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THE ROLE OF TRADE-IN-TASKS FOR THE COMPETITIVENESS OF THE EUROPEAN PIG INDUSTRY

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Abstract

The global trend of agro-industrialisation is increasingly transforming farms and firms into specialist component suppliers within a multi-stage food processing chain. The trade-in-tasks theory predicts in this context that declining costs for cross-country outsourcing of certain stages of the production process (tasks) generates intra-industry trade and may increase the competitiveness of the final product. Based on this theory, a conceptual framework was established and empirically applied to the EU27 pig industry. The results suggest that the average EU country could increase the competitiveness of its processed meat exports; one potential source of these gains can be structural change among pig farms in other EU countries, which is utilized through vertical intra-industry trade in live pigs. In contrast, changes in outsourcing costs since 2002 due to changes in EU membership or due to the adoption of the Euro appeared non-significant in panel regressions.

Keywords

Outsourcing, Trade-in-Tasks, Intra-Industry Trade, Structural Change

1 Introduction

Global and regional trade is drastically changing. An increasing share of global production is part of increasingly vertically and horizontally integrated supply chains (ELMS AND LOW, 2013). Even the production of primary agricultural products is becoming more vertically integrated, increasing the knowledge content as part of value added (e.g. GOODHUE, HEIEN, LEE and SUMNER, 2000). This process of "agro-industrialisation" is accompanying institutional and organisational change among farms and processing firms in the food sector. At the same time, the importance of farms as a market for inputs is steadily increasing and is being matched by a highly specialised and growing industry delivering ever more sophisticated farm supplies (REARDON and BARRETT, 2000).

Within the European Union, where agriculture is still based on family farms, the industrialisation of agriculture is especially obvious as regards products of animal origin, such as eggs and meat. Partly in response to food scandals and diseases, EU farmers, slaughterhouses and retail chains have established programmes to certify and thus integrate the supply chain for meat products. TRIENEKENS, PETERSEN, WOGNUM and BRINKMAN (2009) identify the driving forces behind this trend: reduce risk, save time for adoption of new trends in consumer preferences, reduce costs of intermediate products and transactions, add value to production through innovation by new products and customer services, and improve and maintain quality and food safety.

However, this trend of agro-industrialisation is increasingly transforming farms and other producers of primary products into component suppliers and sub-contractors of food processing firms and retail chains. Within the service sector and the manufacturing industry in particular, such networks of sub-contracting have frequently been described using the term 'outsourcing' or 'offshoring': Certain stages of a firm's production process are sourced from

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external providers, which causes trade by definition. Depending on the location of the external provider (or sub-contractor), this type of intra-industry trade (IIT) can take any dorm from trans-continental to intra-regional. However, analysis of trade flows, sectoral competition and structural change in agriculture is becoming increasingly complex in this new setting. A few decades ago, the comparative advantages of a country or region for the export of certain agricultural products could often be easily deduced from information about its relative abundance of certain agro-climate factors such as soil, water and temperature. Consequently, many partial equilibrium[2] agricultural trade and sector models tended to rely heavily on the Ricardo-Heckscher-Ohlin-Stolper-Samuelson (hereafter HO) view on IT between regions regarding their comparative advantage. In this view, factors of production are immobile between regions and only final products are traded. Comparative advantage is the result of different relative endowments with primary factors such as land, labour and capital. Consequently, agricultural production is often modelled according to a "representative regional farm", implying that all farms and firms in a region would contribute to regional exports proportionally to their size.

For an increasingly knowledge-based, industrialising agri-food sector, however, the heterogeneity of farmers and firms in each region has to be considered in order to understand the origin of trade flows and the nature of comparative advantage. Empirical applications of the MELITZ (2003) framework to agriculture have shown e.g. the complexity of entry and exit dynamics for the Swedish food and beverage sector (GULLSTRAND and JÖRGENSEN, 2008). RAU and VAN TONGEREN (2009) developed a partial equilibrium trade model with heterogeneous firms and applied it to the issue of compliance within Polish meat production with EU food standards.

Furthermore, productivity differences between firms (MELITZ, 2003) may evolve according to ongoing structural change, and the same applies to the farm sector (CHAVAS, 2008). In addition, in the case of non-agricultural trade, it is increasingly being observed that the organisation of firms changes when they enter or exit the export sector. A growing body of theoretical literature deals with the interplay of organisational change and trade, but empirical analyses in this context are usually complicated by the need for detailed firm-level data (ANTRÀS and ROSSI-HANSBERG, 2008).

In general, recent studies on related new trade theories (reviewed e.g. by BALDWIN AND ROBERT-NICOUD, 2014; CRINÒ 2009, HELPMAN, 2006) seem to conclude that the conventional HO workhorse model is being increasingly challenged by a global trade reality that requires the fragmentation of the production process across country borders, rather than the exports of final products from one specific country, to be placed in the centre of any analysis on the origin of comparative advantage in trade.

GROSSMAN and ROSSI-HANSBERG (2008) (hereafter GRH) argue in this context that global trade is increasingly of an intra-industry (IIT) type, driven by "trade-in-tasks" resulting from increased offshoring/outsourcing of intermediate steps of the production process or, in other words, numerous forms of vertical contracting activities within multinational supply chains. BALDWIN and ROBERT-NICOUD (2014) suggests viewing a "task" as a fragment of the production chain and, as with any intermediate input, as being composed of a specific combination of labour and capital. Those authors therefore theoretically integrate a GRH trade-in-tasks framework with the HO model and argue that analysis of a trade-in-tasks general equilibrium is theoretically possible within the familiar HO framework if offshoring is treated as *'shadow migration'* of *'foreign'* factors to the offshoring firm or region (*'home'*) but being paid *foreign* wages. Thus, the potential to outsource intermediate parts of the production process to regions of lower supply cost acts in the same way as a positive shock to technical change in the out-

[2] Note that models that employ the widely used "Armington-Assumption" do not exactly correspond to this theoretical framework.

sourcing *('home')* region, and this actual effect comes from the comparative advantage of *'foreign'* sources to supply a certain intermediate product for home production.

With respect to agro-industrialisation, this would imply that the comparative advantage of the lower end of a food processing chain (e.g. the competitiveness of a brand label for shelf-ready pork) is determined by its ability to gain access to the lower unit cost of upstream providers, e.g. farms in neighbouring countries. IIT in agricultural products could then be viewed as "shadow migration" (BALDWIN and ROBERT-NICOUD, 2014) of 'tasks' from sub-contractors to their assembly site in a certain *home* region.

European meat production and processing chains provide a case in which structures and trends towards 'agro-industrialisation' seem to resemble these patterns quite closely. In Northern Europe in particular, mergers of farmer-owned slaughter cooperatives have led to the formation of large multinational food processing businesses (e.g. Vion, Danish Crown, HK Scan). These companies alone account for substantial shares of their home country's total exports of processed meat products.

The purpose of this paper was therefore to develop an analytical framework that allows empirical testing of whether and to what extent "trade-in-task" structures (=outsourcing as the economic driver) in addition to "trade-in-final-goods" (=relative factor endowments and other conventional drivers) can explain European trade in pigs and processed pork products.

Understanding trade patterns in this respect clearly has implications for EU policies that try to regulate spatial agglomerations of pigs in certain regions (e.g. aiming at nitrogen reductions), as well as the heterogeneous set of regulations that address animal welfare issues (SCHMID and KILCHSBERGER, 2010). This paper therefore sought to analyse whether "trade-in-tasks" theories are potentially suited as a theoretical approach that can enrich the existing toolbox of agricultural trade and policy analysis.

2 A model of outsourcing, intra-industry trade and export performance

Consider a hypothetical firm F that sells a processed food product ω either to consumers or further processors. In the context discussed here, EU27 member countries and their national production of pigs and pork are interpreted as such firms F_r, for $r=1...27$ European countries. Modelling the final market demand for ω was not within the scope of the analysis presented here, but ω could very well represent a variety within the Chamberlain-Dixit-Stiglitz framework of monopolistic competition and as such could be integrated into a sectoral partial equilibrium model (e.g. RAU and VAN TONGEREN, 2010). Following GRH, the production of ω can be understood as the assembly of certain tasks t_i. In our case, e.g. ω = "chilled boneless pig meat" is 'assembled' based on each of the following (and other) tasks t after they have been executed either in F_r or elsewhere: $t_{breed\ piglets}, \ldots, t_{fatten\ \ pigs}, \ldots, t_{slauthter}, \ldots, t_{cut\ desired\ parts}$.

Definition: A task t is a fraction of the production process that can be specified as a tradable input y_t to the production of the final product ω: $t_i \equiv y_i^t$. All t tasks together form a set, the supply chain $T=\{t_1,...,t_n\}$.

Assembly of the final product ω follows a Leontief technology, which assumes a constant flow of intermediate products being available for assembly of ω. Most theoretical frameworks refer in this context then to a continuum of tasks, justifying this by the fact that each individual t_i will have to remain unobserved due to confidentiality issues within multinational firms and due to the number of elements in T being very large, e.g. when assembling automobiles (GROSSMAN and ROSSI-HANSBERG, 2008).

For the purposes of a food supply chain representing ω, however, it was assumed here that t_i reflects an observed intermediate product or service necessary to assemble the final product ω. The production of ω takes place according to a two-stage process:

1. Provision (=production according to technology G) of all required quantities of the tasks $t_i \equiv y_i^t$ necessary to assembly a certain quantity of ω under a general multi-input-multi-output technology.
2. Final assembly of ω at location F under the Leontief technology described above.

The input requirement set that allows for production of a certain quantity of ω is defined as $V(\omega)=\{y_t:(y_t,\omega)\in F\}$. It is now assumed that under Stage 1, 'firm' F (=country in our context) initially has to produce all $t_i \equiv y_i^t$ in-house (in *home* region F_r) and faces the following cost-minimisation problem for provision of certain quantities of each y_i^t at the assembly place:

$$C(y^t,w)= min\{wx : (-x, y_t) \in G\} \tag{1}$$

Outsourcing then means that F can potentially benefit from lower cost of tasks entering the assembly of ω, if F is allowed to "source" any or all y_i^t from locations $F\neq F_r$ (=other countries) where these tasks are provided at a lower cost than F can achieve at home. However, even if y_i^t is cheaper in some other country, F still has to pay the resulting trade and transaction costs involved for bringing y_i^t to the assembly place of ω. GRH derived that the marginal task will be outsourced/insourced according to the following condition (GRH p.1982): $w=\beta t(I)w^*$. This expression states that in a hypothetical industry, the marginal task t out of a set of tasks ordered according to index I is performed at *home*. The condition to determine this task is that wage savings just balance the offshoring costs, where β is a shift parameter that reflects the technology (or transaction costs) for offshoring, and w, w^* are wages in the *home* and *foreign* country, respectively. In this context BALDWIN and VENABLES (2013) developed two related models, one of which represents a hub where all intermediate tasks are assembled simultaneously and the other constitutes a chain that requires each task to be completed before the next task can begin.

Similarly, we assumed for our analytical framework for EU27 pig production that F's cost function (1) is not bound to 'produce' y_i^t in region r_F, but can choose for each x_j between factor prices for *home* production ($w_{j,F}$) and factor prices in *foreign* regions ($w_{j,F\neq F_r}$). However, due to the fact that factor prices are evaluated at the *home* location, the transport and transaction costs of having y_i^t ready for assembly in F_r are incorporated in $w_{j,F\neq F_r}$.

This implies that the transaction cost τ of shipping y_i^t from $r\neq r_F$ to r_F is *implicitly* considered in observed trade flows between F and its outsourcing destinations. Due to the assumed cost minimisation, F_r will sub-contract with any region $r\neq r_F$ that provides y_i^t such that it reaches final assembly at minimum factor price w_i^*. The following equilibrium relationship – similar to GRH – determines, for each task y_i^t, whether it is produced for final assembly of ω in *home* at F_r or outsourced to other regions:

$$w_{i,r_F}^* \leq w_{r\neq r_F}^* + \tau \tag{2}$$

Equation [2] considers unit-opportunity cost at F_r. Furthermore, since w_i corresponds to the output price that potential sub-contractors in $r\neq r_F$ receive from F, it is equivalent to their marginal cost of providing y_i^t. Hence, the equilibrium in [2] will determine if and how much y_i^t in ω comes from F or from another country, and this will depend on the question: *how low are the corresponding transport and transaction costs τ between other countries and F for a specific task y_i^t compared with the marginal cost of producing y_i^t in each of these countries?*

Obviously, equation (2) provides an explanation for trade flows between two countries as long as the traded goods are used in the importing country's production process. In our analysis of the European pig industry, this implies the following:

Based on the general heterogeneous firm paradigm in international trade (MELITZ and TREFLER, 2012; Melitz, 2003), it can be assumed that by referring to a European country, only its corresponding farms and firms involved in the export or import of pigs and pork products are implied.

Furthermore, observed changes in the competitiveness of pig or pork exports from *F* must then correspond to a relative fall in either *i)* the production cost for the provision of relevant tasks (e.g. pigs finished for slaughtering) at *home* or in other countries, or, if all other costs have remained constant, *ii)* the transport and transaction costs for the corresponding tasks.

Examples of such potentially relevant transport costs in the EU 27[3] constitute differences in the taxation for road usage, changing restrictions on the conditions under which live animals can be transported over long distances, and potential EU accession of a new member state or whether a country *F* is a member of the Eurozone. In addition, the literature based on the gravity model shows that language barriers and cultural differences constitute important transaction costs in international trade (see literature cited by BALDWIN and TAGLIONI, 2011). However, for the case of the European Union, one would expect transportation and communication infrastructure to be relatively well-developed, with rather minor differences between countries and with roughly similar quality over the past 10-15 years, so that we do not expect this to explain a major share of intra-EU trade along pork supply chains.

Instead, the agricultural sector of European countries, in particular the livestock and pig sector, is undergoing rapid structural change processes, leading in most countries to strongly rising numbers of pigs per farm, but not necessarily to a larger total number of pigs per country. These structural changes are tending to lead to an ever increasing average number of livestock units per farm across Europe.

The trade-in-tasks perspective suggests that this structural change can be considered a potentially important source of declining transaction costs for trade-in-tasks partners. As larger farm units specialising in a certain task within the supply chain (e.g. animal breeding) emerge in a certain country, the average productivity of these farms rises along with their inclination to become involved in exporting (MELITZ and TREFLER, 2012). At the same time, foreign partners can find larger quantities of a certain type of pig provided by fewer individual farms that they have to deal with.

Thus, observed changes in the export competitiveness of downstream pork products should partly be related to corresponding changes in IIT in upstream tasks in the pork chain, and these changes should partly result from structural change among the pig farms from where a certain task has been sourced. This implies that declining trade flows between two countries do not need to be the result of declining absolute productivity in the supplying country, but can also reflect a decline in the relative advantage of a country over other countries where structural change among supplying farms is more dynamic.

These considerations concerning interpretation of the European trade in live pigs and pork products within the trade-in-tasks paradigm suggest the following hypotheses:

If the trade-in-tasks paradigm about multinational supply chains can serve as an explanation for changing trade flows of observed trade patterns, then:

- Observed changes in the export performance of a certain product of live or processed pigs will be related to changes in the share of vertical intra-industry trade (VIIT) such that increased VIIT reflects increased outsourcing activities and would be related to increased export performance between two periods.
- Observed changes in the export performance of a certain product of live or processed pigs will be related to structural change among the related pig farm types as an indication of declining transaction cost for outsourcing: larger farms improve the competitiveness of processed exports.

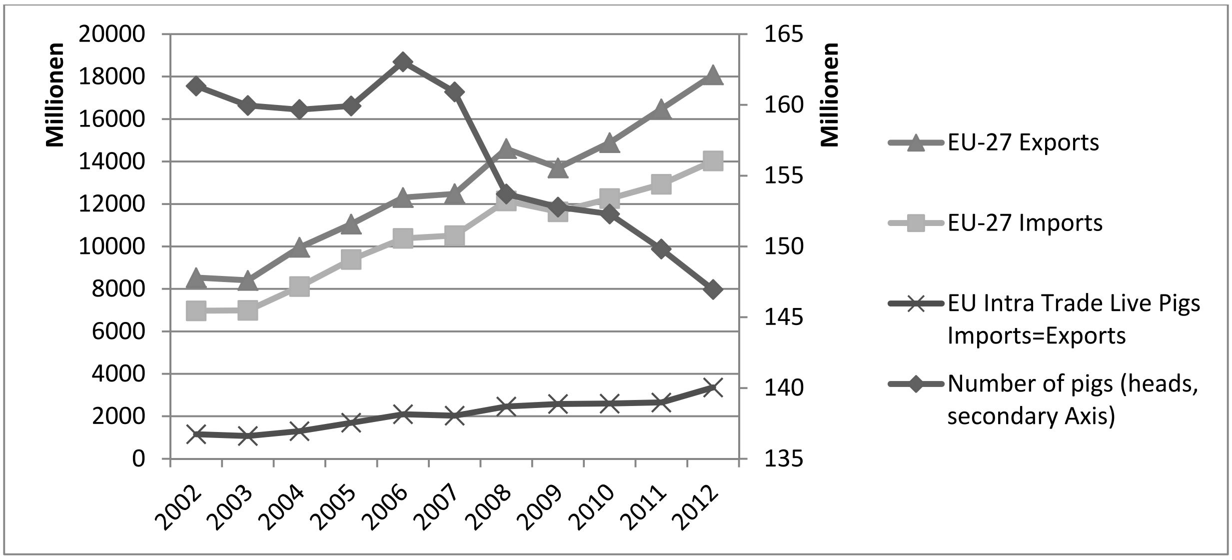
[3] Note that we treat the EU27 as a reference sample of countries even if certain of these countries have not formally entered the European Union yet.

- Observed changes in the export performance of a certain product of live or processed pigs will be related to changes in this country's membership status in the European Union and the Eurozone. That is, accession to the European Union is expected to lower transaction costs and thus raise the potential to benefit from either outsourcing tasks to other EU countries or supplying to other countries. However, the effect of flexible exchange rates is ambiguous, since it may increase or decrease the competitiveness of exports over time.

3 Empirical Implementation

The hypotheses derived in the previous section can be tested using conventional trade statistics. The CN8 trade database was employed for this purpose and all categories of traded live pigs were considered. Furthermore, for the next highest category of trade in processed meat products, aggregate trade in this category was considered, as shown in Figure 1. In the subsequent analysis, the focus was on the largest sub-category according to trade volume "chilled or fresh boneless meat of swine, CN8-G02031955", (hereafter CMnoB). Product categories of higher processing level can be identified within CN8 but most often constitute mixtures of meat from pigs and other animals.

Figure 1: Total extra- and intra-EU trade in pork products in 22 CN8 categories of group G02, and intra-EU trade in live pigs, volume in Euro.



As Figure 1 shows, both exports and imports of processed meat products (CN8 group 2 for pig meat, 02031110-02032990) more than doubled on aggregate during the 10 years from 2002 to 2012 (the latest year with consistent data availability). During the same period, total intra-EU trade in live pigs also doubled. However, total trade volume in live pigs was only roughly 20 per cent of the corresponding value of processed pork traded in 2012, and the total number of live pigs declined from 167 to 147 million head.

3.1 Measuring changes in the meat industry's competitiveness

We used a Constant Market Share measure of changes in a country's export performance for CMnoB, taking into account that this product will be further processed and is therefore subject to import substitution. However, since the outsourcing framework as outlined in the previous section does not apply to the last product of the chain ω, it is only necessary to determine aggregate export performance relative to a set of exported products from relevant other countries.

Constant market share analysis (reviewed in AHMADI-ESFAHANI, 2006) is a concept for assessing the change in the relative export performance of a country compared with a set of reference countries. Constant market share analysis was therefore employed here in order to determine the relative change in export performance for CMnoB. In contrast to what is usually presented in the literature (AHMADI-ESFAHANI, 2006), constant market share analysis was applied here in terms of net exports x: $X_{ir} - M_{ir} \equiv x_{ir}$ in order to take into account the fact that the processed meat product in question is not the final product and may still face import competition from substitutes within the same CN8 category ($i=1...n$ categories). Thus, we assessed changes for each of the $r=1...27$ EU countries' net exports x for i=CMnoB between any two years in the range 2002-2012. This change in $x_{ir,t}$ compared with $x_{ir,t-1}$ was then compared against the corresponding change from $x_{ir,t-1}$ to $x_{ir,t}$ that would have occurred for CMnoB in the same period if its net exports had changed at the same rate as all net exports for all CN8$_i$ processed meat products across all r EU 27 members on aggregate:

$$x_{ir,t} - x_{ir,t-1} = \rho x_{ir,t-1} + \varepsilon_{ir} \qquad \text{with} \quad \rho = \left(\sum_r \sum_i x_{ir,t}\right) \Big/ \left(\sum_r \sum_i x_{ir,t-1}\right) \tag{3}$$

This approach is based on the assumption that country- and sector-specific changes in export performance are partly due to overall global changes in related trade over the same period, and partly to a residual product- and country-specific effect ε that is commonly interpreted as the country's change in competitiveness. Thus, for example, a country with zero x_{ir} in t and zero x_{ir} in $t-1$ will exhibit a residual trade performance effect of $\varepsilon=0$, since the overall EU export rate ρ is multiplied by zero $x_{ir,t-1}$. In the subsequent analysis, this constant market share residual ε_r for CMnoB relative to all processed pig meat net trade of all EU27 countries on aggregate was used as an empirical approximation of a country's change in net export performance (y) for the final pork chain output ω: $\varepsilon_{ir} \equiv \Delta y^{\omega}_{irt,t-1}$

Thus, if the exporting meat processors in country r have indeed benefited from outsourcing activities of their *home* pig sector with other countries, then positive values of $\Delta y^{\omega}_{irt,t-1}$ must be statistically related to increasing shares of VIIT in live pigs.

3.2 Measuring marginal changes in trade patterns along the supply chain for pig meat

In order to relate $\Delta y^{\omega}_{irt,t-1}$ to the structure of VIIT and other trade in upstream intermediate inputs to the chain, it is also necessary to assess changes in these trade flows rather than absolute values. In the literature this is referred to as marginal IIT and THOM and MCDOWELL (1998) extend the work of BRÜHLHART (1994) by suggesting a decomposition of IIT into horizontal and vertical components for an arbitrarily defined aggregation of subsectors in an industry: In general, total trade (TT) is viewed as the sum of exports (X) and imports (M) and composed of inter-industry trade (IT) as well as horizontal (HIIT) and vertical (VIIT) intra-industry trade[4]: $TT=X+M = IT + HIIT + VIIT$.

The THOM and MCDOWELL (1998) indices can thus be employed for analysis of the European trade in live pigs in the six sub-categories of CN8 category 1 "Live animals" (we used categories 01031000-01039290) for each of the 27 EU countries. Noting that $X_J = \sum_{i=1}^{N} X_i$; $M_J = \sum_{i=1}^{N} M_i$, hereafter aggregate exports and imports of the EU trade in live pigs, aggregated over the $i=1...n$ categories of THOM and MCDOWELL (1998), decompose TT according to:

$$A_w = \sum_{i=1}^{N} \left(1 - \frac{|\Delta X_i - \Delta M_i|}{|\Delta X_i| + |\Delta M_i|}\right) \left(\frac{|\Delta X_i| + |\Delta M_i|}{\sum_{i=1}^{N} |\Delta X_i| + |\Delta M_i|}\right) \tag{4a}$$

[4] Note that "intra-EU" trade refers in this context to trade among partners that both belong to the EU27 sample; their bilateral trade however may still be of any of the three types of trade.

$$A_J = 1 - \frac{|\Delta X_J - \Delta M_J|}{\sum_{i=1}^{N} |\Delta X_i| + \sum_{i=1}^{N} |\Delta M_i|} \quad ; \quad A_I = 1 - \frac{|\Delta X_J - \Delta M_J|}{|\Delta X_J| + |\Delta M_J|} \tag{4b}$$

Thus, $d\,IT = 1 - A_J$; $d\,IIT = A_J$; $d\,HIIT = A_w$ and this implies that $d\,VIIT = (A_J - A_w)$. This decomposition of marginal IIT allows an assessment of changes in the relative composition in the trade of live pigs in the EU 27. Since the index values are expressed as percentage changes for the corresponding type of trade between two periods, these values can be consistently compared across countries and time periods.

However, the hypotheses derived in section 2 suggest that an increase in $\Delta y^{\omega}_{irt,t-1}$ may not only be related to an increase in VIIT, but also to declining offshoring costs in the same or previous periods.

3.3 Measuring changes in outsourcing costs

Since transport costs within the European Union were assumed to have remained practically constant across member states, it is instead of interest to assess potential trade effects of changes in EU membership and membership in the Eurozone. This information is readily available for each EU member country. Furthermore, a major change in outsourcing costs within European pork chains must have occurred due to structural change within the pig farm sector. This was measured according to a dynamic decomposition of the Theil-L index, which in its static version (for one year) is defined as follows (HAUGHTON and KHANDKER, 2009):

$$Theil_L = L = \frac{1}{N} \sum_{i=1}^{N} ln\left(\frac{\bar{k}}{k_i}\right)$$

Higher values of L are typically interpreted as rising inequality of the distribution of a resource K between j statistical subgroups of a population N. Here, K=pigs in a country and N farms with this type of pigs in t,r were distributed across J categories of Livestock Size Units (LSU, Eurostat). Furthermore, $\bar{k} = K/N$ and $k_j = K_j / N_j$; $n_j = N_j/N$.

HAUGHTON and KHANDKER (2009) show how for small changes, the change in the value of this index between two periods can be expressed as $\Delta L = \Delta L_A + \Delta L_F + \Delta L_G$:

$$\Delta L \approx \underbrace{\sum_j n_j \left[ln\left(\frac{\bar{k}_{,t}}{\bar{k}_{,t-1}}\right) - ln\left(\frac{\bar{k}_{j,t}}{\bar{k}_{j,t-1}}\right)\right]}_{\Delta L_A = \textit{change of animals in LSU group}} + \underbrace{\sum_j \left[L_j + ln\left(\frac{\bar{k}}{\bar{k}_j}\right)\right]\Delta n_j}_{\Delta L_F = \textit{farms move between LSU categories}} + \underbrace{\sum_j n_j \Delta L_j}_{\Delta L_G = \textit{change of inequality within group}_j} \tag{5}$$

These three partial changes capture for a certain farm type in a country how structural change is composed of an overall change in the relative number of pigs in each LSU category, a change in the number of existing farms within LSU categories, and the average number of a certain type of pigs per farm in each of these LSU size categories.

3.4 Econometric Model

The previous sub-sections established the strategy for how changes in downstream export performance and upstream changes in outsourcing potential between countries could be empirically approximated. The hypotheses derived in section 2 could then be empirically tested based on the following econometric model:

$$\Delta y_{irt} = \beta_0 + \beta \Delta it_{irt} + \beta \Delta hitt_{irt} + \beta \Delta vitt_{irt} + \beta \Delta L_{irt} + \beta eu27 + \beta eu + \upsilon_r + u_{irt} \tag{6}$$

In this model, the net export residual $\Delta y^{\omega}_{irt,t-1}$ is explained as a function of changes in the composition of various trade types, the three components of the Theil-L index as an approximation to changing outsourcing costs across Europe, and dummies that capture a country's membership status in the European Union and in the Eurozone. The model was estimated as a panel model for 20 countries and nine changes between the study periods. A random effects specification for countries was rejected in favour of the fixed effects estimator. Since changes in trade patterns among the explanatory variables refer to live pigs only and omit the category of trade in frozen carcasses as a task prior to deboning of CMnoB, potential endogeneity was reduced. Furthermore, only extra EU exports were considered in order to avoid potential endogeneity with established HIIT trade flows, e.g. as a result of geographical proximity, and time lags for the explanatory variables were introduced.

Estimating the model as a dynamic GMM panel model with an autoregressive term would potentially have increased the explanatory power, but proved to be problematic because $\Delta y^{\omega}_{irt,t-1}$ and the explanatory variables were already given in first differences.

An alternative conceptual approach might have been to estimate a modified gravity equation. However, as discussed above, the trade distance alone should hardly matter and is difficult to determine for IIT in live pigs in Europe (for example, consider the distance from Denmark to northern or southern Germany in comparison to the distance from Denmark to Holland). Furthermore, the approach by BALDWIN and TAGLIONI (2011) to estimate supply chains within a gravity framework does not apply to trade at a very disaggregated level.

3.5 Data

Data on bilateral trade flows in live and processed pigs were obtained from the CN8 trade database at Eurostat, because this database shows slightly more categories of trade in live pigs than the HS8 classification. Export and import flows were harmonised before analysis by matching $X_{A,B,t}$ to $M_{B,A,t}$ such that the higher of the two values provided was always retained. Data on structural change among pig farms in Europe were obtained from Eurostat. However, while data on the number of sows, piglets and fattening pigs were available for each year and almost every EU27 country, data on the number of farms with pigs according to categories of economic farm size or LSU were only available for the years 2000, 2003, 2005, 2007 and 2010. The missing values in the periods in between were imputed using predicted values from log-linear regressions, whereby the corresponding predicted share in each year was multiplied by the total number of pigs, such that in each year of unavailable farm data only the distribution and number of farms had to be imputed, while the total number of pigs across all categories was still covered by available data[5].

3.6 Results

Table 1 presents estimation results from the econometric model; further time lags >1 showed no statistical significance. According to the estimation results, the average European country experienced a relative increase in the competitiveness of its net exports in CMnoB if it increased the share of VIIT in live pigs in the previous period. If HIIT increased instead, this was related to a decline in the net export competitiveness of CMnoB. Structural change across the EU27 sample of countries exhibited strong and significant positive coefficients for rising inequality ΔL_{F_1} (=more relatively large farms in terms of pigs/farm) and ΔL_{G_1} (=change of inequality within each type of pig produced). The significant coefficients occurred in the lag period, which is plausible given that investments, biological reproduction and other structural change at farm level may take about one year until they affect the competitiveness of processed exports of CMnoB.

5 Malta, Cyprus and Luxembourg were omitted due to minor pig production and partly missing data.

Table 1: Regression results for a fixed effects panel model

Explanatory Variable	*Coef.*	*t-ratio Beck-Katz*	*t-ratio Arrelano HAC*	*Explanatory variables continued:*	*Coef.*	*t-ratio Beck-Katz*	*t-ratio Arrelano HAC*
const	0.6853	0.4606	0.4777	**ΔLA_1 Fatten.**	**-1.6043**	**-2.0614**	-1.4359
Δextra-EU HHIT	0.6556	0.248	0.4326	ΔLF Sows	**5.933**	**2.6302**	**2.7341**
Δextra-EU HHIT_1	-0.4945	-0.2044	-0.3064	**ΔLF_1 Sows**	**4.7434**	**1.9206**	1.6819
Δintra-EU HHIT	2.4845	0.8086	1.0901	ΔLG Sows	1.148	1.0311	0.5993
Δintra-EU HHIT_1	**-2.2893**	-0.6848	**-1.971**	ΔLG_1 Sows	1.0136	0.765	0.685
Δintra-EU VIIT	-0.3469	-0.266	-0.3171	ΔLA Sows	-0.5915	-1.6973	-1.3639
Δintra-EU VIIT_1	**2.7641**	**2.2183**	**1.8977**	ΔLA_1 Sows	-0.1402	-0.4891	-0.6864
Δextra-EU IT	0.2769	0.2385	0.3646	ΔLF Piglets	-0.3477	-0.3681	-0.5128
Δextra-EU IT_1	-1.3124	-1.0772	-0.8978	**ΔLF_1Piglets**	**-1.4251**	**-1.7036**	**-1.6869**
ΔLF Fattening Pigs	0.8412	0.3727	0.301	ΔLG Piglets	-0.2352	-0.1484	-0.1615
ΔLF_1 Fattening Pigs	**4.6126**	**2.1147**	1.1603	ΔLG_1 Piglets	1.0719	0.8848	0.5563
ΔLG Fattening Pigs	0.8343	1.2717	0.6765	ΔLA Piglets	-0.3522	-0.4482	-0.3779
ΔLG_1 Fattening Pigs	**1.5248**	**2.4408**	1.3625	ΔLA_1 Piglets	-0.3703	-0.565	-0.3585
ΔLA Fattening Pigs	0.0899	0.1136	0.077	(insignificant dummies on EU membership dropped)			
R-squared: 0.22619		Log-likelihood: -605.52		Time-series length = 9, Includes 24 cross-sectional unit fixed effects, n= 216 observations			

Rising inequality between farms due to a rising number of fattening pigs on large farms showed a significant negative coefficient, implying that the number of pigs produced had on average not been a source of competitiveness. This is in line with the observation that the total number of pigs in the EU27 declined by about 9-10% between 2002 and 2012. Furthermore, inequality among farms with piglets affected export competitiveness negatively, most likely due to the declining number of specialist rearing farms that only keep piglets after weaning and before selling to a fattener, given that this system does not seem to prevail under very large structures of pig production.

The results presented in Table 1 are robust to specifications of the explanatory variables, e.g. removing the set of explanatory variables on the farms with piglets did not affect the qualitative findings on other farm types except that the coefficient for intra-EU HITT became non-significant in that case. Dummies for membership of the EU 27 and the Eurozone were both insignificant and were therefore omitted. For all regressors included, collinearity was assessed based on variance inflation factors and a level of 5 was tolerated. However, as Table 1 indicates, the findings appeared somewhat sensitive to the choice of robust standard errors and therefore two alternative specifications suitable for this type of panel data regressions are presented.

4 Discussion & Conclusions

This paper explored whether and how the emerging theory of trade-in-tasks can be operationalised for empirical applications relating to trade in agri-food. The theory addresses the rising importance of trade in intermediate products, components and services as part of global assembly processes for manufacturing products. An important empirical problem arising from this trend is that conventional global trade statistics potentially overestimate the export performance of countries that are strongly involved in such international trade-in-tasks. This problem is currently spurring research efforts to construct new global trade databases that take this so-called trade-in-value-added explicitly into account (see ELMS and LOW, 2013). However, agriculture remains highly aggregated in such databases, so meaningful sectoral and regional analyses are not yet possible and would in future require tremendous data collection about intermediate factor content in different agri-food products. However, disaggregated analyses, e.g. for specific sectors such as pig production in the EU, are highly relevant for the analysis and design of agricultural policies. Therefore, based on the theoretical trade-in-tasks argument that a decline in outsourcing transaction costs will improve the productivity of the multinational 'firm', in this paper we argue that European supply chains for pork can be viewed as such a multinational firm, with the assembly place for a final product residing in each European country. Furthermore, we assumed that a change in any country's relative exports of processed pork meat products must come at least partly from increasing specialisation of pig production across European country borders (=outsourcing). This specialisation in corresponding tasks along the pork chain (such as breeding, fattening and slaughter) must appear within conventional trade statistics as IIT, from which we isolated the share of VIIT as a representation of outsourcing activities. Official statistics show in this respect that intra- and extra-IIT trade in live animals and processed pork products in the EU 27 has strongly increased over the past decade, while the number of pigs produced has fallen.

Furthermore, changes in transport costs within the EU27 have largely been constant over the last 10 years and therefore do not provide any economic explanation for potential increases in cross-country specialisation patterns. Instead, we hypothesise that structural change among pig-producing farms across Europe has led to the emergence of larger and more specialised farms, which constitute an important source of declining offshoring costs. Empirical estimations for a panel of 24 European countries over nine periods did not allow rejection of these hypotheses: for the European sample on aggregate, structural change, especially among farms with sows, together with rising vertical IIT in the following period showed a statistically significant positive contribution to changes in the export performance of extra-EU exports of chilled boneless pig meat.

Rising net exports by individual European countries must therefore be viewed as "made in the European Union" (ELMS and LOW, 2013), implying that an increasing share of export performance is due to the supply chain's ability to benefit from low costs of certain tasks in other countries. Even though within-EU differences in specific factor costs, e.g. for slaughter, animal welfare and wages, potentially provide an additional explanation for VIIT, we emphasise structural change in the pig farm sector as an important driver for regional integration of European pork chains. In line with the trade-in-tasks theory, this structural change has proved to be an empirically important source of technological progress that benefits the extra-EU export performance of processed meat exporting EU countries, as long as they mange to incorporate such structural change among their trading partners into their own supply chains through VIIT.

With respect to future research, the analysis presented here showed that existing conventional trade statistics can be operationalised to test hypotheses deriving from the trade-in-tasks paradigm. Furthermore, the empirical results indicate the potential relevance of the trade-in-tasks paradigm, not only for the global trade in manufacturing goods but also for intra-EU trade in live pigs.

With respect to agricultural policies in Europe, our results imply that attempts to restrict the growth of pig farms or trade and transport of live animals will not only affect the farms concerned, but also the export competitiveness of meat processing exports. However, in the perspective that increasing IIT in live pigs within Europe is undesirable for animal welfare reasons, the analysis presented here suggests that the harmonisation of animal welfare regulations and elimination of cost differences in the slaughter sector would be a policy alternative to reduce offshoring incentives for cross-country outsourcing, compared with transport restrictions or taxes on the transport of animals.

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