains 1-in year investment)	Model 2 (contains lagged investment)	Model 3 (extended model with interaction terms)
Number of dairy cows	0.078***	0.196***	0.197***
Milk yield	0.516***	0.544***	0.541***
Stocking density	0.073***	0.101***	0.108***
Purchased feed per cow	-0.068***	-0.087***	-0.092***
Labour input per cow	-0.337***	-0.134***	-0.123***
Hired labour share	0.114*	-0.066	-0.077
Age	0.086	0.138	3.082***
Age squared			-0.396**
Education - A levels, Agric. college or above	0.030*	0.052**	0.784***
Education - Agric. college only			
Age* Education - A levels, Agric. college or above			-0.199***
Net investment per cow	-0.065***		
Net investment per cow *(3-year lagged)*		0.012**	0.015***
Net investment per cow *(3-year lagged)* *** Education - A levels, Agric. college or above**			0.059*
Share of payments in farm outputs	-0.093	-0.181**	-0.164**
Share of milk in farm outputs (specialisation proxy)			
Off farm participation ratio	-0.008	-0.022	-0.019
Severely disadvantaged area	-0.012	-0.052	-0.006
Disadvantaged area	-0.033	-0.014	-0.020
Observations	1,343	866	866
Number of farms	169	137	137

Notes: Model 1 represents model with net investment per cow variable at the current time (that is, at time *t)*; Model 2 incorporates net investment per cow variable in their lagged form (three-year lag, that is, *t*-3) *** p<1%, ** p<5%, * p<10% denote significance at 1%, 5% and 10% levels respectively