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Profitability Development and Resource Reallocation: The Case of Sugar Beet Farming in Germany

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Abstract

Following the 2006 reform of the European Union sugar market, and in anticipation of the quota abolition, a reallocation of sugar production has occurred. Using a Lowe quantity index, we evaluate the productivity and profitability of sugar beet farming in Germany from 2004 to 2013. The results show that an increase in total factor productivity partly compensated for losses in terms of trade. Moreover, the contribution of production reallocation to sector productivity growth varied across regions with distinct ownership structures of sugar processing companies. These findings have implications for policy and industry, as it transitions to a liberalised market.

Keywords: *Beet production*; *Lowe index*; *resource reallocation*; *sector productivity*; *sugar market reform*; *terms of trade*.

JEL classifications: *L52, O47, Q13, Q18*.

1. Introduction

The abolition of the sugar quota in 2017 constitutes a turning point for the sugar sector in the European Union (EU). Because the industry is now allowed to produce unlimited amounts of sugar, the demand for sugar beet is expected to increase, at least in the short term. On the other hand, domestic sugar prices are increasingly linked to world market prices, which have been far below the EU's sugar price in the EU in the past. In addition, production and use of isoglucose (high-fructose corn syrup) as a substitute increases the economic pressure on the sugar beet industry. Therefore, questions arise about the EU sugar sector's response to the new market situation without quota and whether sugar beet farming will remain profitable in the future. To prepare the sector for an era without quotas, a reform of EU sugar policies was implemented

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in 2006. Most importantly, minimum prices for sugar and sugar beets were stepwise reduced, and a voluntary restructuring scheme was introduced to buy back production quotas from sugar companies. The goal of the reform was to encourage less competitive manufacturers to reduce production (e.g. Szajner *et al*., 2016). Substantial consolidation in the EU sugar sector has taken place with a decline in the number of sugar processing factories by 42% between 2005/06 and 2015/16 while the harvested area dropped by 69% and beet production declined by only 30% (CEFS, 2016).

While increased sugar beet yields indicate productivity gains in sugar beet production, output per area of land is only a partial measure of productivity that ignores the use of other inputs such as seed or labour. Our objective is twofold. First, we evaluate changes in profitability and total factor productivity (TFP) for sugar beet production in Germany during the deregulation of the EU sugar market, both at the individual farm level and at the aggregate level. Second, we examine the role of delivery rights with respect to productivity-enhancing resource reallocation. Generally, policy reforms increase sector productivity if productive activities shift from less productive firms towards more productive ones (e.g. Eslava *et al*., 2004). Thus, it can be expected that resource reallocation is more efficient in regions where delivery rights can be effectively traded among farmers.

To achieve these objectives, we use farm-level data for German sugar beet producers from the EU Farm Accountancy Data Network (FADN) for the years 2004 to 2013. We decompose profitability change into TFP change and changes in terms of trade (TT) using a Lowe quantity index proposed by O'Donnell (2012b). This index is particularily suitable to our application because it allows consistent comparison across time and space. We then evaluate the contribution of average farm productivity change (within-effect) and reallocation of production between farms with distinct productivity levels (between-effect) on aggregate productivity growth, and test whether the contribution of the between-effect has increased after the 2006 reform.

O'Donnell (2012b) applied the Lowe index to decompose agricultural profitability change into changes in TFP and TT using state-level data in the US. The results illustrate that declines in TT are associated with increases in TFP, in line with profit-maximising behaviour of farms. More recently, the index has been applied by Mugera *et al*. (2016) to investigate sources of farm-level profitability change in a sample of Kansas dairy farms. They find that TFP change is the main driver of profitability change at the farm level. The effect of market deregulation on aggregate productivity change and reallocation of activities has been studied by Frick and Sauer (2018) for the dairy sector. They provide evidence that abolition of milk quota contributed to a more efficient resource allocation across dairy farms and thus increased sector productivity. Previous studies concerned with sugar market liberalisation primarily analyse production and trade effects *ex ante* (e.g. Elobeid and Beghin, 2006; Frandsen, 2003; Gohin and Bureau, 2006; Poonyth, 2000). To the best of our knowledge, only two studies address production responses and profitability at the farm-level. For a sample of Belgian sugar beet farms in 2002, Buysse *et al*. (2007) predict that Belgian sugar beet production will decline by 13% in response to the 2006 reform, reducing aggregate farm gross margins by 8%. Bogetoft *et al*. (2007) show that under an efficient quota allocation, EU market liberalisation would lead to a 25% decline in Danish sugar beet production while aggregate profits were predicted to fall by 70%. In a different context, Wu *et al*. (2003) study technical efficiency of sugar beet farms in Idaho, and Thirtle (1999) and Amadi *et al*. (2004) compute changes in TFP for sugar beet from 1954 to 1996 in the UK.

Our article contributes to the literature in three ways. First, we investigate farm-level changes in profitability and productivity following the 2006 reform from an *ex-post* perspective. Second, we examine the effect of deregulation in the sugar market on resource reallocation and sector productivity in beet production, which has attracted little attention in previous literature. Third, our empirical case of Germany provides unique insights into how the delivery relationships between farmers and processing factories may affect the reallocation process, because the three major sugar processing companies differ in their ownership structures and, as a result, have different mechanisms to allocate delivery rights to farmers. The results are also relevant in the larger European context, as Germany is one of the EU's major sugar producers besides France, the UK and Poland, and the pace of the sector's consolidation process has been similar to the EU-15 average (see section 2).

The article is structured as follows. In the next section, we provide a brief description of the history of EU sugar policies. The economic framework in section 3 describes our methods to compute profitability change and to decompose aggregate productivity into the within- and between-effects. Section 4 outlines the empirical framework, including the evaluation of drivers of resource reallocation with a particular focus on delivery relationships. In section 5, we describe the data and section 6 presents the results. Finally, section 7 discusses the results and offers implications for policy and industry.

2. Sugar Policy in the European Union

The EU's common market organisation (CMO) for the sugar sector was introduced in 1968 to stabilise the sugar market and to ensure living standards for EU sugar beet growers.[2] Along with quantitative supply restrictions imposed by a sugar quota system, support prices for producers were set at a level substantially higher than the world market price. The quota was subdivided into A- and B-quota, and the minimum price for sugar beet produced for A-quota was set at a higher level than the minimum price for beet produced for B-quota. A-quota sugar was primarily used for domestic consumption, but the remaining sugar was exported with subsidies (Poonyth, 2000). Further, out-of-quota sugar (C-sugar) could be exported at the world market price or carried over to the following year. By EU legislation, the supply quota was distributed across Member States, which allocated A- and B-quota across processing factories. The factories, in turn, issued delivery rights to beet growers (Burrell *et al.*, 2014).

Entering into force in 1995, the Uruguay Round Agreement on Agriculture required the EU to limit subsidised sugar exports, while the quota system and price mechanisms remained in place (Frandsen, 2003; Poonyth, 2000). Sugar policies remained largely unchanged despite major CAP reforms in the past decades. However, in 2005, the WTO ruled that C-sugar exports do not qualify as unsubsidised even though they were sold at world-market prices. The members of the WTO panel argued that minimum prices for A- and B-sugar cross-subsidises the production of C-sugar by covering the factories' fixed costs (Burrell *et al.*, 2014; Gohin and Bureau, 2006). As a result, the EU implemented a significant reform of the sugar policies in 2006.

[2]Council regulations No 1009/67EEC.

This reform involved the replacement of public intervention storage, the conflation of A- and B-quotas, and the introduction of a limit on out-of-quota sugar exports. Most importantly, the minimum prices for white sugar and quota beet were gradually reduced by 36% and 20%, respectively. To compensate for their income loss, farmers received 64% of the price cut as part of the single farm payment. Since Germany has adopted the dynamic hybrid model for implementation of the single payment scheme, entitlements within a region were harmonised over time. Therefore, not only beet growers, but also farms without sugar beet production benefited from this compensation. Further, a voluntary compensation system worth \euro5.4 billion was introduced to facilitate the restructuring of the sector. With this programme, the EU offered to buy back quota at fixed prices (e.g. 730 EUR/tonne in the marketing year 2006/07) from sugar companies that – in turn – had to compensate farmers who lost delivery rights following this restructuring process. Germany, for example, returned 15.2% of their quota, amounting to more than 500,000 tonnes of sugar. Other countries, such as Bulgaria, Ireland and Latvia, ceased sugar production completely. In total, the EU sugar quota decreased from 17.5 to 13.3 million tonnes between 2006/07 and 2010/11 (Burrell *et al*., 2014). Because the EU-wide quota reduction was sufficient to comply with WTO regulations, the Commission refrained from further mandatory quota cuts (Nolte *et al*., 2012). Finally, supply quotas were prolonged in the 2006 reform until 2015 with no commitment for further renewal in the 2006 reform. The understanding in the market was that quotas would be abolished thereafter (Burrell *et al*., 2014).

With the 2013 CAP reform, a final decision was made to abolish the quota system in 2017, along with minimum prices and export restrictions, to further liberalise the EU sugar sector. Thus, while sugar companies were encouraged to reduce production in the 2006 reform, they are now allowed to increase production beyond their former quota levels. In an *ex-ante* analysis, Nolte *et al*. (2012) forecast that EU sugar production would increase from 13.3 (excluding out-of-quota sugar) to 15.5 million tonnes by 2019/20 without the quota system. Along with the sugar quota abolition, restrictions on the production of isoglucose are also repealed. The European Commission estimates that isoglucose production in the EU will increase to 10% of the sweetener market by 2026 (DG Agri, 2016), which is about twice as much as before the quota abolition. Notwithstanding the elimination of quota, delivery rights continue to be used to coordinate the supply and demand of sugar beet between processing companies and beet growers. The sugar processing companies differ in their approaches to the issue and distribution of delivery rights due to different organisational forms (see below).

Figure 1 illustrates price movements in the EU domestic market, compared to world market prices, between 2006 and 2019 as well as EU reference prices. While the 2006 EU price for white sugar was almost twice as high as the world market price, it dropped after implementation of the 2006 reform but then recovered after 2010 with an increase of the world market price. Now, EU and world market sugar prices are increasingly linked to each other.

The deregulation of the sugar market had a significant impact on the structure of the EU sugar industry. According to the European Association of Sugar Manufacturers (CEFS, 2016), the number of sugar processing factories in the EU declined from 189 in 2005/06 to 109 in 2015/16 (–42%). In the same period, beet production declined by 30% from 128 million tonnes to 89 million tonnes, and sugar production went down by 25%, from 20 million tonnes to 15 million tonnes (including out-of-

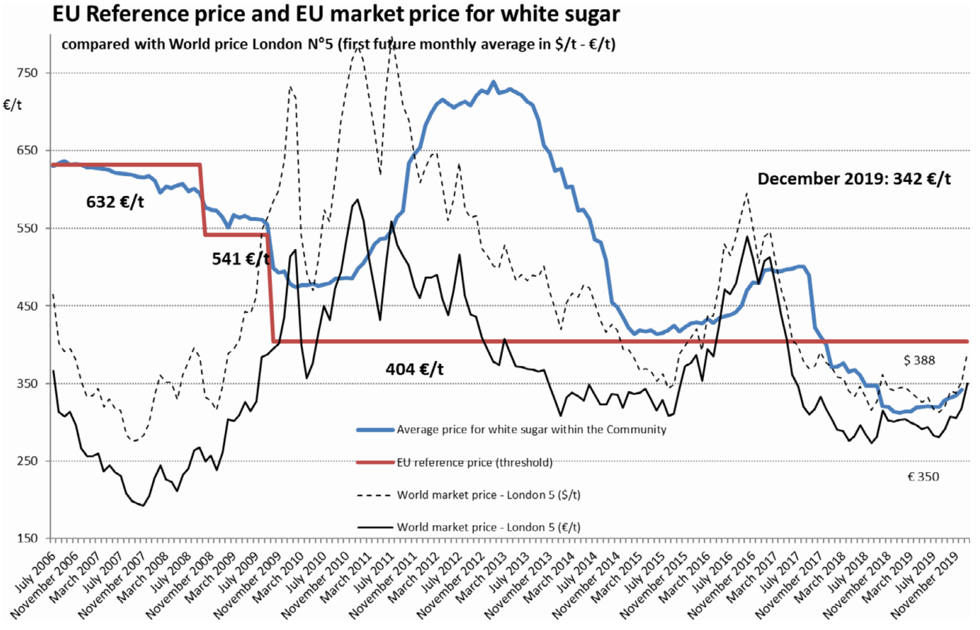

Figure 1. The EU reference price and white sugar market price, compared with the World Price London No. 5; *Source*: Committee for the Common Organisation of Agricultural Markets, 27 February 2019.

quota production). In Germany, the number of factories decreased by 23%, beet production by 11%, and sugar production by 27% (CEFS, 2016).

3. Economic Framework

3.1. Profitability and productivity

The link between productivity and profitability is illustrated in Figure 2, where (aggregate) output is plotted against (aggregate) input. The curve through the origin and points A, B and C represents the production frontier. The points A, B and C represent the output-input combinations of three different farms (or one farm in three periods). Productivity is given by the ratio of aggregate output Q to aggregate input X. In the present example, farm A maximises productivity. In contrast, profitability is maximised where the isoprofit line is tangent to the production frontier (farm B). On the other hand, farm C is both less productive and less profitable than farm B. Note that the slope of the isoprofit line varies with the ratio of input prices to output prices: If input prices increase more than output prices, the slope becomes steeper, moving profit-maximising farm B closer to the productivity-maximising point of production.

With aggregate output price P and input price W, profitability of farm i in period t is defined as $PROF_{it} = (P_{it}Q_{it})/(W_{it}X_{it})$. Comparing the profitability of farm i in period t with the profitability of farm h in period s, the profitability index is defined as (O'Donnell, 2012b):

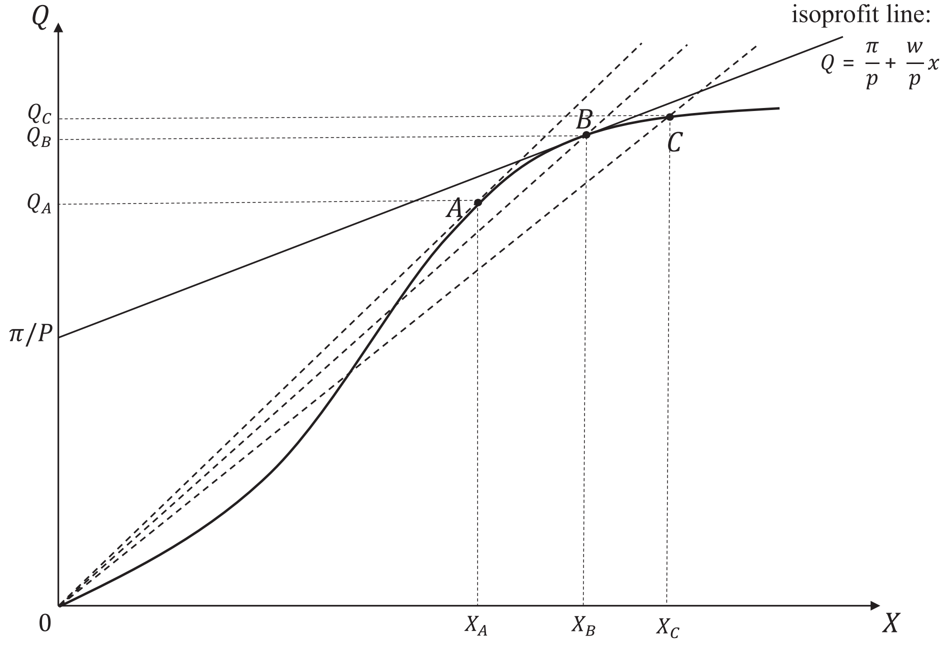

Figure 2. Productivity and profitability

$$PROFI_{hsit} = \frac{PROF_{it}}{PROF_{hs}} = \frac{P_{it}Q_{it}}{W_{it}X_{it}} \times \frac{W_{hs}X_{hs}}{P_{hs}Q_{hs}} = \frac{PI_{hsit}}{WI_{hsit}} \times \frac{QI_{hsit}}{XI_{hsit}} = TTI_{hsit} \times TFPI_{hsit}. \quad (1)$$

Equation (1) shows that the profitability index can be decomposed into a productivity index and an index for terms of trade. In our empirical application to sugar beet production, we consider one output (sugar beet) and multiple inputs. Therefore, only inputs have to be aggregated to calculate the TFP index in equation (1). We use a linear aggregator function that O'Donnell (2012b) attributes to Lowe (1822). O'Donnell (2012a) shows that in contrast to the commonly used Laspeyres, Paasche, Fisher and Tornqvist indices and their EKS[3] counterparts, the Lowe index satisfies all economically relevant axioms from index number theory, including the transitivity and identity axioms. These two axioms guarantee that direct and indirect comparisons of two observations yield the same value change and that the index takes a value of one if respective outputs and inputs are unchanged between two observations. Therefore, the Lowe index is particularly useful for our comparisons of sugar beet productivity and profitability across both time and space. Conceptually, the Lowe quantity index consists of values for different baskets of goods, evaluated using the same set of reference prices. For one output (sugar beet) and multiple inputs, we obtain:

[3]Named after Eltetö and Köves (1964) and Szulc (1964) who computed unweighted geometric averages of Fisher indices to ensure transitivity.

$$
\begin{aligned}
QI_{hsit} &= \frac{q_{it}}{q_{hs}} \\
XI_{hsit} &= \frac{X(x_{it})}{X(x_{hs})} = \frac{w_0' x_{it}}{w_0' x_{hs}} \\
TFPI_{hsit} &= \frac{QI_{hsit}}{XI_{hsit}} = \frac{q_{it}}{q_{hs}} \times \frac{w_0' x_{hs}}{w_0' x_{it}}.
\end{aligned} \tag{2}
$$

An important decision to be made is the choice of the reference prices. O'Donnell (2012b) uses sample mean values as reference prices w_0 and emphasises that the chosen prices should reflect the relative importance that decision-makers place on different outputs and inputs. Mugera *et al.* (2016) use the farm with maximum TFP in a certain year as reference farm. In our analysis, reference prices are sample median values because of their robustness in the presence of possible outliers.

3.2. Productivity decomposition

As noted by Mahler (1994), rigidities in the quota market have prevented an efficient reallocation of beet production for a long time. To investigate if resource allocation became more efficient after the 2006 reform, we decompose TFP following Olley and Pakes (1996), where sector productivity at time t is defined as an output share-weighted average of firm-level productivity. We define output share as the portion of sugar beet produced by an individual farm in the respective region. Given productivity (TFP_{it}) and output share (σ_{it}) of farm i at year t, sector-level productivity TFP_t is decomposed as follows:

$$
TFP_t = \sum_{i=1}^{N} \sigma_{it} TFP_{it} = \overline{TFP}_t + \sum_{i=1}^{N} (\sigma_{it} - \overline{\sigma}_t)(TFP_{it} - \overline{TFP}_t). \tag{3}
$$

The first term represents the unweighted mean productivity of farms in a specific year (within-effect), and the second term is denoted as a covariance term (between-effect). If there is no correlation between productivity and output share, the covariance term is zero and sector-level productivity is equal to the average, unweighted firm-level productivity. If more productive farms have a higher market share than less productive farms, sector-level productivity exceeds the unweighted average. On the other hand, if more productive farms hold a lower market share than their counterparts, sector-level productivity is below the unweighted average. This representation provides a straightforward way to derive the sources of sector productivity growth over time: changes in unweighted, average productivity describe changes generated within farms ('within-change'), while changes in the covariance term reflect productivity change stemming from reallocation of market shares ('between-change'). In other words, it analyses the relative contribution of growth at the farm level, e.g. due to technical progress or an increase in production efficiency, and growth by reallocating production away from less productive towards more productive farms.

4. Empirical Implementation

4.1. Allocation of inputs

As usual in data from bookkeeping records, our data do not report input use for individual crops but aggregated over all farm outputs. Focusing on specialised sugar beet farms only – as in Wu *et al.* (2003) – is not possible because farms are restricted to planting beet on no more than 30% of their utilised agricultural area. To calculate TFP for an individual crop,[4] we need to estimate input allocation among individual crops. For variable inputs (crop specific inputs and other inputs), we employ the 'behavioural approach' proposed by Just *et al.* (1990), exploiting the fact that land allocation per crop is observed in the data-set.[5] The underlying assumption is that farmers make decisions on land allocation and the ratio between variable inputs and land, while they behave as if the production technology is characterised by constant returns to scale. They are assumed to receive and follow similar recommendations by, for example, extension services (in terms of 'quantity per hectare'), and deviations from the average ratios are possible due to seasonal (e.g. economic or weather conditions) and farm-specific (e.g. soil quality and farmers' ability or perceptions) variations.[6] Thus, the total use of input j, which *is* observed in the data-set, can be expressed as (Just *et al.*, 1990):

$$X_{jit} = \sum_{k=1}^{K} \left[\alpha_{kj} + \beta_{ji} + \gamma_{jt}\right] \times L_{kit} + \epsilon_{jit}, \tag{4}$$

where α_{kj} denotes the average use of input j for producing the k^{th} output, β_{ji} is the i^{th} farm's deviation, and γ_{jt} captures the time effect. Furthermore, L_{kit} is the land used to produce crop k by farm i in year t, and ε_{jit} is the error term to account for statistical noise. After estimating (4) using ordinary least squares (OLS) regression, the allocation of input j to crop k is calculated as:

$$\hat{X}_{kjit} = \left[\hat{\alpha}_{kj} + \hat{\beta}_{ji} + \hat{\gamma}_{jt}\right] L_{kit}. \tag{5}$$

At this point, it must be emphasised that farm heterogeneity may cause endogeneity problems in input allocation equations (Carpentier and Letort, 2012). For example, farmers whose input use for a specific crop is above the population's average may allocate less land to this crop because it is less profitable to them. In this case, crop-specific input use affects land allocation, and thus the acreage levels in equation (4) would be correlated with the error term. However, if crop margins within farms are positively related, the heterogeneity bias does not significantly affect individual acreage decisions. Given the lack of valid instruments for individual acreage levels, we are not able to test for the potential endogeneity. We trust that the heterogeneity bias has only a limited impact on the results, as was also the case in the empirical application in Carpentier and Letort (2012). Nevertheless, this qualification must be kept in mind when interpreting the results. For fixed inputs (labour and capital), on the other hand,

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[4]It is more common to find crop-specific TFP measures at the aggregate level, for example in Jin *et al.* (2002) who possess data on crop-specific inputs for Chinese provinces. In the non-agricultural sector, Cherchye *et al.* (2013) and Walheer (2019) estimate product-specific productivity with observed input allocations.

[5]More recently, this approach has been applied by Serra *et al.* (2009).

[6]An alternative approach is to model input use as a function of input and output prices based on profit-maximising behaviour. This approach and its results are outlined in online Appendix 2. The resulting crop-specific input usage shows unreasonably large standard deviations. The rigid specification ruling out substitution between inputs may be one reason for these econometric results. We opt for the behavioural approach because it yields far more reasonable crop-specific input usage (see section 5).

we use revenue shares from sugar beet as weights similar to Foster *et al.* (2008) and Collard-Wexler and de Loecker (2015). With observed revenue shares, however, we would endogenously obtain higher values of TFP in times of low prices. Therefore, to avoid misleading conclusions about productivity and profitability development, we calculate revenue shares using each farm's average crop prices over the whole period of the study.[7]

4.2. Drivers of resource reallocation

The delivery relationship between beet growers and sugar processing factories differs across German regions. Three major sugar companies, distinguished by their ownership structure, operate sugar factories in Germany. *Südzucker* (henceforth company 1) and *Nordzucker* (company 2) are joint-stock companies (in German: *Aktiongesellschaft*) that mainly run factories in southern and northern Germany, respectively. The stocks of company 1 are publicly traded and the major shareholder is a farmers' cooperative. In exchange for their capital contribution to the sugar company, the farmers hold delivery rights, which can be sold or lent out to other farmers. In contrast, the stocks of company 2 are not publicly traded, and delivery rights arise only from stock possession. Finally, *Pfeifer & Langen* (company 3) is a private business that operates sugar factories in the west of Germany. Even though delivery rights are usually linked to agricultural land, there is no binding commitment to any capital contributions. From economic theory, resource allocation is most efficient if there is a free market for delivery rights. Thus, we expect to find productivity-enhancing reallocation primarily in the catchment areas of company 1 where delivery rights can be traded and of company 3 were delivery rights are not linked to capital contributions.

To explore the potentially different effect of the sugar reform in 2006 on resource reallocation, we regress the farm-level covariance term ($Cov_{it} = (TFP_{it} - \overline{TFP}_t)(\sigma_{it} - \overline{\sigma}_t)$) on a set of explanatory variables, motivated by Lin and Huang (2012) and Frick and Sauer (2018)[8]:

$$\begin{aligned} Cov_{it} &= \beta_0 + \beta_1 \times Cov_{i,t-1} + \beta_2 \times Comp1_i + \beta_3 \times Comp3_i \\ &\quad + \beta_4 \times (Comp1_i \times Post\text{-reform}_{it}) + \beta_5 \times (Comp3_i \times Post\text{-reform}_{it}) \\ &\quad + \beta_6 \times UAA_{it} + \beta_7 \times Shbeet_{it} + \sum_t \beta_t \times Year_t + \epsilon_{it}. \end{aligned} \tag{6}$$

The dependent variable (Cov_{it}) represents the contribution of resource allocation towards sector productivity for each farm observation. A higher value represents more efficient resource allocation (i.e. more productive farms hold a higher market share). Therefore, a positive coefficient of explanatory variables indicates a positive relationship with resource allocation. We include the lagged value of the covariance term ($Cov_{i,t-1}$) as explanatory variable, because we expect both productivity and market shares to be persistent over time due to the use of long-term delivery rights. Further, *Comp1* and *Comp3* are dummy variables for the catchment areas of company 1 and company 3 (e.g. *Comp1* = 1 if the farm is located in the catchment area of

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[7]As a robustness check, we applied the behavioural approach by Just *et al.* (1990) for fixed inputs as well, making the same assumption as for variable inputs. This procedure did not change any of the main results.

[8]Lin and Huang (2012) use cross-sectoral rather than firm-level covariances.

company 1, 0 otherwise). Our primary interest lies in the heterogeneous effect of the 2006 market reform across the catchment areas of the three companies, represented by interaction terms between dummy variables for the reform (*Post-reform* = 1 if *year* > 2006, 0 otherwise) and catchment areas. Company 2 is used as reference, so that parameters β_4 and β_5 capture the heterogeneous effects of the 2006 reform on productivity-enhancing production reallocation in the catchment areas of companies 1 and 3 in comparison to the catchment area of company 2. We further control for the utilised agricultural area (*UAA*) as a proxy for farm size and for the share of farmland devoted to sugar beet production (*Shbeet*). Finally, we include a set of year dummies. The ε_{it} is a composite error term, consisting of fixed effects, μ_i, and idiosyncratic shocks, v_{it}.

Using lagged values of the dependent variable as regressors induces endogeneity because the lagged variable is correlated with the fixed effect μ_i (Nickell, 1981). In addition, utilised agricultural area and land share of sugar beet may be endogenous in our specification, because the covariance term includes a performance measure (productivity). Consequently, estimating (6) with OLS methods would yield biased estimates. Arellano and Bond (1991) and Blundell and Bond (1998) designed GMM-estimators that are particularly useful when there are no instrumental variable candidates available other than lagged values of endogeneous variables (Roodman, 2009). We employ the system-GMM approach by Blundell and Bond (1998) because it is more efficient and allows inclusion of time-invariant regressors, so that the linear terms of catchment areas in our model specification are not omitted. With this system-GMM procedure, the levels equation in (6) is simultaneously estimated with its first-difference transformation, where endogeneous variables are instrumented with first-differenced lagged variables. However, the lagged variables are only valid instruments if there is no autocorrelation between the idiosyncratic error terms (e.g. Roodman, 2009). To make sure that this is the case in our estimation, we employ the Arellano and Bond (1991) test for autocorrelation. Finally, we use the Sargan (1958) and Hansen (1982) tests of overidentifying restrictions to confirm that the used instruments are uncorrelated to the error term.

5. Sample and Data Description

For the empirical analysis, we use farm accountancy data for specialised crop farms in Germany obtained from the EU Farm Accounting Data Network (FADN) covering the years 2004 to 2013 and amounting to a total of 16,717 observations. In our time period, 1,940 farms produce sugar beet at least once. Of these farms, 87% produce beet in every year, 12% cease beet production and 4% start beet production.[9] In total, there are 8,749 farm observations with sugar beet production. The average yield of sugar beet varies between 57 tonnes per hectare in 2006 and 73 tonnes per hectare in 2011 and the yearly fluctuations are very similar to the population averages in Germany.

Farm-level productivity and profitability of sugar beet production are calculated considering five inputs and their respective price indices: land, labour, capital, crop-specific inputs (seed, fertiliser and pesticides), and other inputs (fuel, electricity,

[9]The shares add up to slightly more than 100 because some farms seize and start again or vice versa during the study period.

contract work, insurance and other farming overheads).[10] Land is measured in hectares and labour is measured in annual working hours, including both paid and unpaid labour. Capital usage is proxied by depreciation costs. Crop-specific inputs and other inputs are also measured in costs. All monetary values are deflated using agricultural price indices from the German statistics agency (Destatis) to obtain implicit quantities.

The price for sugar beet is directly observed in the data-set. Input price indices for crop-specific inputs and other inputs are computed using weighted average cost shares. The price for capital is calculated as the sum of the rental price of acquisition, measured by dividing the financial expenses by the debt, and the rate of depreciation obtained by dividing depreciation costs by the initial value of capital (de Frahan *et al*., 2011). Finally, prices for land (both owned and rented) and labour (both paid and unpaid) are calculated as district-specific (NUTS 2) values using the farm-level data on land rental prices and prices for hired labour, respectively. In both cases, farm-level prices below the 5% and above the 95% percentiles are not included in the calculation of regional averages to be robust against potential outliers.

Summary statistics for the variables used in the analysis are provided in Table 1. The use of crop-specific inputs and other variable inputs were estimated using equations (4) and (5) based on our entire FADN sample (n = 16,717) to exploit as much information as possible. We report the estimated per hectare use (implicit quantities, or constant costs, measured in EUR) of these inputs for distinct crop categories in Table A.1 in the online Appendix. Below this table, we present cost estimates by a contribution margin calculator provided by the Bavarian State Research Center for Agriculture (LfL) for Bavaria. Our estimates are in line with these values, both in absolute terms and relative values across crop categories. We therefore trust that the estimated quantities are reliable.

6. Results

The unweighted averages of profitability and its components are presented in Table 2. We also report yield levels (tonnes per hectare land) for two reasons. First, beet output and land devoted to beet production are both directly observed in the data-set and thus land productivity can be computed without estimating input allocations. Second, yield is an intuitive measure often used for benchmarking by farmers and stakeholders. This measure is inconclusive because it neglects changes in the use of other inputs and therefore does not allow conclusions about farm performance. However, it may be used as approximation, and it is interesting to see whether land productivity growth is offset by an increased use (or cost) of other inputs.

The profitability levels can be interpreted as quota rent, because they represent the residual profit after accounting for all variable and fixed inputs. Values above unity indicate that sugar beet production values exceed sugar beet production costs. This was the case in all years except for the four years following the 2006 reform (i.e. 2007–2010). The year 2008 was the least profitable year for sugar beet farming in Germany, with a profitability level 35.0% ((0.91 − 1.40)/1.40) below its 2004 level. During the

[10] Another source of (opportunity) costs can arise from the possession of delivery rights. While they do play a role for the farmers in making production decisions, they are not included in our measure of productivity and profitability, which only considers the use (and thus cost) of physical inputs and outputs.

Table 1
Summary statistics for variables used in the analysis

Variable	Mean	Std. Dev.	Minimum	Maximum
Sugar beet output (tonnes)	1,172.4	1,471.9	12.0	26,892.0
Sugar beet area	18.5	23.5	0.2	428.7
Labour (hours)	1,141.0	1,755.2	8.1	52,405.4
Capital (cEUR)	7,806.7	10,387.2	0.0	199,121.0
Crop-specific inputs (cEUR)	15,625.3	19,032.7	149.0	29,4102.8
Other variable inputs (cEUR)	11,135.7	14,623.5	88.0	28,4538.9
Price for sugar beets (EUR/tonne)	43.7	10.4	14.8	142.0
Rental price for land (EUR/ha)	286.9	93.0	100.8	590.3
Price of labour (EUR/hour)	9.0	1.4	3.9	12.7
Price of capital (EUR)	0.1	0.1	0.0	0.7
Price index for crop-specific inputs	1.0	0.1	0.7	1.3
Price index of other inputs	1.0	0.1	0.8	1.2
Utilised agricultural area	258.7	480.5	3.9	5,745.5
Share of land allocated to sugar beet	0.1	0.1	0.0	1.0

Note: n = 8,749; cEUR is constant Euros with base year = 2010.

Table 2
Unweighted averages of profitability, terms of trade, TFP and yield

Year	PROF		TT		TFP		Yield (t/ha)	
2004	1.40	(0.41)	1.43	(0.27)	1.00	(0.28)	59.67	(11.55)
2005	1.27	(0.38)	1.31	(0.26)	0.99	(0.28)	58.98	(11.41)
2006	1.10	(0.33)	1.16	(0.21)	0.95	(0.27)	57.36	(12.84)
2007	0.96	(0.28)	0.95	(0.20)	1.03	(0.31)	62.23	(13.14)
2008	0.91	(0.26)	0.88	(0.20)	1.07	(0.33)	60.92	(14.18)
2009	0.98	(0.29)	0.85	(0.21)	1.19	(0.34)	67.16	(13.36)
2010	0.92	(0.28)	0.84	(0.21)	1.11	(0.30)	63.90	(12.96)
2011	1.22	(0.32)	1.00	(0.19)	1.25	(0.33)	73.03	(13.42)
2012	1.24	(0.31)	1.05	(0.20)	1.21	(0.30)	69.58	(12.00)
2013	1.19	(0.34)	1.05	(0.22)	1.15	(0.29)	66.22	(13.71)

Note: n = 8,749. Standard deviations are in parentheses. PROF is profitability, TT is terms of trade, TFP is total factor productivity.

period 2004–2008, terms of trade sharply decreased at an average rate of −9.7%, and recovered after 2010 along with increasing profitability levels. This observation suggests that changes in profitability were largely driven by changes in terms of trade during the study period. TFP, on the other hand, shows an increasing trend. Declines in TFP (2004–2006, 2009–2010, and 2011–2013) were accompanied by yield declines, illustrating the important role of land productivity in determining TFP. Overall, profitability was 15.1% lower in 2013 compared to 2004, despite a 15.1% growth in TFP, at the sample mean.

The changes in TFP, profitability and terms of trade are illustrated in Figure 3, separated by catchment areas of the three sugar companies. These indices compare productivity, profitability and terms of trade to their respective values in 2004. Since it is not indicated in the data which factory farms deliver their beets to, we assume that each farm delivers beets to its nearest factory and exclude farms that are located at border regions.[11] This reduces the sample size from 8,749 to 6,107 observations. The figure shows that profitability closely followed changes in terms of trade in all regions. Further, it is seen that increasing TFP compensated for the loss in terms of trade. In particular, the considerable TFP growth between 2006 and 2009 counteracted profitability losses in all regions. As a result, profitability level in 2013 equals the profitability level in 2004 even though terms of trade are 20% below the initial level in catchment area 1. In catchment areas 2 and 3, by contrast, sugar beet profitability in 2013 is about 20% and 10% below 2004 levels, respectively. Terms of trade, on the other hand, are 22% below 2004 levels in 2013. Thus, reduced terms of trade were fully compensated by TFP growh in catchment area 1 and partly compensated in catchment areas 2 and 3.

6.1. Sector productivity

Table 3 reports levels of sector productivity, the within-effect (unweighted average sugar beet TFP) and the between-effect (the effect of resource allocation). The values of the average TFP are from Table 2. The positive values of the between-effect mean that – throughout the study period – farms with more productive beet production hold larger market shares than farms with lower sugar beet TFP. Therefore, sector TFP is above the unweighted average TFP in all years. Further, it can be seen that there was an increase in the between-effect in the years immediately after the 2006 reform. This indicates that resource allocation positively contributed towards sector productivity in these years. However, the value of this term is relatively unstable after the year 2009. Therefore, we cannot definitively say whether resource allocation continues to be significantly more efficient in recent years. On average, at least, the covariance term takes higher values after 2006 compared to the years previous to the

Table 3

Decomposition of aggregate sugar beet TFP

Year	Sector TFP	Within-effect		Between-effect	
2004	1.12	1.00	(89.57%)	0.12	(10.43%)
2005	1.10	0.99	(90.25%)	0.11	(9.75%)
2006	1.04	0.95	(91.02%)	0.09	(8.88%)
2007	1.17	1.03	(88.43%)	0.14	(11.57%)
2008	1.21	1.07	(88.50%)	0.14	(11.50%)
2009	1.32	1.19	(90.05%)	0.13	(9.95%)
2010	1.22	1.11	(91.22%)	0.11	(8.78%)
2011	1.39	1.25	(90.15%)	0.14	(9.85%)
2012	1.31	1.21	(92.06%)	0.10	(7.87%)
2013	1.26	1.15	(91.10%)	0.11	(8.90%)

Note: $n = 8,749$; Numbers in parantheses are shares of sector productivity.

[11]The procedure was assessed to be appropriate by experts from sugar beet farming associations.

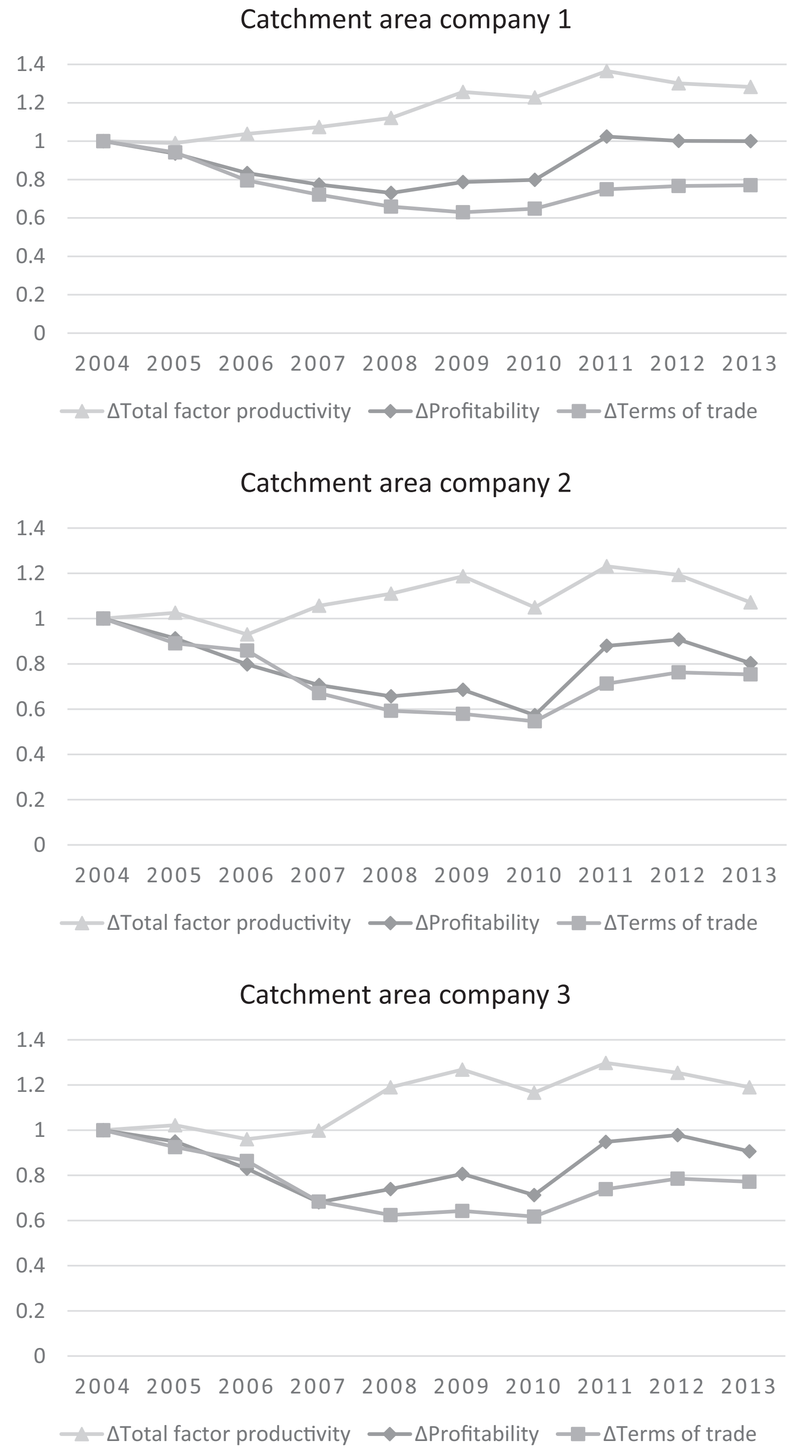

Figure 3. Changes in total factor productivity, profitability and terms of trade by catchment areas

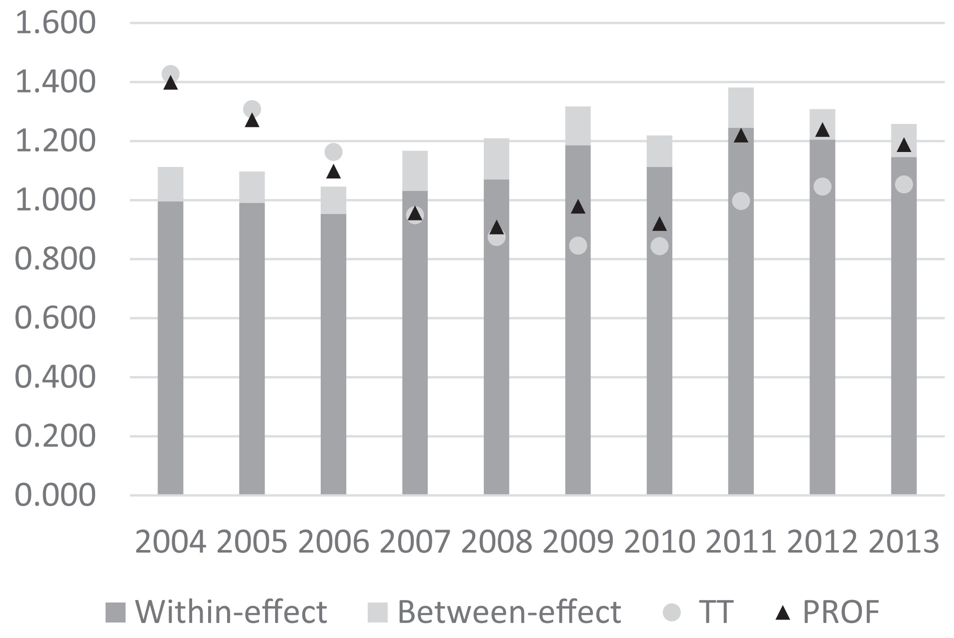

Figure 4. Productivity decomposition, terms of trade and profitability

reform, providing some support for the hypothesis that the reform contributed to an increase in sector productivity.

Figure 4 visualises the development of sector productivity, decomposed into the within-farm component and the between-farm component, along with profitability and terms of trade. The figure underlines that the contribution of the between-effect towards sector productivity became slightly more important after the 2006 reform, and that productivity growth worked against unfavourable price developments. Overall, the within-effect played a larger role in the determination of sector productivity changes than the between-effect. We investigate the contributions of the two effects over time in more detail in the following section, segmented by catchment areas of the three main sugar companies in Germany.

6.2. Reallocation and ownership structure

To describe the association between ownership structures of sugar companies and the resource allocation across sugar beet growers, we calculated the decomposition of productivity in (3) separately for farms within catchment areas of different sugar companies. Changes in sector productivity, as well as the contributions of the within-effect and the between-effect, are illustrated in Figure 5. The 2004 value of catchment area of company 1 is used as the base value for all indices. The upper panel shows that sector productivity of beet growing in the catchment area of company 1 was below that in the areas of companies 2 and 3 throughout the data period. Comparing the three panels, it becomes clear that sector productivity growth was largely driven by average farm productivity growth in all regions. The contribution of the between effect is far less pronounced.

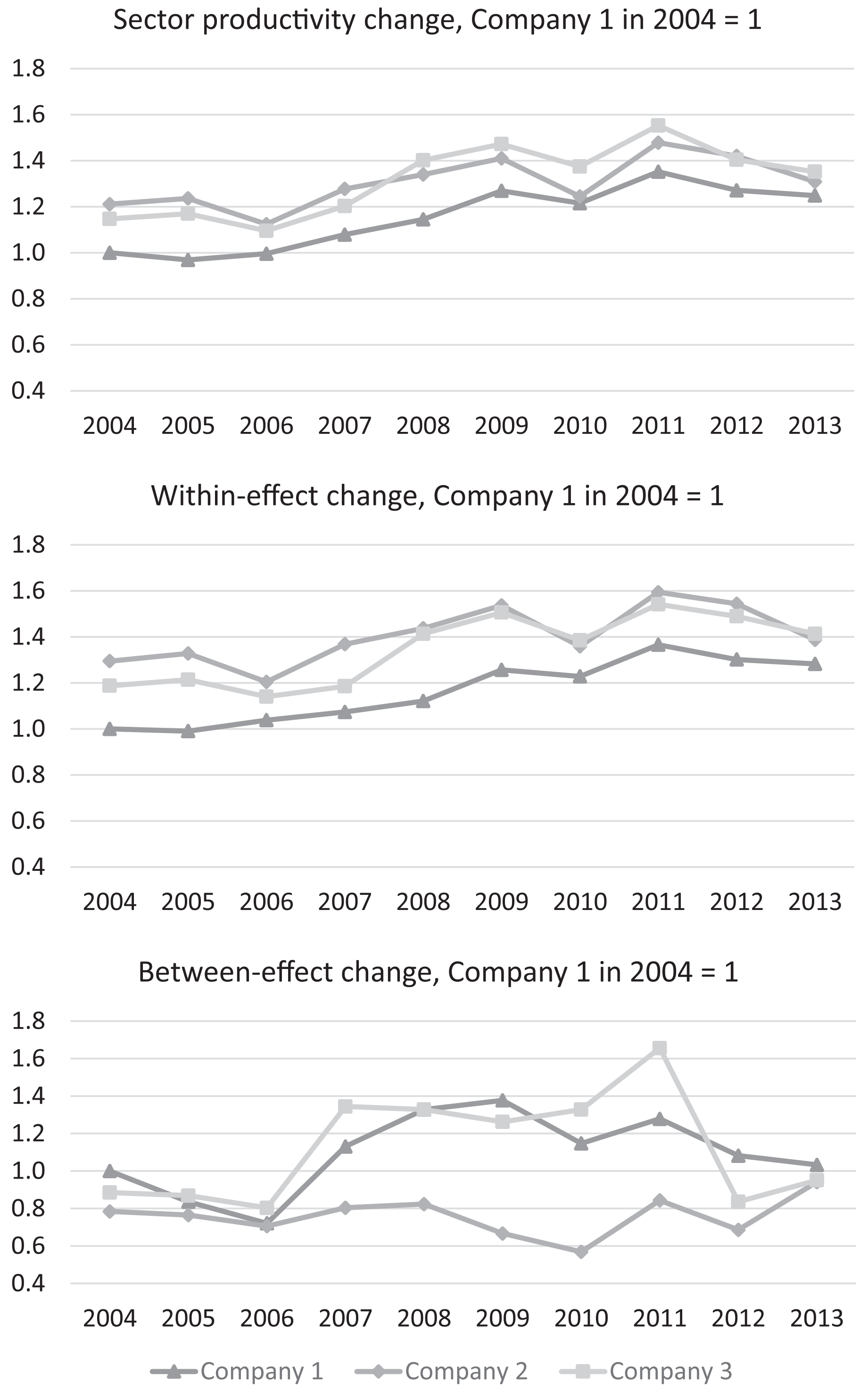

Figure 5. Contributors to sector productivity growth by catchment areas

The bottom panel shows that the between-effect in the catchment area of company 2 was consistently below that of farms in the catchment areas of the other two sugar companies, indicating that the contribution of resource allocation to sector productivity was lowest in the catchment area of the company with the least transparent market for stocks and delivery rights. In the other two regions, a sudden increase in the contribution of resource reallocation to sector productivity growth is observed after 2006, the year the sugar market reform was implemented. However, a decline in the between-effect occurred towards the end of the study period, especially within the catchment area of the company 3. This is surprising because it implies that more productive farms lost market shares, or that farms with higher market shares suddenly become less productive. One possible explanation is that productivity differences between farms can vary because of production uncertainty and weather fluctuations. Further, the data show that average TFP levels as well as farm-level heterogeneity in TFP were considerably lower in 2012 than in 2011, in particular for company 3, giving less scope for sector productivity gains from efficient allocation. Nevertheless, the results indicate that resource allocation became on average more efficient after the 2006 reform. We performed the sectoral analysis for profitability levels as well. The results are shown in Figure A.1 in the online Appendix. It is plausible that the between-effect resembles the one from the productivity decomposition, as productivity change is, along with price changes, a component of profitability change. The changes in the between-effect, however, fluctuate more than those observed from the productivity decomposition, as they are confounded by year-to-year variations in the terms of trade.[12]

The results of the system-GMM estimation for the model in (6), reported in Table 4, allow us to draw statistical inferences about resource allocation in sugar beet farming. Both the Sargan (1958) and Hansen (1982) tests of overidentifying restrictions and the Arellano and Bond (1991) test of second-order autocorrelation show the desired results, namely that the null hypotheses of joint validity of instruments and no autocorrelation cannot be rejected at the usual levels of significance. The statistically significant estimate for the lagged covariance term confirms the expected persistency of the farm-level between-effect. The positive estimate for company 1 indicates that resource allocation is on average more efficient in its catchment area compared to the catchment area of company 2, even though the difference is only statistically significant at the 10% level. This difference increased after the 2006 reform, as indicated by the significantly positive coefficient for the interaction term between the post-reform dummy variable and company 1. Both the coefficient for company 3 and its interaction term with the post-reform dummy are statistically insignificant. However, they are jointly significant at the 10% significance level (*p-value* = 0.066), implying that resource allocation after the 2006 reform is more efficient in the catchment area of company 3 compared to the catchment area of company 2. Overall, the regression results show that the contribution of resource reallocation towards sector productivity growth after the 2006 reform was significantly higher in the catchment area of

[12]Foster *et al.* (2008) compare the effects of productivity, prices and idiosyncratic demand on firms' survival in the manufacturing sector. Noting that more productive firms tend to charge lower prices, they use physical productivity as instrument for firm-level prices to estimate the demand function and derive producer-specific demand shocks. In our empirical case of sugar beet production, producers are price takers and demand shocks can be assumed to affect competing producers equally. Thus, we focus on cross-farm variation in productivity when analysing resource reallocation.

Table 4
Effect of the 2006 reform on productivity-enhancing resource reallocation

Variable	Coefficient	Std. Err.	z-statistic
One-period lag of covariance	0.661***	0.217	3.04
Company 1	4.21E-05*	2.40E-05	1.76
Company 3	1.85E-05	1.92E-05	0.96
Post-reform × company 1	4.11E-05**	2.05E-05	2.00
Post-reform × company 3	2.63E-05	2.43E-05	1.08
Utilised agricultural area	5.76E-07*	3.12E-07	1.85
Land share sugar beets	4.79E-04	4.10E-04	1.17
Year 2005	7.15E-05***	2.68E-05	2.66
Year 2006	2.68E-05	3.35E-05	0.80
Year 2007	6.88E-05	1.64E-05	4.20
Year 2008	8.41E-05***	1.99E-05	4.23
Year 2009	−2.89E-05	2.21E-05	−1.31
Year 2010	−7.39E-06	1.01E-05	−0.73
Year 2011	1.79E-05	1.09E-05	1.64
Year 2012	7.98E-07	1.10E-05	0.07
Year 2013	*reference year*		
Constant	−1.77E-04	1.17E-04	−1.52
Nr. of observations	4527		
Nr. of farms	1045		
Nr. of instruments	50		
Wald test for overall significance			
Chi-squared	124.63***		
P-value	0.000		
Arrelano-Bond test of 2nd order autocorrelation			
Z-statistic	−0.48		
P-value	0.63		
Sargan test of overidentifying restrictions			
Chi squared	38.61		
P-value	0.269		
Hansen test of overidentifying restrictions			
Chi squared	38.37		
P-value	0.278		

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. The dependent variable is the covariance term, representing the between-effect on sector productivity. The first year of the data is omitted due to the inclusion of the lagged value of the dependent variable. Catchment area of company 2 serves as reference for the policy effect. Results are obtained using the Blundell and Bond (1998) estimator with fifth and higher lags of endogeneous variables being used as instruments.

companies 1 and 3 compared to company 2. Finally, utilised agricultural area is positively related to the covariance term, while specialisation in sugar beet production is not statistically significant.

7. Discussion and Conclusion

In this article, we examined changes in profitability and productivity of sugar beet farming in Germany over a 10-year period from 2004 to 2013. We decomposed profitability of sugar beet farming into total factor productivity (TFP) and terms of trade effects using a Lowe quantity index that allows consistent comparisons across times and space (O'Donnell, 2012a,b). The results show that average sugar beet profitability in Germany decreased between 2004 and 2008 due to unfavourable price developments and recovered after 2010. This is in line with the low EU market prices for white sugar in the years following the 2006 reform. From 2007 to 2010, the average production value of sugar beet was below production cost, underlining the importance of single farm payments, which were increased to compensate farmers for the losses as a consequence of a reduction in the minimum price. We also observe that TFP growth partly compensated losses in terms of trade. Regarding the magnitude of TFP growth, there are very few comparable studies in the literature on sugar beet TFP growth because productivity is usually measured at the farm rather than the crop level. Two exceptions are Thirtle (1999) and Amadi *et al.* (2004), who use crop-specific input data for sugar beet to calculate partial and TFP indices. Thirtle (1999) finds that TFP in sugar beet production increased by 2.7% per year between 1954 and 1992. Amadi *et al.* (2004) use more recent data from the same data source to analyse growth rates between 1970 to 1996. According to their estimates, TFP growth rate in the UK was 3.39% per annum. Both studies measure the exponential growth rate, which is obtained by regressing the natural logarithm of TFP on a time trend. Applying this procedure to our TFP values, we obtain an annual growth rate of 2.83% between 2004 and 2013, which lies between the findings of Thirtle (1999) and Amadi *et al.* (2004).

We further find that the contribution of production reallocation on sector productivity growth was rather low. This contradicts our expectation that liberalisation of the market would make resource reallocation more attractive. However, two mechanisms might have worked against this expectation. First, even though minimum prices for sugar beet were reduced, actual prices remained largely above the minimum, especially after 2009. Second, transaction costs for trading delivery rights quota trade may have hampered reallocation of production. To further investigate this, we compared three sub-regions in Germany where the dominating sugar companies differ in the mechanisms of delivery rights transfer between farms. Using a system-GMM estimator to control for potential endogeneity, we find the productivity-enhancing effect of the reform was higher in the regions where delivery rights can be traded between sugar beet growers (company 1) and where delivery rights are not linked to capital contributions (company 3).

In terms of implications for policy and industry, the results demonstrate how essential TFP growth is for maintaining beet profitability in periods of low sugar prices. As suggested by the results, a flexible and market-based approach to coordinate production allocation can be beneficial for aggregate TFP growth. For the industry, higher aggregate beet productivity would improve the competitiveness of the industry if it is reflected in lower beet prices. Generally, aggregate productivity is maximised if delivery rights are allocated to farmers who value them the most (assuming equal prices among farms), e.g. via auction markets (see Bogetoft *et al.*, 2007). However, even though policy encouraged farmers to give up delivery rights through the voluntary restructuring scheme, the magnitude of the observed gain in our empirical example is relatively small. Thus, it is not clear whether additional administrative costs for more effectively distributing delivery rights will actually be covered by the associated gains. Considering within-farm productivity growth as the main determinant of aggregate productivity growth during the study period, promoting research and development remains an important tool to support the sector in times without sugar quota. In this context, we must note that full-time farm enterprises are overrepresented in the FADN data we use in our analysis. Hence, the average farm size in our sample is considerably larger than the German average. If small farms are on average less productive and more likely to give up or transfer delivery rights, then our results for the productivity-enhancing effect of the reform can be viewed as a lower bound measure.

There are at least three avenues for future research in this area. First, the study could be extended to further countries, especially countries where delivery rights are more easily transferred than in Germany. Second, a stronger causal linkage could be established. For instance, one could collect data from farms that are located at the border region of factories run by different companies and compare the contribution of production allocation towards sector productivity between farms that deliver to different companies. This could be done in a regression discontinuity framework (e.g. Hahn *et al*., 2001). Third, one could further disentangle the farm-level productivity changes into technical change and various measures of efficiency changes, as well as weather effects (see, e.g. Njuki *et al*., 2018). Identification of the main drivers of productivity and profitability changes at the farm level would provide additional insight into how the competitiveness of the sector can be increased.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1: Estimated per hectare use of variable inputs for distinct crop categories
Figure A1: Contributors to sector profitability growth by catchment areas.

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