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Outsourcing, Regional Trade and Specialization: An Application to in the German Pig Sector

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Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

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Abstract: The global trend of industrializing agriculture increasingly transforms farms and firms into specialized component suppliers within a multi-stage food processing chain, which creates intra-industry trade between- and within geographical regions. This can be analyzed within the framework of a hypothetical multiregional food-processing firm that benefits from outsourcing various 'tasks' to other sub-contracting regions, in order to utilize lower production cost there. This is modeled as a multi-output cost minimization problem of the processing firm, and it is argued that with respect to agriculture, the outsourcing opportunities for the firm are determined by economies of diversification. Trade is implicitly reflected as the movement of intermediate factors towards the processing firm, and firm-level specialization of the sub-contractors is an observable outcome. This framework is applied to pig production in 1150 municipalities in southern Germany. The estimated multi-output production frontier is decomposed according to a primal measure of diversification economies. Results show that pig farms located closer to slaughterhouses tend to specialize more in one of the tasks 'piglet production', 'rearing' or 'fattening', while farms in regions distant from slaughterhouses tend to in-source all of these tasks. Future research may extend the framework towards comparative static analyses of relevant policies.

Keywords: Outsourcing, Trade of Tasks, Economies of Diversification, Pig Production

1. Introduction

Global and regional trade of agricultural and processed food products is changing drastically: An increasing share of global food production is part of vertically and horizontally ever more integrated food supply chains. These are characterized by diversification of primary products according to quality characteristics, which induces marketing contracts, quality control schemes and brand labels. Therefore, even the production of primary agricultural products is becoming increasingly knowledge-based (e.g. Goodhue, Heien, Lee and Sumner, 2000). This process of "agro-industrialization" is going along with institutional change between farms and processing firms in the food sector, and at the same time is the importance of farms as a market for inputs, provided by a highly specialized and growing industry, steadily increasing (Reardon and Barrett, 2000).
"It's not 'pork' for 'corn' anymore"[1] may therefore describe best the large and increasing trade of intermediate food products and services (Intra-Industry Trade, IIT) within global agriculture. Consequently, the interaction of trade flows, sectoral competition and structural change is becoming increasingly complex: Few decades ago, the comparative advantage of a country or a region with respect to agricultural production could often be determined by geographical factors. It was common that most farms in a region would face one and the same (world) market price, and as consequence farm policies were mostly price-oriented. For an increasingly knowledge-based, industrializing 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) develop a partial equilibrium trade model with heterogeneous firms and apply it to the issue of compliance with the EU food standards in Polish meat production. Greenaway, Gullstrand and Kneller (2008) show empirically for Sweden that regional dynamics may

[1] Adapted from the conference paper *"The Rise of Offshoring: It's not Wine for Cloth any more"* by Grossman and Rossi-Hansberg (2006), who were arguing for a 'new paradigm' in international trade theory.

look very different from national averages when heterogeneous firms and a heterogeneous workforce are considered. Similar changes have been described e.g. by Kilkenny (2002) for rural areas in the USA.

This indicates that productivity differences between firms (Melitz 2003) evolve according to ongoing structural change. Chavas (2008) explains how technical innovations have induced farmers around the globe to increasingly specialize in order to exploit economies of scale and scope, while at the same time having to diversify the portfolio of their activities in order to hedge against risk, and gradually shifting favor towards larger, specialized agro-corporations. Indeed, especially in transitional countries, but also in the Western USA, can the formation large Agro-Holdings already be observed. Such firms incorporate all steps from primary production to sales in own supermarkets (Nikolaev 2007).

Within the still family-farm based European Union, industrialization of agriculture is especially obvious with regard to products of animal origin, such as eggs and meat: Partly in reaction to food scandals and diseases, EU farmers, slaughterhouses and retail chains have established programs 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 to new trends among consumer preferences, reduce cost of intermediate products and transactions, add value to the production through the innovation of new products and customer services, improve and maintain quality and food safety.

This trend of Agro-Industrialization, however, transforms farms and other producers of primary products increasingly into component suppliers and sub-contractors of food processing firms and retail chains. Especially within the service sector and the manufacturing industry have such networks of subcontracting frequently been described according to the term 'outsourcing' or 'offshoring': Certain stages of a firm's production process are sourced from external providers, which causes trade by definition. Depending on the location of the external provider (or sub-contractor), this type of IIT may take any dimension from trans-continental to intra-regional.

Grossman and Rossi-Hansberg (2008) (hereafter GRH) label this the "trade of tasks" and argue that IIT to a large extend results from increased offshoring/outsourcing or, in other words, numerous forms of vertical contracting. However, GRH and related theoretical work (reviews e.g. in Baldwin and Robert-Nicoud, 2010; Crinò 2009, Helpman 2006) do not define a "task" explicitly; Baldwin and Robert-Nicoud (2010) however suggests to think of a "task" as a fragment of the production chain, and, as any intermediate input, composed out of a specific combination of labor and capital. Especially agricultural trade- and sector models used to rely heavily on the Ricardo-Heckscher-Ohlin-Stolper-Samuelson (hereafter HO) view on trade between regions due to their comparative advantage. Does this necessarily contradict observed trends of agro-industrialization? Baldwin and Robert-Nicoud (2010, p.2) theoretically integrate a GRH- trade-of-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 if *'foreign'* factors would migrate to the offshoring region *('home'*) but being paid *foreign* wages.

With respect to Agro-Industrialization, this would imply that the comparative advantage of the upper end of a food processing chain (e.g. the competitiveness of a brand label for shelf ready pork) would be determined by its ability to get access to the lower unit cost of downstream providers, e.g. farms. Trade of agricultural products could then be viewed as the movement -or shadow migration (Baldwin and Robert-Nicoud, 2010)- of 'tasks' from sub- contractors towards the final point of sale.

The purpose of this paper is therefore to develop an analytical framework that represents the structure of a typical agricultural supply chain based on the concept of 'tasks' being traded between a 'home' region and potential sub-contractors. It is argued that in agricultural production the comparative advantage of potential sub-contracting farms or regions (as representative farms) can empirically be determined best by a *"…trade-off between diversity and specialization…" (Chavas 2008*) at each location. Therefore, a decomposition of economies of diversification, introduced by Chavas and Kim, (2007, 2010) is suggested as a flexible framework to analyze the formation of downstream supply networks in rural areas. The empirical application illustrates how the comparative advantage of pork producing municipalities in southwest Germany changes due to the interaction of diversification economies and due to their distance to a slaughterhouse.

2. A model of outsourcing, regional trade and specialization

There have been multiple approaches to model the outsourcing decision of the multi-regional firm (reviews e.g. in Baldwin and Robert-Nicoud, 2010; Crinò 2009, Helpman 2006). GRH have coined the term 'tasks' for intermediate inputs to production and determine the marginal task to be out/in-sourced according to the following condition (GRH p.1982): $w=bt(I)w^*$

This expression says 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 b is a shift parameter that reflects the technology (or transaction costs) for offshoring, and w, w^* are wages in *home* and *foreign*, respectively. GRH index the tasks in their hypothetical industry by $i \in [0,1]$ and order them such that the costs of offshoring are increasing. Harms, Lorz, and Urban (2009) argue that this is unrealistic because industrial processes require that tasks have to be performed in a certain sequence and therefore are related to each other through technology rather than through outsourcing cost. Rawley and Simcoe (2010) investigate outsourcing in the US taxi industry. They argue that firms re-organize their production according to diversification economies. In other words, firms outsource parts of their production process in order to manage diseconomies of scope. The argumentation of Rawley and Simcoe (2010) is interesting with respect to industries for which ordering of related tasks according to simplified criteria is meaningless. Unfortunately, their theoretical approach is unrelated to any of the trade-theoretical literature mentioned before and rather refers to institutional economics. However, their argumentation applies well to the ecosystem-based nature of agriculture:

Consider a hypothetical firm F that sells a processed food product ω either to consumers or e.g. directly to a chain of retail stores. For the purpose of illustration it is referred to a typical European supply chain for Pork. The firm chooses it's headquarter (Helpman 2006) initially such that it is closest to its customers (*home* region r_F). However, the absolute size or location of this geographical unit where the headquarter is established does not need to be defined further; it is any region $r=1,\dots,R$, (any geographical unit under consideration, for instance the boundaries of a farm, a community, or country). Note that modeling the final market for ω is not within the scope of this paper, but ω could either represent aggregate supply of a sector or could e.g. be understood as a variety within the Chamberlain-Dixit-Stiglitz framework of monopolistic competition. This could lead to integration into a partial equilibrium model with firm-level productivity differences (e.g. Rau and van Tongeren, 2010).

Following GRH, the production of ω can be understood as the outcome of certain tasks t_i from a set of tasks $T=\{1,\dots,I\}$. Furthermore, most theoretical frameworks refer to a continuum of tasks, which implies 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. For the purpose of a food supply chain representing ω, it is however assumed that t_i reflects an intermediate product or service necessary to assemble the final product ω. Thus, shelf-ready pork will be 'assembled' based on some of the following tasks: $t_{vean\ piglets},\dots, t_{castrate\ male\ piglets},\dots, t_{feed\ pigs,}, \dots, t_{fill\ out\ paperwork},\dots, t_{transport\ to}$

$_{slauther}$,…, $t_{inspect\ carcass}$,…, $t_{cut\ desired\ parts}$, $t_{pack\ and\ label\ \omega}$. With extensive agricultural planning data being available, it is realistic to define and quantify most relevant agricultural tasks. Furthermore, comparative static analyses are facilitated through adding or removal of individual tasks. We will see how this alters the resulting equilibrium of specialization among sub-contractors, e.g. farms.

Definition: A task t is a fraction of the production process that can be specified as an 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 technology F such that $Y(y_t)=\{\ \omega:(-y_t,\omega)\in F\}$ which represents all feasible input-output combinations given by technology F. The assembly-line character can for instance be represented by a Leontief technology, which ignores the time-order in which certain tasks are performed, and instead assumes a constant flow of intermediate products. For relevant scales of operation in animal production this should be realistic: $\omega = min(\frac{t_1}{\alpha_1},...,\frac{t_i}{\alpha_i})$, with α_i being the input coefficients. 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 'firm' F has to produce initially all $t_i \equiv y_i^t$ in-house (in *home* region r_F) and faces the following profit maximization problem:

$$\Pi_F = \max_{\omega,\ z} \{p\omega - wy^t : (-y^t,\omega)\in F\} \quad [1]$$

However, it is assumed that this profit maximization problem of F is divided into two sub-firms that interact according to a Stackelberg-type game (e.g. Mas-Colell, Whinston and Green 1995). The sub-firm labeled as "Front Office" (FO) is the Stackelberg leader and takes over the part of revenue maximization with respect to ω:

Front Office: $$R(p,y^t)=max\{p\omega : \omega \in Y(y_t),\ p>0\} \quad [2]$$

The Stackelberg-Follower is "Back Office" (BO) that faces the problem to deliver all y^t to FO. Since FO and BO are both located at r_F this delivery is assumed to take place instantaneously and without cost. Thus, BO has to provide multiple outputs y^t at minimum cost, given factor price vector w for input vector x, and under the technology G (feasible set), with $(-x,\ y_t)\in G$:

Back Office: $$C(y^t,w)= min\{wx : (-x,\ y_t)\in G\} \quad [3a]$$

From the perspective of FO corresponds to each optimal output level of ω a set of fixed quantities required of task $t_i/\alpha_i \equiv y_i^t/\alpha_i$. Inputs (tasks) are fixed for firm F in a sense that F has no capabilities to change the input level of any task $t_i \equiv y_i^t$. Rather, in case that a change in the optimal quantity of ω should become necessary, e.g. due to a change in p_ω, F communicates the new required optimal quantities immediately to BO. Furthermore, it is assumed, that FO takes care of product innovations: certain t_i are removed from or added to the assembly line, depending upon the requirements for ω to stay in the market. For instance, FO may introduce a new $t_{take\ pigs\ to\ pasture}$ in order to satify consumer demand for animal welfare. However, FO is unable to determine how $t_{take\ pigs\ to\ pasture}$ could enter F at lowest cost. For this purpose, FO has to rely on BO to simultaneously minimize $t_{take\ pigs\ to\ pasture}$ along with the cost-minimal provision of all other tasks.

While FO determines the assembly of ω through adjustment of output to the market for the final good ω, BO knows everything about the 'sourcing technology' G. As the Stackelberg-follower[2], BO learns from FO which quantity of task $t_i \equiv y_i^t$ should be provided. BO therefore faces the problem to

[2] Note that the alternative specification of a network technology according to a dynamic production process would restrict F to constant returns to scale, compare Färe and Grosskopf (1996).

minimize the cost of producing multiple outputs y^t simultaneously. For this purpose, BO is not bound to 'produce' y_i^t in region r_F but can chose for each x_j between factor prices for *home* production ($w_{j,rF}$) and factor prices in *foreign* regions ($w_{j,r\neq r_F}$,). However, due to the fact that factor prices are evaluated at the *home* location, transport- and transaction cost of having y_i^t ready for assembly in r_F are incorporated in $w_{j,r\neq r_F}$, reflecting 'shadow factor migration' (Baldwin and Robert-Nicoud, 2010).
This implies that the benefit of outsourcing some tasks y_i^t from *home* r_F to regions $r \neq r_F$ comes from F getting access to lower $w_{j,r\neq r_F}$: $C(y^t,w_r^*)=min\{w_r^* x : (-x, y_t) \in G\}$ [3b]
This implies that the transaction cost of shipping y_i^t from $r \neq r_F$ to r_F is *implicitly* considered; BO will sub-contract with any region $r \neq r_F$ that provides y_i^t such that it reaches final assembly location r_F at minimum factor price w_i^*. From BO's perspective does the following equilibrium relationship - similar to GRH- determine for each task y_i^t, whether it is produced *home* for final assembly (in r_F) or outsourced to regions $r \neq r_F$:

$$w_{i,r_F}^* \leq w_{r\neq r_F}^* \qquad [4]$$

Equation [4] considers unit-opportunity cost at r_F. Furthermore, since w_i corresponds to the output price that potential sub-contractors in $r \neq r_F$ receive from BO, it is equivalent to their marginal cost of providing[3] y_i^t at r_F. Hence, the equilibrium in [4] will depend on the question: *i) how low are the minimum factor prices* w_i^* *that F can reach in any region for assembly of* ω. This question, however, is directly related to the following question: *ii) how is the marginal cost of providing task i affected by the production of task j?* Problem *ii)* corresponds to

$$\frac{\partial MC(y_i^t)}{\partial MC(y_j^t)} = \frac{\partial C(y^t, w)}{\partial y_i^t \partial y_j^t}$$

which is an expression for the economies of scope between y_i^t and y_j^t. Hence, the total minimum cost in [3b] may depend upon the composition of all $y^t \in T$: Given the multi-input, multi-output structure of BO's problem, it is likely that the decisions whether to produce y_i^t at r_F (in-house, *home*) or to outsource it to $r \neq r_F$, will depend on the interaction of economies of scale and scope at any location r. Understanding the implications that a change in the optimal quantity of output ω transmits to the composition of BO's production activities in all r therefore requires an evaluation of [3b].
A method to decompose economies of scale and scope has been developed by Chavas and Kim (2007) for the primal perspective, and by Chavas and Kim (2010) for the dual perspective (ChK hereafter for both references). ChK have generalized the familiar concept of economies of scope and label it "economies of diversification". In the context of outsourcing, negative economies of diversification over a given set of tasks lead to a fragmentation of the production process into different firms at different locations.

2.2 Decomposing Economies of Diversification

ChK consider the multi-output firm producing $m=1,...,M$ positive outputs $y = (y_1, ..., y_m)$ and divide this firm into $k=2,...,K$ specialized firms. Firm k specializes in $y^k = (y_1^k, ..., y_m^k)$ such that $y=\sum_{k=1}^{K} y^k$. Outputs are produced from inputs $x = (x_1, x_2, ..., x_n)$; or, in netput notation, $z \equiv (-x, y) \in F$, and this

[3] Note that this implies that all transport- and transaction cost is added to the MC of the sub-contractor. This is reasonable with respect to many real subcontracting network. Furthermore, this still affects cost of ω through higher input prices.

production process F, which corresponds to G in[4] [3a], is assumed to fulfill the standard properties of a multi-input, multi-output technology (e.g. Chambers, 1988, chpt. 7). Economies of scope are usually evaluated from the dual perspective based on the cost function. For evaluation of the primal perspective, ChK choose the shortage function $\sigma(z,g)=min_{\gamma}\{\gamma: (z - \gamma g) \in F\}$, if $(z - \gamma g) \in F$ for the scalar γ and $+\infty$ otherwise. $\sigma(z, g)$ measures the distance of point z to the frontier of F. This distance is expressed in units of the reference bundle g. Properties of the shortage function $\sigma(z, g)$ are discussed in ChK. However, ChK also note that the same analysis can be performed based on the directional distance function $D(z,g) = max_{\alpha}\{\alpha:(z+\alpha g) \in F\}$, if $(z+\alpha g) \in F$ and $-\infty$ otherwise (Chambers, Chung and Färe, 1996). By re-interpreting the ChK framework, the multi-output technology F exhibits "economies of outsourcing", for the production of output y if:

Primal Perspective: $S \equiv \sum_{k=1}^{K} \sigma\left(\frac{-x}{K}, y^k, g\right) - \sigma(z,g) < 0$; Dual Perspective: $S \equiv \sum_{k=1}^{K} C(y^k, p) - C(y,p) < 0$ [5]

In turn, if S from expression [5] is positive, diseconomies of outsourcing or "economies of diversification" (ChK) are present and imply that the firm enjoys synergy effects from producing y under in one firm instead of having it performed by k specialized firms or farms. ChK then derive a decomposition of S into several different components, which is of interest for a deeper understanding of the driving forces for in- or outsourcing decisions at the firm or farm level. According to ChK, S in [5] should be viewed as a gross effect of economies of diversification. This effect S can be decomposed further and allows for partial (or incomplete) specialization of the K hypothetical firms, which constitutes a generalization of the conventional concept of economies of scope. Partial specialization is, according to ChK, given by the following reasoning:

Consider M positive outputs $y = (y_1, \ldots, y_m)$ to be indexed in the set $I=\{1,\ldots,M\}$. This set can be described further as $I=\{I_{A1}, I_{A2},\ldots I_{AK}, I_B\}$. Thus, it consists of two subsets I_A, I_B: one containing all I_{Ak} and the other consisting of I_B. The latter subset contains all outputs that no firm specializes in. Each I_{Ak} however is the subset of outputs that the k^{th} firm specializes in. Varying degrees of specialization for output y_i of the k^{th} firm can now be imposed as follows (ChK, here a summary of the notation from both of their papers):

$$y_i^k = \begin{cases} y_i^+ = & \beta y_i & if\ i \in I_{Ak} \\ y_i^- = & y_i(1-\beta)/(K-1) & if\ i \in I_A \backslash I_{Ak} \\ y_i^k = & y_i/K & if\ i \in I_B \end{cases} \quad [6]$$

In this context, β is a parameter that reflects the proportion of y_i that is produced by the k^{th} firm, and $\frac{1}{K}<\beta\leq 1$. With respect to the analysis of the economies of outsourcing, this framework thus provides an analytical framework that allows for comparisons of productivity- or cost differences between an integrated firm, comprising all tasks in set I, against alternative patterns of disaggregation according to tasks in subsets I_A, I_B. Furthermore, for the tasks in set I_A, alternative specialization schemes defined by K, the number of sub-firms, and their degree of specialization β can be evaluated (note that β is assumed to be constant across k firms). The decomposition of specialization effects is then given by:

$$S \equiv S_C + S_R + S_V + S_L \quad [7]$$

These components of S have the following interpretation (ChK):

S_C = Complimentary: This effect represents economies of scope in the strict sense and evaluates how $y_{A\backslash Ak}$ affects the marginal cost or the negative of the marginal product of y_A. Thus, the sign of S_C depends on the question whether y_A and $y_{A\backslash Ak}$ are complements ($S_C > 0$), competitors ($S_C < 0$) or independent ($S_C = 0$).

S_R = Returns to Scale: $S_R >$ (<) 0 under increasing (decreasing) returns to scale. Firms that operate under DRTS should reduce the size of their operation, while firms under IRTS can gain by expanding

[4] In this Section the notation of ChK is adopted in order to facilitate comparisons.

their size.

S_V = Convexity Effects: $S_V \geq 0$ if the technology/the cost function is convex (cost function convex in y). For the primal perspective this reflects diminishing marginal productivity; for a linear cost- or production function $S_V = 0$. S_V thus can be thought of as the effect of resource scarcity, and this specific effect contributes positively to equation [7], implying that increased resource scarcity makes outsourcing of the relevant intermediate products less profitable and rather drives the overall effect S towards insourcing.

$S_{L\text{ or }F}$ = Discontinuities: For the dual perspective in [5], this reflects the effect of fixed cost and is zero in case of no fixed cost; for the primal this reflects discontinuities in the production process as induced by catalytic effects that one output exhibits with respect to the others.

These components of S in [7] can now be evaluated using the decomposition framework according to K and β as outlined in [6]. For instance, the effects S_R and S_V are given for the primal (left panel) and the dual perspective (right panel), respectively, by

$$S_R \equiv K\sigma\left(\tfrac{z}{K},g\right)-\sigma(z,g) \qquad\qquad S_R \equiv KC\left(\tfrac{y}{K},p\right)-C(y,p) \qquad [8]$$

$$S_V \equiv \sigma\left(\tfrac{-x}{K},\beta y_{Ak},\tfrac{y_B}{K},g\right)+(K\text{-}1)\sigma\left(\tfrac{-x}{K},\tfrac{(1\text{-}\beta)}{(K\text{-}1)}y_A,\tfrac{y_B}{K},g\right)\text{-}K\sigma\left(\tfrac{z}{K},g\right) \qquad\qquad S_V \equiv C\left(y_A^+,\tfrac{y_B}{K},p\right)+(K\text{-}1)C\left(y_A^-,\tfrac{y_B}{K},p\right)\text{-}KC\left(\tfrac{y}{K},p\right) \qquad [9]$$

The calculation of S_C and S_L is more involved and does not need to be repeated from ChK. Instead, we are now in a position to decompose economic effects that induce firms or farms to either outsource some of the tasks to other firms or to rather integrate the entire production chain in-house. For parametric applications it is necessary to estimate either the shortage function σ or the cost function C in equation [5] econometrically.

3. Empirical application

3.1 Data

Instead of firm-level data based on hardly observable information on w in [4], the empirical application presented illustrates the flexibility of the theoretical framework outlined above based on regional data of agricultural production from r =1152 municipalities in the German state of Baden-Württemberg. In geographical terms, Baden-Württemberg is slightly smaller than Switzerland, but larger than Belgium. An overall family-farm based character and some clusters of fertile soil and intense animal production in the north- east and south-east, make this greater region a good candidate to represent structural conditions typical for many rural areas within Germany and the western- and northern European Union.

The outsourcing framework outlined before is interpreted as a regional model of vertical integration, with focus on the economies of diversification within each municipality, which is considered as a representative farm. This is appealing since the number of farms per municipality is nowadays usually small (sample mean 11.7 pig farms) and farm-level data could not be obtained.

Consider the production chain for pork in this region (Baden-Württemberg) with the following tasks: $T=\{t_{slaughter}, t_{fattening}, t_{rearing}, t_{piglet\ production\ hogs}\}$. Thus, according to [1] a hypothetical slaughterhouse faces the decision to either produce all these intermediate products in-house or subcontract some or all of them to other firms or farms. Equation [3] shows that this can be translated into a general multi-output cost minimization problem for a production process involving M outputs $y^t=(y_1^t, \ldots y_n^t)\in \mathbb{R}_+^m$ produced from n inputs $x = (x_1, x_2, \ldots, x_n) \in R_+^n$. It is assumed that y^t is measured in number of pigs produced in r, using inputs barley and triticale (measured in hectares as a proxy for the size of the municipality), number of people working in fulltime farms, number of people working in part-time farms, and transport services measured in kilometer to the nearest slaughterhouse as an empirical representation of the role of the reference location r_F for the specialization of sub-contractors in r.

With output data on the number of pigs for slaughter and the number of hogs for breeding in each municipality, two intermediate outputs corresponding to two important tasks can be identified. Furthermore, it is well known that different types of specialized pig-farms coexist with fully integrated systems that bread, rear and fatten "in-house". From the Department of Statistics Baden-Württemberg the number of farms producing any type of pig ($N_{p,r}$), the number of farms producing piglets ($N_{h,r}$), and the number of farms fattening (finishing) pigs ($N_{f,r}$) is known. However, $N_{h,r}+N_{f,r}$ correspond only in very few municipalities exactly to $N_{p,r}$. While measurement error cannot be completely out ruled, the difference $N_{p,r} -(N_{h,r}+N_{f,r})=d_r$ contains important information: Since the questionnaire issued by the Department of Statistics literally asks "are you a piglet producer" and " are you a finisher?", integrated farms are double-counted. On the other hand, there is a specific type of farms that specializes on rearing of juvenile pigs during the first weeks after weaning. If the questionnaire asks "do you farm pigs?", specialized rearers agree, however, they deny to be either piglet producers or finishers. This explains why $d_r < 0$ if some farms in r run an integrated system and $d_r > 0$ if more farms are specialized rearers. From this, ignoring measurement error, we can reconstruct from d_r whether the representative farmer in each municipality has rather an integrated system or is rather specialized. Thus, by knowing the total number of pig farms ($N_{p,r}$), the shares $\theta_{Breeder,r} + \theta_{Rearer,r} + \theta_{Finisher,r} + \theta_{Integrated,r} = 1$, or 0 if no pigs at all in r.

3.2 Estimation Strategy:

As for the estimation of distance functions, the shortage function $\sigma (z, g)$ can be written as $\sigma (z, g) = y_m - F(x, y_1, ..., y_{m-1})$, which corresponds to estimation of an implicit multi-output production frontier. This frontier can be estimated in a consistent way as the mean shortage function $E[\sigma (z, g)] = y_m = F(x, y_1, ..., y_{m-1}) + u$ (Chavas and Di Falco, 2008) if the endogeneity of $y_1, ..., y_{m-1}$ is taken into account through specification of an appropriate estimator. For the application to pig production, a quadratic specification is chosen (rather than a transcendental or translog) because some municipalities do not show any pig production, and cannot be discarded from the dataset due to potential spatial interaction effects. Equation [10] is estimated using two stage least squares (2SLS):

$$y_{r,l}^{finished} = \delta + \alpha' y_{r,l}^{hogs} + \beta' x_{r,l} + x_{r,l}' B x_{r,l} + x_{r,l}' A y_{r,l}^{hogs} + \varphi' \theta_{m,r,l} + \mu' (N^{\circ}, E^{\circ}) + u_{r,m,l} \quad [10]$$

With x, θ being the vector of inputs and specialization shares as described above, and N°, E° are geographical coordinates for each municipality and their interaction effect in order to control for geographical correlation of u (note that the evaluation of spatial lag or spatial error effects is not in the scope of this application). Furthermore, we compare the model [10] for datasets from two different years $l=\{2003,2007\}$ in all $r=1150$ municipalities. The vectors α,β contain estimates of linear and quadratic explanatory variables. A,B are matrices containing the estimated parameters of the interaction effects. The corresponding instruments are formed by the Theil- indices for the distribution of land and labor in each municipality in the years of evaluation and in the year 1991.

4. Results:

Table 1 shows that the mean shortage function (or implicit production frontier) estimated in equation [9] fits the dataset overall very well. The specialization shares θ in each municipality are highly significant and can be interpreted as estimates of the parameter β in equation [6] given $K=3$. Furthermore, by setting either $\theta_{Breeder,r}$, $\theta_{Rearer,r}$, $\theta_{Finisher,r} = 0$, or alternatively $\theta_{Integrated,r} = 0$, the model estimated in [10] (Table 1) allows for simulations (predicted values) of output of finished pigs per municipality under alternative hypothetical specialization schemes and for the corresponding calculation of S according to [5]. Furthermore, S can be decomposed by simulating and calculating the various components as outlined above. It is assumed that that discontinuity effects do not exist (S_L=0), which corresponds to a long run perspective. After obtaining S_R and S_V, the complimentary component S_C can be inferred as $S_C = S - S_R - S_V$. Table 2 summarizes these simulated effects for the average municipality: The overall effect S is negative, indicating that within the average municipality outsourcing of the production, in other words specialization at the farm-level, is more efficient than a fully integrated system. Within one standard deviation, however, effects can vary between farms such that for some farms an integrated approach is preferable. Returns to scale effects indicate that most pig farms are still 'to small', but this effect has slightly decreased from 2003 to 2007 while the effect of convexity has also decreased over time.

Table 1: Estimated 2SLS Quadratic Production Frontier

Estimated Coefficients for 2007	Estimate	Std. Error	t-value	Pr(>|t|)		**Estimated coefficients for 2007 continued:**	Estimate	Std.	t-value	Pr(>|t|)	
(Intercept)	-127879.5	27543.2	-4.643	0.0000	***	[5]×[7]	-0.0000131	0.0000122	-1.074	0.2830	
[1] Shr. Hogfarms	-914.2	207.6	-4.404	0.0000	***	[5]×[8]	0.0152019	0.0039747	3.825	0.0001	***
[2] Shr. Finisher	285.2	69.9	4.083	0.0000	***	[5]×[9]	0.0020250	0.0016343	1.239	0.2156	
[3] Shr. Rearear	-308.9	150.6	-2.052	0.0404	*	[5]×[10]	-0.0248389	0.0046715	-5.317	0.0000	***
[4] Shr. Integrated	1674.6	376.9	4.443	0.0000	***	[6]×[7]	0.0000027	0.0000007	3.705	0.0002	***
[5] No. of Hogs	0.9809131	0.1407661	6.968	0.0000	***	[6]×[8]	-0.0004829	0.0001919	-2.516	0.0120	*
[6] Barley (Hectare)	0.0507630	0.0074726	6.793	0.0000	***	[6]×[9]	-0.0002618	0.0000881	-2.971	0.0030	**
[7] Triticale (Hectare)	-0.0360617	0.0233597	-1.544	0.1229		[6]×[10]	0.0000596	0.0002438	0.245	0.8067	
[8] Labor (Fulltime)	-4.5514949	3.9651827	-1.148	0.2513		[7]×[8]	-0.0000621	0.0005716	-0.109	0.9135	
[9] Labor (Part-time)	5.3833089	2.5621855	2.101	0.0359	*	[7]×[9]	-0.0009388	0.0003344	-2.808	0.0051	**
[10] Km to slaughter	8.5441912	6.7601172	1.264	0.2065		[7]×[10]	0.0029336	0.0007980	3.676	0.0002	***
Square [5]	-0.0000522	0.0000156	-3.357	0.0008	***	[8]×[9]	0.0885205	0.0312650	2.831	0.0047	**
Square [6]	0.0000004	0.0000001	3.543	0.0004	***	[8]×[10]	0.2809480	0.1216315	2.310	0.0211	*
Square [7]	0.0000018	0.0000013	1.378	0.1684		[9]×[10]	-0.1011764	0.0959631	-1.054	0.2920	
Square [8]	-0.0691741	0.0258010	-2.681	0.0074	**	Latitude	2638.7	570.0	4.629	0.0000	***
Square [9]	-0.0295352	0.0125530	-2.353	0.0188	*	Longitude	15001.3	3081.3	4.869	0.0000	***
Square [10]	-0.3036545	0.1335627	-2.274	0.0232	*	Latit×Long	-309.8	63.7	-4.863	0.0000	***
[5]×[6]	-0.0000103	0.0000023	-4.533	0.0000	***						
Diagnostic for Year 2007						**Diagnostic 2SLS for 2003, results on request.**					
N: 1155	SSR: 442738238	R^2: 0.85				N: 1155	SSR: 376176382	R^2: 0.837			

Source: Own estimation based on Data from Statistisches Landesamt Baden-Württemberg

Convexity effects are strongest in municipalities that are at the margin of agricultural production (see Figure 1-IV, the Blackforest Region in the southwestern corner of the map). On the other hand, these effects are compensated by a strong (calculated) economies of scope effect S_v, which is negative. This effect implies that the marginal productivity in pig fattening (finishing) is negatively influenced by rising marginal productivity in hog production. Technically, both outputs are competitors, which is plausible given the higher skill intensity in piglet production, the limited labor capacity in family farms and the competition for farm-own feeds such as barley and triticale.

Table 2: Sample mean and standard deviation of predicted values

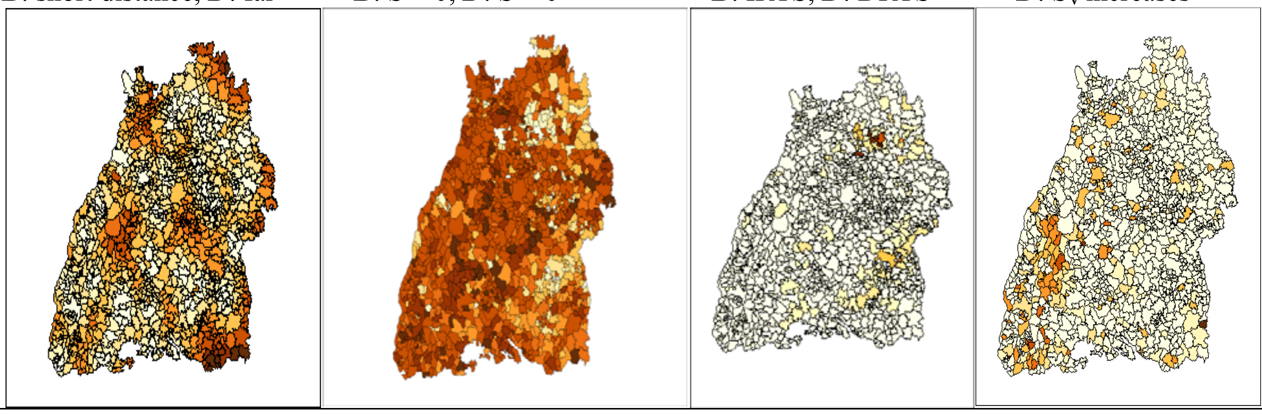
Year		S	S_{scope}	$S_{ReturnsToScale}$	$S_{Convexity}$
2003	Sample Mean	-43.96	-1284.58	1168.01	72.60
	Std	150.02	2597.67	2570.65	123.68
2007	Sample Mean	-79.85	-1282.39	1162.98	39.56
	Std	213.09	3089.54	3005.77	87.44

Both simulated effects S_V and S_R can be explained by structural change that has taken place within the five years considered and gave the largest pig farms more opportunities to grow. However, the direction of this change, as well as the overall level of specialization in each municipality is also influenced by the distance to the nearest slaughterhouse. Figure 1-I indicates that short distances to a slaughterhouse tend to coincide with municipalities for which S (second panel from left) is relatively low and negative, implying that specialization is more favorable. Convexity effects are strongest in those regions far away from commercial slaughterhouses, and this effect contributes positive to in-sourcing at the farm level (equation [7]). Figure 1 also reveals that farms tend to specialize more if more other specialized farms are geographically located next to them (the southeast and northeast pig clusters in Baden-Württemberg, compare Figure 1-II). Farms instead tend to in-source more tasks from the supply chain if they are relatively isolated in terms of geographic location.

Figure 1: Decomposition the of the Economies of Outsourcing in Pig Production in year 2007

Brighter colors *(B)* or darker colors *(D)* indicate the numerical direction of the corresponding variable.

I: Dist. to slaughter (km)	**II: Total Effect S**	**III: Scale S_R**	**IV: Convexity S_V**
B: short distance, ***D***: far	***B***: S < 0, ***D***: S > 0	***B***: IRTS, ***D***: DRTS	***D***: S_V increases



5. Discussion and Conclusion

By assuming a representative multiregional firm that minimizes the cost of providing various tasks to a certain reference location, it can be shown that the "economics of outsourcing" constitute an analytical framework that is well suited to understand regional specialization effects within pig production in southern Germany. The approach could readily be extended to inter-regional trade, e.g. between the European Union and supply networks formed with other trading partners. In this context, the 'trade-in-tasks' paradigm may apply especially to products of animal origin due to the complex role of economies of diversification at different locations (ChK).

The empirical analysis presented here has decomposed outsourcing effects for the pig sector by using the ChK framework as an empirically traceable decomposition of the comparative advantage that firms and farms at different locations experience. Correspondingly, the competitiveness of ω – not modeled explicitly in this application- depends on the extend up to which lower marginal cost of certain tasks can be utilized through outsourcing them to other regions. Hence, the model presented here represents intra-industry agricultural trade *implicitly* as 'shadow migration' (Robert-Nicoud 2010), and observed farm-level specialization is the outcome of this process.

However, by use of firm-level surveys more specific supply chain networks can be analyzed, and their role for regional and international shadow migration of factors can be traced within the same framework. Furthermore, the concept of 'tasks' relevant for the final food product *(ω)* would allow to specify e.g. certain product quality criteria as individual tasks and analyze their structural impact on supplying firms, which is promising with respect to comparative static analyses of relevant policies.

In summary, the trade-of-tasks framework seems to be well suited for future analyses of industrializing agriculture. Combined with the decomposition of economies of diversification it provides insights into the question how firm-level productivity differences change in regions that are affected by a change in the composition of tasks required for assembly of a final food product.

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