THE IMPACT OF PRODUCT SUBSIDIES ON PLANT-LEVEL TOTAL FACTOR PRODUCTIVITY IN BRITAIN, 1997-2014

ABSTRACT

The United Kingdom's imminent departure from the European Union provides the opportunity for a more selective industrial strategy. This paper therefore analyses the effect of product subsidies on productivity in British manufacturing plants between 1997 and 2014 in order to provide evidence on the desirability of extending their use. The results suggest that low rates of subsidisation had either a positive or no effect but higher rates had a negative effect on total factor productivity in some sectors. This implies that increasing the generosity of subsidies does not offer a means of improving the United Kingdom's productivity performance.

JEL Classification Numbers: D2; D24; O4

Keywords: Subsidies; total factor productivity; Britain

1. Introduction

The United Kingdom's vote to leave the European Union (EU) will have many far-reaching economic implications. While discussion has focused on the effects on trade (Dhingra *et al.*, 2017; Dhingra *et al.*, 2018), investment (McGratten and Waddle, 2017; Bailey and De Propis, 2017) and the labour market (Portes and Forte, 2017), another important consequence is that EU state aid rules may cease to apply. These prohibit selective intervention, which has or may distort competition and is likely to have an effect on trade between member states (European Commission, 2016). The replacement of these rules with the less stringent World Trade Organisation rules on subsidies[1] is more likely in the event of a 'hard' Brexit in which the UK leaves the single market and does not secure a free trade agreement with the EU (Crafts, 2017). The incentive to pursue such policies will also be greater as the government seeks ways to encourage firms, now facing higher trade costs with the EU, to continue operating in the United Kingdom (UK).[2] While the level of tariffs that the UK will face after Brexit is currently unclear,

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[1] Jozepa (2018) summarises the key differences between EU and WTO rules as follows: the default position is that subsidies are generally illegal under EU rules but generally legal under WTO rules; WTO rules cover only goods while EU rules also cover services; EU rules are applied before support is awarded while WTO rules are applied reactively and only if a member country lodges a complaint; WTO rules require state-to-state enforcement while action can be taken by individuals and businesses under EU rules; the repayment of illegal state aid is required under EU but not WTO rules.

[2] The UK government's recent industrial strategy appears to indicate a more favourable view of selective policy as it involves 'sector deals' between the government and particular sectors – currently these have been agreed with the life sciences, automotive, creative

Figure 1 shows that these may be substantial for some sectors. For example, the average tariff faced by food manufacturers selling into the EU ranges from 6% for producers of oilseeds, fats and oils to 35.5% for dairy producers. Although the UK government plans to transpose EU state aid rules into UK legislation in the event of a 'no deal' Brexit (Department for Business, Energy and Industrial Strategy, 2018), the effect of these rules will differ since state aid that distorts competition or affects trade within the EU will not necessarily do so within the UK. The narrower test will therefore increase the scope for state aid within the UK (Kotsonis, 2018). Moreover, the opposition Labour Party appears to favour less restrictive state aid rules with its leader, Jeremy Corbyn, citing EU state aid rules as a reason for his party's opposition to the UK remaining within the single market (Corbyn, 2018).

Figure 1 around here

The provision of financial assistance to industry as part of an industrial strategy has a long history (Schwartz and Clements, 1999). Until recently, such approaches were seen to have been largely a failure for the following reasons (Cohen, 2006, p. 88):

> The state has neither the necessary information nor adequate incentives to make better choices than the market… it tends to misestimate … the negative long-term effects of the protection granted to certain firms and the negative impacts of the benefits granted to promoted sectors on other sectors.

More recently, industrial policy has begun to be regarded more favourably (e.g., Felipe, 2015; Stiglitz and Lin, 2013). Rather than just 'believing' in the beneficence of the market and allowing economic growth to be generated by globalisation allied to government promotion of

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industries, artificial intelligence and construction sectors (Department for Business, Enterprise and Industrial Strategy, 2017) - to increase productivity, employment, innovation and skills.

liberalisation, privatisation and deregulation (the so-called Washington consensus), "… it has become obvious that all governments are engaged in various forms of industrial policies… (therefore) the question is not *whether* any government should use industrial policy but rather *how* to use industrial policy in the best way" (Stiglitz *et al.* 2013, pp. 5-6).

EU State Aid rules do not completely prohibit assistance to firms. Member states "can offer financing to specific firms, sectors or projects using state aid in the form of grants, fiscal incentives, equity, soft loans and guarantees or through public procurement" (Farla *et al.*, 2015, p. 356). However, they are required to obtain permission from the European Commission if the aid exceeds €200,000 over 3 years (although there are certain 'General Block' exemptions – see Chapter 5 of Department for Business, Enterprise and Industrial Strategy, 2015, for details). These exemptions have allowed the UK government to spend substantial sums on subsidies to firms in recent decades. In order to provide evidence on whether this has been successful, and whether this policy should be pursued with greater vigour after the UK's departure from the EU, this paper empirically tests whether such state aid has had a positive or negative impact on productivity in British manufacturing plants in the period, 1997-2014. Although subsidies were provided across the UK economy during this period, manufacturing is the focus of the analysis here since this sector receives particular attention in the recent industrial strategy (Department for Business, Enterprise and Industrial Strategy, 2017), and would therefore appear likely to receive disproportionate support under a more selective industrial strategy. Manufacturing is also of intrinsic interest since, despite only contributing 10% of UK gross value added (GVA), it accounts for around half of UK exports and three-quarters of R&D expenditure and has strong linkages with other sectors of the economy (Government Office for Science, 2013). Subsidies are defined as the amounts received from UK government bodies or the EU to reduce the price of products sold into a market environment but exclude grants. In the UK over the period 1997-2014, grants have mostly taken the form of discretionary payments to reduce the cost of capital

(Wren, 2005). In the absence of data on grant receipt, and due to their relatively small value, they are not considered in the empirical analysis below.

The paper is set out as follows. In the next section, the rationale for government provision of product subsidies to firms is discussed and previous empirical research on the effects of subsidies is reviewed. The form of the subsidies analysed here is explained and some background information on their importance to firms is provided in section 3. In Section 4, the results are presented. The paper concludes with a summary and some ideas for further research.

2. Literature Review

The traditional neoclassical position is that markets are efficient and, as such, are the best mechanism to allocate resources (cf. the model of Walrasian general equilibrium associated with Arrow and Debreu, 1954); the exception is where there are market failures. In terms of providing a justification for product subsidies, the most relevant market failure is perhaps incomplete markets, which prevent or raise the cost to firms of private sector finance. This is particularly a problem for start-up firms or small firms seeking to expand their operations. Agglomeration externalities, arising either within (Marshall, 1890; Arrow, 1962; Romer, 1986) or across (Jacobs, 1970, 1986) industries provide an alternative justification[3] since they suggest

[3] Justification for government intervention on the grounds of market failure has been criticized by those who do not adhere to the neoclassical tradition. For example, evolutionary economists (e.g., Metcalfe and Georgiou, 1997) have argued that information costs, leading to asymmetric outcomes, are a feature of the market, and are in part necessary as a selection device for promoting the fittest firms and in providing incentives for learning and discovery. The latter is crucial to the process of variety creation upon which the evolutionary view of

that government policy to encourage spatial agglomeration will give rise to cost reductions in co-located firms.

The nature of the subsidies analysed here has implications for the results expected below. Unlike investment grants, which lower the cost of capital and hence lead to substitution of capital for labour and intermediate inputs, product subsidies are provided to firms to allow them to reduce prices. The direct effect of product subsidies is therefore to reduce revenue productivity but to have no effect on physical productivity. However, such an outcome is unlikely since a firm receiving a subsidy or a grant that faces a downward sloping demand curve will increase production. This increase will generally be greater for product subsidies than capital grants since the latter lead to a distortion in the choice of inputs away from the cost-minimising combination. While an increase in output will not generate TFP effects if the firm simply changes its use of factor inputs while (total factor) productivity remains unchanged, positive effects on productivity will be found if the greater production increases the rate of learn-by-doing (Arrow, 1962; Yang and Borland, 1991; Thompson, 2012). Moreover, if the subsidies allow firms to become competitive in international markets, they may also generate learning-by-exporting effects (Wagner, 2007, 2012; Harris and Moffat,

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markets is based (as Metcalfe and Georgiou, 1997, point out "a profit opportunity known to everybody is a profit opportunity for nobody"). This does not mean that there is no rationale for government intervention, assuming that it leads to a direct increase in economic benefits from more firms gaining and acting on that information (e.g., by adopting certain technologies, increasing their overall capabilities, etc.). For example, Casson (1999) argues that the government has a comparative advantage in information, and it is on this basis that it can justify intervention. See also Cohen (2006, section 3.1).

2015a). Alternatively, if firms use the subsidy, not to reduce prices, but to increase investment in intangible assets, this may also improve productivity (Hall *et al.*, 2010; Ugur *et al.*, 2016). On the other hand, Porter (1990) argues that subsidies can dull the market incentives faced by firms and create a culture of ‘rent seeking’. In such circumstances, the management of firms will focus less of their efforts on innovation and improving efficiency (Leibenstein, 1966). Since subsidies are likely to be easier to access on a recurrent basis than grants, this effect is likely to be stronger for subsidies. In sum, the direction of the effect of subsidies and the relative strength of the effect vis-à-vis grants on productivity is an empirical question.

Previous empirical studies have considered the impact of subsidies on outcomes such as employment growth (Girma *et al.*, 2007; Kösters, 2010; Koski and Pajarinen, 2013; Garsaa and Levratto, 2015), R&D spending and innovation (Parsons and Phillips, 2007; Görg and Strobl, 2007; Gelabert *et al.*, 2009; Einiö, 2014; Becker, 2015; Castellacci and Lie, 2015; Bronzini and Piselli, 2016; Catozzella and Vivarelli, 2016; Cowling, 2016), market share (Buts and Jegers, 2013) and productivity (Irwin and Klenow, 1996; Managi, 2010; Einiö, 2014; Huang, 2015; Koski and Pajarinen, 2015). The limited evidence on the impact of subsidies on productivity mostly analyses the effect of R&D subsidies on labour productivity (rather than TFP) and has produced mixed results. For example, Irwin and Klenow (1996) found no impact of R&D subsidies on the labour productivity of high-tech companies in the United States. Einiö (2014) reports no instantaneous impacts of R&D support programmes in Finland on productivity (although there is evidence of long-term gains). Koski and Pajarinen (2015) report that R&D subsidies had no statistically significant impact on labour productivity in Finnish firms during 2003-2010, although employment subsidies and other subsidies were negatively related to output-per-worker.

For the UK, there have been some analyses of the effect of *grants* on productivity. Harris and Robinson (2004), Criscuolo *et al.* (2019), Harris and Trainor (2005) and Moffat (2014) considered the impact of investment grants on plant/firm performance in Britain. Criscuolo *et al.* (2019) and Harris and Robinson (2004) found no effect on productivity. Harris and Trainor (2005) reported that capital grants had some positive impact on TFP in manufacturing plants in Northern Ireland, although the results differed across industries. Finally, Moffat (2014) found the impact on TFP in Scottish manufacturing was either neutral or negative. However, this is the first paper to analyse the effect of *subsidies* on productivity in the UK.

3. DATA

The data used in this study, as described in Table OA1 in the online appendix, comprise mostly plant-level data from the Annual Respondents Database (ARD), which has been extensively discussed by previous users (Griffith, 1999; Harris, 2002; Harris, 2005a; Robjohns, 2006; Harris and Moffat, 2015b).[4] Data on gross output, intermediate inputs and investment that is collected at the reporting-unit level – the composition of which will change over time if the enterprise changes the way in which it reports to the ARD (Harris, 2005a) – is 'spread back' to the plant-level under the assumption of constant ratios of these variables to employment within the reporting unit. Data on R&D spending is available from the Business Enterprise R&D database (BERD) and is matched to the ARD using Office for National Statistics (ONS) enterprise and reporting unit codes (together with information on postcodes and industry classifications) available in both the ARD and BERD. Information on outward foreign direct investment (OFDI) subsidiaries and branches is available from the Annual Foreign Direct

[4] Since 2008, data from the Annual Business Survey (ABS) is used. Since this provides broadly equivalent data and can be appended to the ARD, reference will be only made to the ARD. A more detailed discussion of the data used is provided in the online appendix.

Investment (AFDI) survey. These data are amalgamated into a single observation per firm per year and merged into the ARD using the ONS codes available in both datasets. Estimates of plant-level capital stock are obtained from plant-level estimates of real investment using the perpetual inventory approach; the methods used are set out in Harris and Drinkwater (2000), Harris (2005b) and summarised in the online appendix. Since the detailed information required for the analysis is only collected in the ARD for a stratified sample of plants, the figures presented below are weighted to be representative of the population (the need for weighting the data, especially for econometric modelling, is discussed in Harris, 2002, and Harris, 2005a). The weights are calculated by dividing total employment in the population by the total employment of plants in the sample within year-size-industry-region cells (using 10 size-bands, industries defined at 3-digit standard industrial classification level and 11 regions).[5]

Figure 2 around here

Of particular relevance is the question asked in the ARD relating to subsidies. Data is collected on the value of subsidies received to reduce the price of products.[6] Respondents are

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[5] When the sample data is weighted using this approach, the total employment of the sample equals the total employment of the population. An alternative would be to count the number of plants in the population in each cell and divide by the number of plants in the sample for that cell; the correlation between the weighting variable thus obtained and the one used is 0.998. However, alternative approach does not ensure that the total employment of the sample equals the total employment of the population.

[6] The following guidance is provided to those completing the survey: "These are amounts receivable from UK government bodies or the EU to reduce the price of products (goods or services) sold into a market environment. INCLUDE: Import and Export refunds (e.g. under

told to exclude grants, as well as receipts from government for goods and services supplied free (or at a subsidised rate). The subsidies under analysis therefore correspond to 'subsidies on products' under the European System Accounts (ESA) 2010 where they are defined as 'subsidies payable per unit of a good or services produced or imported' (Eurostat, 2013, p. 95). Subsidies related to payroll or the workforce, which are 'other subsidies on production' under the ESA, are also recorded in the ARD but are not considered in this study as only small amounts of such subsidies were provided during the period covered. The ESA further disaggregates subsidies on products into 'import subsidies' and 'other subsidies on products' which includes subsidies on products consumed domestically and export subsidies. Unfortunately, no such disaggregation is required in the ARD which means that we are unable to determine precisely the nature of the subsidies. Figure 1 shows that the figures derived from the ARD broadly match those from the UK National Accounts Blue Book[7], produced in accordance with the ESA, both in terms of magnitude and trend.

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the EU's Common Agricultural Policy). EXCLUDE: (i) Grants received from any source i.e. UK government bodies, EU, charitable organisations etc. Grants are defined as one-off payments received with the intention to lessen the burden of capital expenditure i.e. new building work, machinery etc.; (ii) Receipts from government for goods and services supplied free (or at a subsidised rate) under the National Health Service and similar public services; (iii) Grants to cover historical losses or for the cancellation of debt."

[7] The Blue Book definition of subsidies is "current unrequited payments made by general government or the European Union to enterprises". Subsidies on products are "made on the basis of a quantity or value of goods or services" (Office for National Statistics, 2018, p. 82).

As stated above, these figures do not include grants made to firms. The major source of grants to private sector firms during 1997-2014 were government schemes under sections 7 (available in EU designated 'assisted areas') and 8 (to non-assisted areas) of the Industrial Development Act (1982). Data provided in the annual reports to Parliament on the Industrial Development Act show that expenditure under section 7 amounted to £1,694 million while grant expenditure under section 8 summed to £787 million between 2010-11 and 2014-15. For 2010-2014, expenditure on product subsidies was £23,072 million (£27,295 million) using the ARD (Blue Book) figures. Thus, expenditure on product subsidies was around 10 times greater than grant expenditure under sections 7 and 8 of the Industrial Development Act in this period.

Tables 1 and 2 around here

Tables 1 and 2 show the total value of subsidies (in nominal and real values), total subsidies as a percentage of GVA,[8] and the mean value of subsidies across plants receiving assistance both in terms of the average value per plant and the average value as a percent of GVA for manufacturing. Information is provided across time (Table 1) and industry (Table 2). The value of subsidies, in absolute terms and as a percentage of GVA, were highest at the start of the period but declined substantially after 2004 and then further after the onset of 'austerity' under the Conservative/Liberal Democrat coalition government in 2010. Over the full period, subsidies averaged 0.25% of GVA. Across sectors, the highest rate of subsidisation was observed in the Coke, Refined Petroleum Products and Nuclear Fuel sector, which is likely to reflect high rates of subsidy provided to producers of nuclear power (Ecofys, 2014). Otherwise,

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[8] That is for each plant, we calculate the value of subsidies divided by the value of GVA (both measured in the same year *t*), multiplied by 100. This is the measure used below in the econometric analysis, representing how important subsidies were to their recipients.

subsidies as a percentage of GVA does not exceed 0.89% in any manufacturing sector. Among plants receiving a subsidy, the mean subsidy rate was 8.8% but this rate varied across time and sector.

4. Methodology

In order to obtain estimates of the effect of receiving the subsidy on TFP, the following log-linear Cobb-Douglas production function is estimated:

$$y_{it} = \alpha_i + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_S S_{it} + \alpha_X X_{it} + \varepsilon_{it} \quad (1)$$

y_{it}, e_{it}, m_{it} and k_{it} refer respectively to the logarithms of real gross output, employment, intermediate inputs, and the capital stock in plant i at time t $(i = 1, \ldots, N;\ t = 1, \ldots T)$. The main variable of interest is S_{it}, a dummy variable that equals one if plant *i* received a subsidy at time *t*. In order to show whether the effects are heterogeneous with respect to subsidy rate, this variable is replaced by three dummy variables indicating whether the plant received a subsidy worth up to 1% of its gross value added (GVA), 1-5% of its GVA and more than 5% of its GVA in a second specification of the model. The relatively small amounts of subsidy provided over the period (consistent with the rules governing State Aid) explains the selection of these bands (see the figures at the bottom of Table 4). While it might be interesting to estimate effects for higher subsidy rates, the very small numbers of plants receiving subsidies in excess of, for example, 10% of GVA mean that any effects would be imprecisely estimated. X_{it} is a vector of observed variables determining TFP (see Table 3 below).

Equation (1) is estimated as a dynamic model – i.e. including lagged values of output and the factor inputs – using system Generalised Methods of Moments (GMM) (Arellano and Bond, 1991; Blundell and Bond, 1998). This involves simultaneous estimation of Equation (1) in first-differences and levels using lagged values of the endogenous variables as instruments in the first differenced equation, and first-differences of the same variables as instruments in the levels equation (Blundell and Bond, 1998).[9] This addresses the endogeneity of the lag of output and the factor inputs and allows for fixed effects. Since the two-step estimator is used, the Windmeijer (2005) finite-sample correction is employed to produce robust standard errors.

Because subsidised plants are unlikely to be a random sample of the population of plants, a further issue is that of self-selection bias. The estimated effect of being subsidised may be sensitive to the assumed linear functional form of the covariates included in Equation (1). It is therefore re-estimated using a sample created by propensity score matching (Dehejia and Wahba, 2002; Imbens and Rubin, 2015). This entails the estimation of a logit model in which the dependent variable is S_{it} and the independent variables are the other variables on the right-hand-side of Equation (1). The predicted values from this model are then used to match each subsidised plants to an unsubsidised plant. The validity of this approach remains dependent on the assumption of selection into the treatment group based on observable characteristics.

Table 3 around here

Table 3 presents information on the mean values of the variables used in Equation (1) in the subsidised and unsubsidised groups. Most of these variables are the same as those used by Harris and Moffat (2015b) and further detail and a justification for their use in the current study are available in that paper. For most of the variables listed in Table 3 there is a significant

[9] The model is estimated using the xtabond2 command in Stata (Roodman, 2009). In order to avoid problems of instrument proliferation, which reduce the power of the Hansen test for instrument validity, the instruments are 'collapsed' to create one instrument for each variable and lag length rather than one instrument for each variable, lag length and time period (see Roodman, 2009, for a discussion).

difference in the mean values for plants in receipt of a subsidy vis-à-vis those that were not subsidised. Subsidised plants were smaller in terms of both output and factor inputs and less likely to do R&D. They were also younger and more likely to belong to a single-plant enterprise. In terms of their environment, they operated in areas with higher levels of diversification and were more likely to be located in cities. Subsidised plants also tended to be in less concentrated industries. There were no significant differences in the other variables. Unsurprisingly, there was also some persistence to receiving subsidies: among plants that received a subsidy, 40.5% received a subsidy in the following year with 33.3% received a subsidy two years later.

5. RESULTS

The detailed results from estimating Equation (1) for the five manufacturing sectors that received the largest number of subsidies are presented in Table OA2 in the online appendix. The results are mostly similar to those presented in Harris and Moffat (2015b), to which the interested reader is directed for a full discussion. Table 4 presents the results for the coefficient estimates for the factor inputs and the subsidy variables. The diagnostic tests show that the null hypothesis of valid instruments is not rejected at the 10% level in any of the sectors considered using the Hansen test. Moreover, the null of no second-order serial correlation is not rejected at the 10% level for any sector. In addition, the estimated coefficients on the factor inputs are, with one exception,[10] statistically significant at the 10% level and of a reasonable magnitude which provides confidence that the estimated effects of subsidisation are truly effects on TFP.

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[10] The exception is the Basic Metals and Fabricated Metals sector where the estimated coefficients on capital are significant at the 15% level.

Table 4 around here

The first column of Table 4 shows that in Food Products, Tobacco and Beverages - the most subsidised manufacturing sector - there was a positive and statistically significant effect of subsidisation. The effect was to increase TFP by 4.7% ($(e^{0.046} - 1) \times 100$). When the subsidy variable is split into dummy variables indicating whether the value of the subsidy was up to 1% of GVA, 1-5% of GVA and over 5% of GVA (column 2), only the first is statistically significant. No statistically significant effects of subsidisation are obtained for Pulp, Paper and Paper Products, Publishing and Printing, Electrical and Optical Equipment and Basic Metals and Fabricated Metal Products (columns 3-8). The absence of significant effects of higher rates of subsidy may be explained by the low power of hypothesis tests arising from relatively small numbers of plants in these categories. The point estimate of the coefficient on the dummy indicating whether the subsidy was worth more than 5% of GVA is negative in all three sectors and larger (in absolute value) than the coefficient on the dummy for a subsidy of 1-5% of GVA. For Transport Equipment, the subsidy dummy is not statistically significant (column 9) but, allowing for heterogeneous effects of subsidisation, the effect of receiving a subsidy worth 1-5% of GVA is significant and suggests that receiving a subsidy of this size leads to an increase in TFP of 8.8% (column 10). Although it is also not significant, the effect of receiving a subsidy worth more than 5% of GVA is negative. This is therefore consistent with the view that large rates of subsidy dull market incentives and therefore lead firms to divert their efforts away from innovating and improving their efficiency.

As discussed earlier, a potential source of bias in the results above is misspecification. The model is therefore re-estimated using a sample constructed by 1-to-1 propensity score matching.[11] As is shown by the measures of covariate balance presented in the lower half of Table 5, this process was successful in improving the extent to which the subsidised and unsubsidised plants are matched and will therefore reduce the sensitivity of the estimated effects to the linear functional form of the covariates assumed in Equation (1). In particular, Rubin's B is less than 25 and Rubin's R is between 0.5 and 2 for all sectors and therefore the matched samples satisfy the criteria specified by Rubin (2001) to be regarded as sufficiently balanced. Differences in means for individual covariates across unsubsidised and subsidised plants receiving different rates of subsidy in the full and matched samples are presented in Table OA4. These show that matching improves covariate balance more for plants receiving subsidies worth 0-1% of GVA than for plants receiving higher rates of subsidy. This is the consequence of plants receiving subsidies worth 0-1% of GVA being the largest subsidised group (which leads to matches for these plants forming the largest part of the matched control group). The use of the matched sample will therefore reduce the potential for bias arising from misspecification to a greater extent for the coefficient on the dummy for a subsidy of 0-1% of GVA than for the coefficients on the dummies for subsidies of 1-5% and more than 5% of GVA.[12]

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[11] To test the robustness of the results, the model is also estimated using a sample created by 1-to-5 propensity score matching. The results, presented in Table OA3 in the online appendix, are broadly similar to those in Table 5.

[12] To test whether the use of a single logit model to create the matched sample influenced the results, an alternative matched sample was created from propensity scores from three separate logit models in which the dependent variable takes the value of one if the plant received a subsidy worth 0-1%, 1-5% and more than 5% of GVA. The matched samples

The estimated effects of being subsidised in the upper half of Table 5 are broadly similar to those presented in Table 4. The only sector that shows positive and statistically significant effects of being subsidised remains the Food Products, Beverages and Tobacco sector (column 1). However, the estimated effect is larger and now indicates that a subsidy increases TFP by 6.3%. The estimated effect from estimation of the model using the matched sample is negative in the Electrical and Optical Equipment, suggesting a subsidy decreases TFP by 5.7% (column 5). The effect is driven by large negative effects of larger subsidies: a subsidy worth 1-5% (more than 5%) of GVA leads to a reduction in TFP of 10.8% (12.6%) (column 6). In Transport Equipment, the estimated effect of a subsidy worth 1-5% of GVA is no longer significant but subsidies worth more than 5% are estimated to lead to a significant fall in TFP of 13.3% (column 10). The results from the matched sample therefore strengthen the impression of negative effects from large values of subsidy.

Table 5 around here

Because of the high numbers of subsidised plants in the Food Products, Beverages and Tobacco sector, Table 6 provides the coefficient estimates on the subsidy variables for the three largest components (defined using the 3-digit level of the standard industrial classification) of this sector. Equivalent results to those presented in Table 4 and 5 are presented in Tables OA6 and OA7 in the online appendix. This shows that the positive effects observed for the sector as

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corresponding to each level of treatment were then appended to create a single matched sample for estimation of Equation (1). The results are presented in Table OA5. Although there are some changes to the significance of individual coefficients compared to Table 5, the key findings are unchanged.

a whole are largely driven by the Manufacture of Other Food Products (SIC158) sector.[13] Using the matched sample, larger rates of subsidisation are found to have negative effects on TFP in the Production, Processing and Preserving of Meat and Meat Products (SIC151) sector.

Table 6 around here

6. SUMMARY AND CONCLUSIONS

The UK's departure from the EU may enable it to pursue a more selective approach to industrial policy. This paper therefore analyses the effect of subsidies to UK manufacturing plants on TFP between 1997 and 2014. Despite the application of EU state aid rules over this period, the provision of product subsidies was significant over this period and there has been no test of the extent to which such subsidies have impacted on TFP.

The results indicated that low rates of subsidisation had a positive effect on productivity in the Food Products, Beverages and Tobacco sector, which received the largest number of subsidies in the period considered, but no significant effect in the other four sectors considered. Using a sample created by propensity score matching, the impact of larger rates of subsidy was not statistically significant in three sectors and negative in two sectors. The latter is therefore consistent with the view that subsidies harm productivity by reducing the exposure of firms to

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[13] This includes manufacture of the following: bread, fresh pastry goods and cakes (SIC1581); rusks and biscuits, preserved pastry goods and cakes (SIC1582); sugar (SIC1583); cocoa, chocolate and sugar confectionary (SIC1584); macaroni, noodles, couscous and similar farinaceous products (SIC1585); processing of tea and coffee (SIC1586); condiments and seasonings (SIC1587); homogenised food preparations and dietetic food (SIC1588); and other food products not elsewhere specified (SIC1589).

the discipline of the market. Our results therefore suggest that the government should not respond to any relaxation of state aid rules after the United Kingdom's departure from the EU by offering high rates of product subsidy. While we have not considered other forms of subsidies or grants in this paper, our findings are broadly consistent with previous econometric analyses of alternative modes of selective assistance, particularly for the United Kingdom, and therefore confirm the difficulty of designing and implementing effective programmes of selective assistance.

In terms of future research, if a suitable dataset could be constructed, it would be interesting to compare the relative effects of grants and subsidies using a common methodology in order to provide evidence on which form of selective assistance is more beneficial. It would also be useful to model the impact of assistance on the probability of plant closure, to test whether subsidies prolonged production in plants that would otherwise have been expected to close. This would therefore provide an understanding of whether assistance was reducing aggregate productivity growth by preventing the reallocation of resources from low to high productivity plants.

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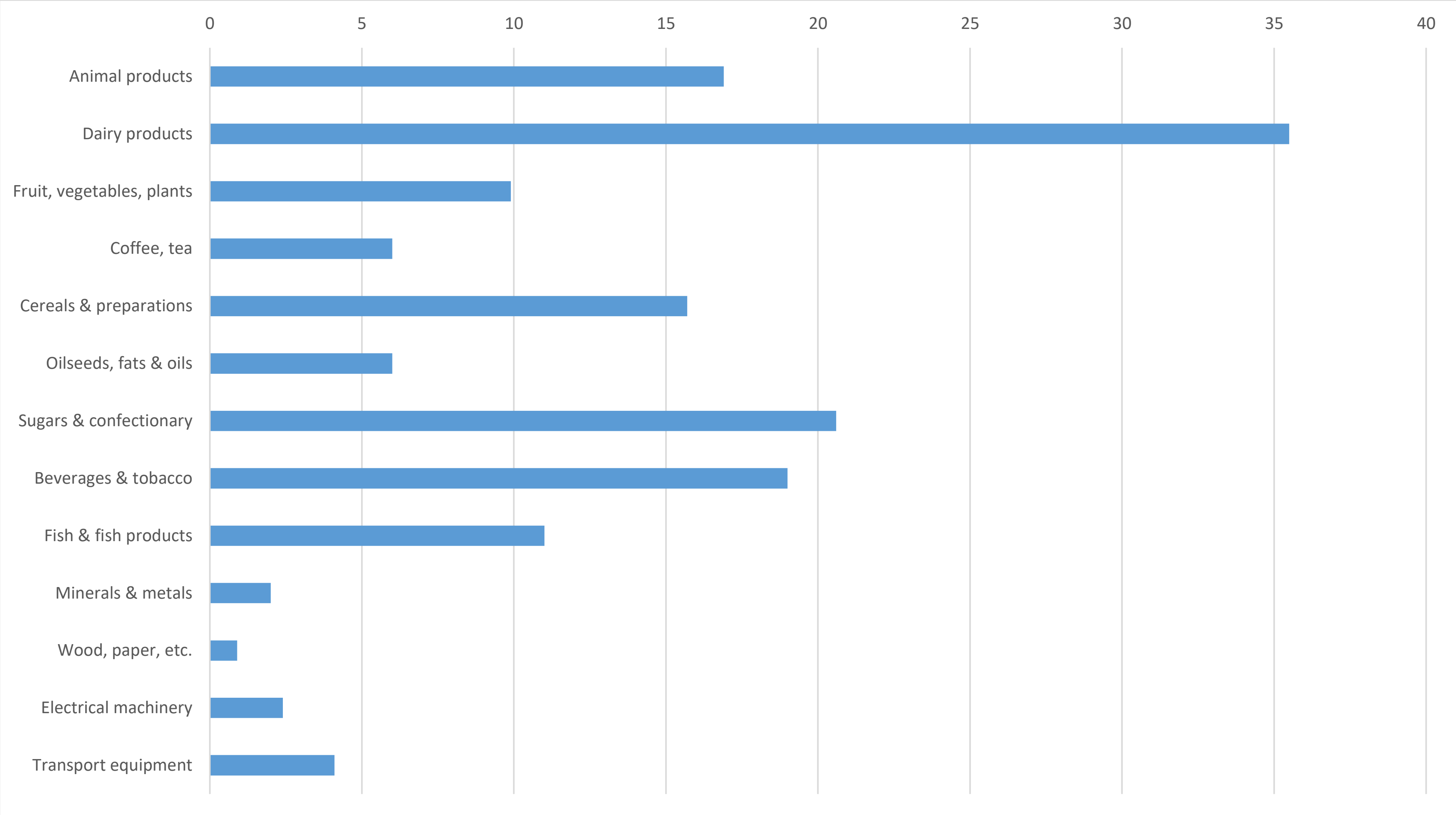
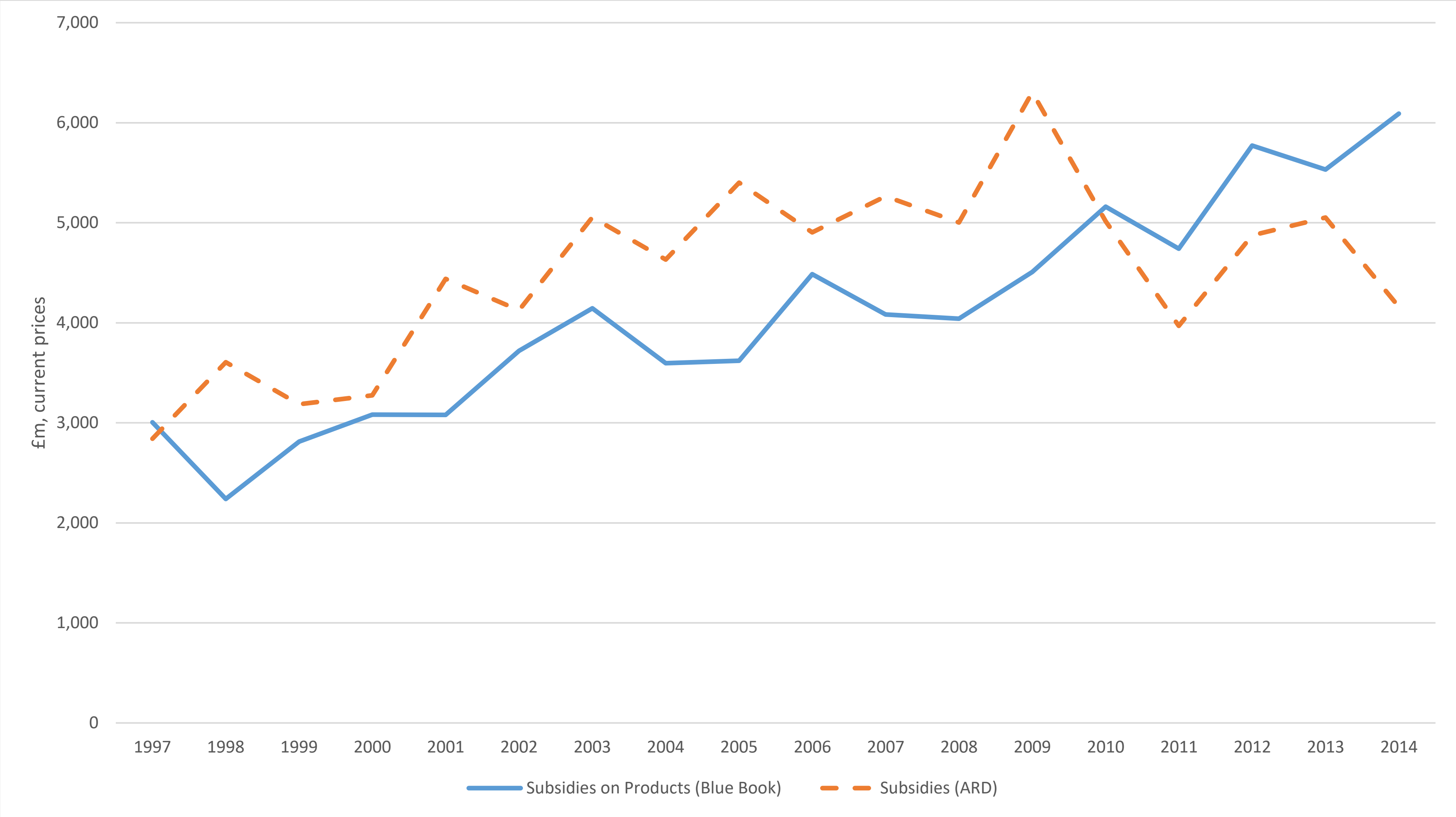
Figure 1. Average final bound tariff rates applied for selected manufacturing sectors by the EU, 2016



Source: World Trade Organisation *et al.* (2016)

Figure 2. Value of product subsidies, all sectors, 1997-2014



Source: ONS UK Economics Accounts (Blue Book) time series (CG: Subsidies on products, paid: D31: CP NSA) and (weighted) estimates from ARD

Table 1. Product subsidies, Manufacturing, 1997-2014, by year

	Value of subsidies (£ millions, 2000 prices)	Subsidies as a percentage of GVA[a]	Mean of subsidy (£ thousands, 2000 prices)[b]	Mean of subsidy as percentage of GVA[b]
1997	418	0.28	102	3.4
1998	698	0.45	183	7.4
1999	623	0.40	131	8.1
2000	724	0.50	158	8.2
2001	721	0.30	196	9.9
2002	593	0.41	195	8.1
2003	691	0.53	177	10.6
2004	614	0.46	173	8.2
2005	297	0.21	107	5.1
2006	182	0.12	83	8.2
2007	286	0.17	149	10.3
2008	221	0.16	91	28.3
2009	361	0.26	102	13.3
2010	117	0.08	41	8.6
2011	54	0.03	23	3.8
2012	112	0.09	47	6.0
2013	167	0.11	45	11.2
2014	127	0.09	25	5.0
Total	7,006	0.25	115	8.8

[a] Column (1) divided by total GVA of all plants (not just those receiving subsidies).
[b] Mean values across all plants receiving a subsidy
Source: population weighted data from the ARD

Table 2. Product subsidies, Manufacturing, 1997-2014, by industry

	Value of subsidies (£ millions, 2000 prices)	Subsidies as a percentage of GVA[a]	Mean of subsidy (£ thousands, 2000 prices)[b]	Mean of subsidy as percentage of GVA[b]
Food products: beverages & tobacco (DA)	1,870	0.46	218	8.6
Textiles & textile products (DB)	121	0.37	87	13.9
Leather & leather products (DC)	5	0.07	24	2.3
Wood & wood products (DD)	47	0.13	19	15.2
Pulp, paper & paper products; publishing & printing (DE)	234	0.18	107	16.8
Coke, refined petroleum products & nuclear fuel (DF)	2,195	3.71	14,692	141.1
Chemicals, chemical products & man-made fibres (DG)	319	0.13	165	8.3
Rubber & plastic products (DH)	96	0.08	26	3.3
Other non-metallic mineral products (DI)	336	0.42	203	12.4
Basic metals & fabricated metal products (DJ)	258	0.18	85	8.3
Machinery & equipment not elsewhere classified (DK)	127	0.05	28	17.1
Electrical & optical equipment (DL)	813	0.89	648	20.3
Transport equipment (DM)	315	0.20	257	14.3
Not elsewhere specified (DN)	271	0.36	84	18.7
Total	7,006	0.25	115	8.8

[a] Column (1) divided by total GVA of all plants. [b] Mean values across subsidised plants

Source: population weighted data from the ARD

Table 3. Means and standard deviations of variables used in estimation of Equation (1), 1997-2014

	Subsidies		No Subsidies		Difference
	Mean	Standard Deviation	Mean	Standard Deviation	Mean
Ln Gross Output	7.61	1.71	7.99	1.87	-0.38***
Ln Intermediate Inputs	6.88	1.93	7.33	2.06	-0.45***
Ln Employment	3.32	1.33	3.53	1.44	-0.21***
Ln Capital	5.95	2.08	6.29	2.28	-0.34***
R&D	0.16	0.36	0.20	0.40	-0.04***
Ln Age	2.28	0.83	2.31	0.87	-0.03*
Single-Plant Enterprise	0.42	0.49	0.35	0.48	0.07***
Multi-Region Enterprise	0.46	0.50	0.48	0.50	-0.02
Foreign Owned	0.19	0.39	0.19	0.40	0.00
Outward FDI	0.15	0.36	0.15	0.36	0.00
Ln Agglomeration	-4.31	1.79	-4.19	1.68	-0.12***
Ln Diversification	-0.39	0.26	-0.48	0.32	0.09***
Ln Herfindahl	-3.03	1.05	-2.88	1.04	-0.15***
City	0.17	0.37	0.14	0.35	0.03***
Observations	5,163		79,392		
No. Firm-Years	2,550		36,570		
No. Plants	3,090		24,543		
No. Firms	1,517		13,332		

[a] Also included in the models estimated are region and year dummies. See Table OA1 for definitions for the variables used.

[b] */**/*** denotes rejection of the null of equality of means across subsidised and non-subsidised using a t-test at the 10%/5%/1% levels.

Table 4. Long-run coefficients from estimation of Equation (1) by sector

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Food Products; Beverages & Tobacco (DA)		Pulp, Paper and Paper Products, Publishing & Printing (DE)		Electrical & Optical Equipment (DL)		Basic Metals & Fabricated Metal Products (DJ)		Transport Equipment (DM)	
Ln Intermediate Inputs	0.585***	0.586***	0.263***	0.263***	0.277**	0.286**	0.446***	0.456***	0.488***	0.487***
	(6.079)	(6.040)	(7.654)	(7.607)	(2.065)	(2.134)	(3.182)	(3.339)	(7.544)	(7.529)
Ln Employment	0.234**	0.227**	0.780***	0.780***	0.521***	0.515***	0.385***	0.381***	0.520***	0.520***
	(2.390)	(2.271)	(16.370)	(16.309)	(3.280)	(3.254)	(3.288)	(3.280)	(6.961)	(6.952)
Ln Capital	0.144**	0.149**	0.111**	0.109*	0.311***	0.308**	0.143	0.139	0.105***	0.104***
	(2.210)	(2.276)	(1.988)	(1.958)	(2.629)	(2.603)	(1.446)	(1.441)	(2.811)	(2.791)
Subsidy	0.046**		-0.008		-0.010		0.016		0.042	
	(2.537)		(-0.286)		(-0.229)		(0.613)		(0.971)	
0-1% Subsidy		0.071***		-0.020		0.000		0.042		0.040
		(3.218)		(-0.595)		(0.002)		(1.281)		(0.787)
1-5% Subsidy		-0.025		0.078		-0.027		-0.042		0.084**
		(-1.151)		(1.453)		(-0.187)		(-0.864)		(2.051)
>5% Subsidy		0.014		-0.085		-0.064		-0.054		-0.074
		(0.264)		(-0.852)		(-0.603)		(-0.349)		(-1.311)
AR(1) z statistic	-3.877***	-3.948***	-6.485***	-6.478***	-2.916***	-2.984***	-3.120***	-3.141***	-3.022***	-3.033***
AR(2) z statistic	0.549	0.567	-0.413	-0.411	1.109	1.140	0.915	0.948	0.799	0.776
Hansen test statistic	7.072	6.505	21.952	22.142	34.733	35.483	7.940	8.193	54.367	53.841
No. Subsidy	2392		725		717		707		622	
No. 0-1% Subsidy	1595		613		533		525		488	
No. 1-5% Subsidy	561		84		115		147		102	
No. >5% Subsidy	236		28		69		35		32	
Observations	25,673		20,801		13,951		15,410		8,720	

z-values in parentheses. */**/*** denotes significance at the 10%/5%/1% levels.

Table 5. Long-run coefficients from estimation of Equation (1) by sector using 1-to-1 matched sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Food Products; Beverages & Tobacco (DA)		Pulp, Paper and Paper Products; Publishing & Printing (DE)		Electrical & Optical Equipment (DL)		Basic Metals & Fabricated Metal Products (DJ)		Transport Equipment (DM)	
Subsidy	0.061**		-0.008		-0.059**		-0.026		0.010	
	(2.081)		(-0.410)		(-2.559)		(-0.662)		(0.767)	
0-1% Subsidy		0.065**		-0.013		-0.040		-0.008		0.021
		(1.973)		(-0.632)		(-1.553)		(-0.272)		(1.407)
1-5% Subsidy		0.029		0.001		-0.114**		-0.093		0.008
		(0.760)		(0.009)		(-2.463)		(-1.009)		(0.150)
>5% Subsidy		0.098		0.062		-0.135**		-0.139		-0.143***
		(1.153)		(0.571)		(-2.147)		(-0.875)		(-2.655)
Mean Bias										
Full	11.248		9.010		7.002		7.304		8.586	
Matched	1.609		2.628		2.111		1.908		2.966	
Rubin's R										
Full	1.130		0.827		1.085		1.233		1.136	
Matched	1.002		0.969		1.040		0.960		0.997	
Rubin's B										
Full	67.126†		63.812†		56.841†		57.639†		59.200†	
Matched	12.152		19.707		17.234		15.961		22.952	
No. Subsidy	2,392		725		717		707		622	
No. 0-1% Subsidy	1,595		613		533		525		488	
No. 1-5% Subsidy	561		84		115		147		102	
No. >5% Subsidy	236		28		69		35		32	
Observations	4,509		1,536		1,394		1,302		1,156	

z-values in parentheses. */**/*** denotes significance at the 10%/5%/1% levels. † denotes Rubin's B > 25 or Rubin's R < 0.5 or > 2.

Table 6. Long-run coefficients from estimation of Equation (1) for Food Products and Beverages

	(1)	(2)	(3)	(4)	(5)	(6)
	Manufacture of Other Food Products (SIC158)		Manufacture of Beverages (SIC159)		Production, Processing and Preserving of Meat and Meat Products (SIC151)	
			Full Sample			
Subsidy	0.035***		0.028		0.007	
	(2.643)		(0.828)		(0.390)	
0-1% Subsidy		0.047***		0.042		0.027
		(3.326)		(1.097)		(1.316)
1-5% Subsidy		0.011		-0.003		-0.024
		(0.447)		(-0.065)		(-0.812)
>5% Subsidy		-0.106		-0.050		-0.208**
		(-0.994)		(-1.016)		(-2.273)
Observations	2,988		3,873		3,735	
			Matched Sample			
Subsidy	0.062***		0.032		-0.006	
	(4.699)		(0.936)		(-0.364)	
0-1% Subsidy		0.074***		0.058		0.009
		(4.818)		(1.307)		(0.535)
1-5% Subsidy		0.028		-0.057		-0.087**
		(1.538)		(-0.883)		(-2.197)
>5% Subsidy		-0.021		-0.055		-0.169***
		(-0.455)		(-0.790)		(-3.110)
Observations	1,885		754		458	

z-values in parentheses. */**/*** denotes significance at the 10%/5%/1% levels.