

Coordination in agri-food supply chains: The role of Geographical Indication certification[☆]

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ABSTRACT

We examine the role of Geographical Indication (GI) certification in coordinating small- and medium-sized food suppliers and large-scale retailers in agri-food supply chains, where retailers seek to procure high-quality goods. Our main contributions are twofold. First, using a principal–agent framework with asymmetric information about supplier efficiency in quality production, we develop a signalling model that illustrates how GI certification enhances the coordination effect of procurement contracts by improving the ability of the retailer to identify efficient suppliers and increasing the provision of high-quality goods. The model also yields predictions about the impact of a supplier's GI certification status and size on the retailer's expected profits. Second, using a novel dataset from a survey of 476 small- and medium-sized food craft suppliers in Germany, we provide evidence supporting the theoretical model's predictions regarding the effects of GI certification and supplier size on the retailer's expected profits. Specifically, we estimate a structural equation model (SEM) that matches the equilibrium equations describing retailer and supplier behaviour in the theoretical model and links the probability of a transaction to a supplier's GI certification and size. Our findings from instrumental variable (IV) approaches and propensity score matching (PSM) indicate that GI-certified suppliers are 19.9% to 42% more likely to transact with a retailer than non-certified suppliers, and medium-sized suppliers are 11.7% to 26.3% more likely to transact with a retailer than micro- or small-sized suppliers. These results suggest a potential role for GI certification in supplier-retailer coordination.

1. Introduction

Agri-food supply chains encompass all entities involved in the production, processing, trading, distribution, and consumption of food products (Zhao et al., 2020). Such supply chains often feature a dominant retailer or processor and various less powerful suppliers (Belaya and Hanf, 2016). Each actor within the supply chain pursues individual objectives, making the coordination of relationships and activities a complex task (Handayati et al., 2015). Coordination refers to managing interdependencies between independent entities working towards a mutually defined goal (Malone and Crowston, 1994; Arshinder et al., 2008), and is especially crucial in the presence of information asymmetries (Vosooghidizaji et al., 2020).

While there is no universally agreed-upon definition of supply chain coordination, we align with Albrecht (2009), interpreting it as the outcome of mechanisms that enhance overall supply chain performance compared to a default situation. In our context, we focus on the contractual relationship between small-scale agri-food suppliers and large-scale food retailers, with the improved outcome being the provision of quality goods, thus mitigating market failures à la Akerlof (1978). We propose Geographical Indication (GI) certification as a device that extends the coordination effect of standard procurement contracts in agri-food supply chains by (i) helping large-scale retailers identify

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efficient suppliers and (ii) incentivising suppliers to provide quality goods.¹

GIs are recognised as intellectual property rights and are defined as “indications that identify a good as originating from a particular place, where a given quality, reputation, or other characteristics of the good are essentially attributable to its geographical origin” (TRIPS, 1994). GIs serve as food labels and branding tools across various agri-food sectors and the wine industry globally (Menapace and Moschini, 2024). The unique characteristics, qualities, and geographical origins of such products are detailed in a code of practice that all producers must adhere to. As a result, GIs are restricted to producers within specific demarcated areas. Compliance with these standards is verified through independent third-party certification (Bramley et al., 2009; Menapace and Moschini, 2024).

The economic literature on GIs is extensive, exploring their role as incentives for quality investment (Lence et al., 2007; Mérel, 2009; Desquilbet and Monier-Dilhan, 2015; López-Bayón et al., 2018), as tools for product differentiation (Moschini et al., 2008; Bouamra-Mechemache and Chaaban, 2010; Mérel and Sexton, 2012), drivers of local economic development (Crescenzi et al., 2022), means to establish firm reputation (Menapace and Moschini, 2012), and mechanisms for enhancing exports (Raimondi et al., 2020; Duvaleix et al., 2021). All these studies conceptualise GI certification as a credible quality signal. Nevertheless, to date, there are no contributions exploring the role of GIs as a coordination mechanism in agri-food supply chains. Therefore, we address the following research questions in this article:

RQ 1: Does GI certification play a role in coordinating the relationship between small-scale suppliers and large-scale retailers, thereby affecting the provision of quality goods?

RQ 2: Does GI certification enhance the ability of small-scale suppliers to access large-scale retailers?

This paper makes two main contributions to the literature. The first is theoretical and addresses RQ 1. Following Shen et al. (2019), we develop a principal-agent (PA) model rooted in the theory of contracts, also known as the “economics of information” (Cachon, 2003), that illustrates the role of GIs as a quality signal for coordination.² Specifically, we model the contractual relationship between a large-scale retailer (principal) and heterogeneous small- and medium-sized suppliers (agents) who hold private information regarding their costs of producing quality products. Using a procurement contract with standard features (i.e. multi-period, delisting), the retailer intends to procure a quality product that is expensive for the suppliers to produce and challenging for the retailer to enforce in a court of law.³ In this

¹ Procurement contracts constitute the prevalent mechanism observed in agri-food supply chains for coordinating large-scale retailers and small- and medium-sized suppliers (Ménard and Valceschini, 2005). Procurement contracts typically comprise a framework agreement established for 1–2 years and subsequent orders. The framework agreement sets out general conditions, especially pertaining to product quality. For a supplier, signing the framework agreement with a retailer means being “listed”, providing the opportunity (though not a guarantee) to receive orders throughout the framework agreement’s duration (Barathova et al., 2020). The structure of the procurement contract gives the retailer significant negotiation leverage, namely, the (implicit) threat of “delisting”, i.e. making the supplier lose all future orders from the retailer (Caprice and Rey, 2015). This threat serves to mitigate opportunistic behaviour, such as delivering low-quality products.

² The principal-agent model assigns all bargaining power to the principal, reflecting the powerful position of large-scale food retailers. These retailers can essentially dictate contract terms due to the presence of numerous suppliers eager to gain market access (Hingley, 2001).

³ Enforcing restitution for opportunistic behaviour in court through fines and liabilities is challenging and costly for the retailer. Determining whether a restitution payment is justified and, if so, the appropriate amount is a complex process. The difficulty in establishing fault in civil liability claims adds a layer of uncertainty, which hinders immediate and decisive retaliation (Boyer and Porrini, 2002; Hobbs, 2006).

setting, the retailer faces the problem of contracting with inefficient suppliers who, even when facing the threat of being delisted, lack sufficient incentives to deliver a quality product. Finally, we assume that suppliers in GI regions have the option to acquire GI certification by incurring a sunk cost and that, while the retailer cannot observe individual suppliers’ production costs, a supplier’s GI certification status, size, and location (the latter two being exogenously given) are observable.

We establish an equilibrium where the retailer offers optimal take-it-or-leave-it contracts with payment terms that are specific to suppliers’ observed characteristics (certification status, size, location). In this equilibrium, optimal contracts are such that more efficient suppliers within the lower range of production costs find it profitable to acquire GI certification and accept the retailer’s take-it-or-leave-it contract. Thus, by contracting with any GI-certified supplier, the retailer is assured of receiving a quality product. Further, since only suppliers in this lower cost range acquire GI certification, the retailer can more accurately predict the production costs of “non-adopters” – those suppliers eligible for GI certification based on their location who choose not to certify. This informational gain enables the retailer to adjust take-it-or-leave-it offers for non-adopters, thereby reducing the likelihood of them delivering low-quality goods. Under the assumptions that GI certification is profitable at least for some producers from GI regions and that some non-adopters deliver a quality product when offered the optimal contracts, the model yields two key results concerning retailer profits: (i) profits are highest when contracting with GI-certified suppliers (for any given size), and (ii) for a given certification status, profits are larger when contracting with larger suppliers compared to smaller ones.

The second contribution of this study is empirical and adds to the scarce literature on incentive alignment and coordination in agri-food supply chains (Norrman and Naslund, 2019). We address RQ 2 by exploring evidence on the access of GI-certified and non-certified suppliers to large-scale retailers within the context of the German food craft sector that is in line with the two results derived from the theoretical model. This sector is particularly suitable for our investigation due to its significant role in the German food production landscape (the food craft sector comprises over 20,000 firms with a total sales value of 41.6 billion Euros in 2021, see Bundesministerium für Ernährung und Landwirtschaft, 2023), the prevalence of registered GIs covering various food craft products (62 products within this sector have a registered GI in the EU) and its structural conditions conducive to large bargaining power imbalances. For instance, 95% of these firms had a turnover of less than 5 million Euros in 2020, underscoring the predominance of small-sized enterprises within the food craft sector (ifo Institute, 2020). In contrast, the German food retail sector is highly concentrated, with the four largest retailers commanding a combined market share of 96% (Hernandez et al., 2023).

We analyse survey data from 476 German small- and medium-sized food craft producers. We estimate a system of two structural equations that captures how the decisions of both the retailer and supplier jointly determine the occurrence of transactions between them and the adoption of GI certification by the supplier. The first equation models retailer profits from a transaction with a supplier as a latent variable linearly dependent on supplier characteristics, certification status and size, with the supplier’s certification status being endogenous in the retailer equation. For any given supplier, we observe whether a transaction with a retailer occurs. This observation reflects the retailer’s decision to offer an optimised contract that the supplier accepts and serves as the discrete independent variable in our retailer equation. The second equation models suppliers’ profits from acquiring GI certification as a latent variable linearly dependent on their costs and benefits associated with certification. The certification status serves as the discrete independent variable in our supplier equation. As the costs and benefits associated with GI certification appear only in the supplier equation, they operate as a shifter in the retailer equation and allow

its identification and estimation through an instrumental variable (IV) approach (Wooldridge, 2010).

Consistent with the interpretation of retailer profits being a latent variable that determines whether a transaction between a retailer and a supplier takes place or not, our theoretical results yield two testable hypotheses: All else equal, (i) GI certification and (ii) supplier size increase the probability of a supplier transacting with a retailer. Across different settings, our empirical results allow us to reject the alternative hypotheses to (i) and (ii) at strong significance levels. Our preferred setting indicates that GI-certified suppliers are, on average, 42% more likely to transact with a retailer than non-certified suppliers, and medium-sized suppliers are, on average, 12.6% more likely to transact with a retailer than small-sized suppliers. Finally, the robustness of these results is further underscored by a propensity score matching (PSM) analysis.

The rest of the paper is organised as follows. We review the relevant literature in Section 2. In Section 3, we outline the model and derive the impact of GI certification on the coordination of agri-food supply chains. In Section 4, we define the empirical strategy and present results. In Section 5, we conclude.

2. Literature review

The economic literature on GIs is extensive, and we refer readers to the recent comprehensive review by Menapace and Moschini (2024). Here, we limit ourselves to summarising key contributions, including theoretical approaches and empirical studies involving quantitative analysis, to position our work within the existing literature on GIs and highlight how our contribution addresses existing gaps.

The economic rationale for GIs in the existing theoretical literature pertains to addressing market failures caused by asymmetric information. GIs serve a dual role: providing information to consumers and incentivising producers to supply high-quality goods. From a modelling perspective, GIs have been analysed within microeconomic models with a vertical product differentiation demand structure (e.g. Mussa and Rosen, 1978), under the assumption that GI products possess superior quality features of interest to consumers compared to generic products. These quality attributes are linked to geographic origin and/or specialised craftsmanship specific to certain regions. Importantly, consumers cannot ascertain the quality of goods through inspection prior to purchase, known as experience attributes (Nelson, 1970). On the production side, the presumption is that producing GI products, being of higher quality, is more costly than producing generic alternatives. This is captured by the higher variable costs associated with producing quality products, a feature also present in our model. These demand and supply conditions make the market ripe for failures à la Akerlof (1978), where too little quality is provided in the market.

In this context, GIs, understood as indications that identify geographically differentiated goods, are modelled as instruments that enable producers to credibly signal the quality of their products to consumers. GIs share similarities with trademarks, which are the chief instruments used by firms for brand development and reputation building. Like trademarks, and as a form of intellectual property, GIs are protected from unauthorised use by imitators or unauthorised producers (i.e. those who do not meet the specified qualities). However, they differ from trademarks in several respects. Notably, compliance with product quality specifications is verified through third-party monitoring rather than through the reputation mechanism of private brands (e.g. Shapiro, 1983). In other words, inspection activities are an established feature of GIs and are the responsibility of a third-party inspection body for GIs, ensuring that quality is met (see, e.g. Moschini et al., 2008; Deconinck and Swinnen, 2021).

Another critical difference is that GIs, unlike brands, are not privately owned and can be used by many producers simultaneously. This, combined with the fragmented production structure that typically characterises GI production, departs from the classical interpretation of

property rights leading to market power. Instead, the prevailing interpretation views GI markets as populated by autonomous producers who act as price-takers, with free entry being a fundamental characteristic. This assumption reflects the fact that any producer is entitled to use GI certifications as long as they adhere to the product specifications set by the GI and produce within the designated geographic area. Such models are characterised by price-taking behaviour on both the buyer and supplier sides (e.g. Moschini et al., 2008; Mérel and Sexton, 2012; Yu et al., 2018; Deconinck and Swinnen, 2021).

Our approach departs significantly from existing models by focusing on asymmetries of information upstream in the supply chain, particularly involving retailers (intermediaries). In contrast to consumers, the food retail sector is populated by powerful entities such as large-scale food retailer chains, which exert substantial bargaining power over suppliers. At this junction of the supply chain, the asymmetry of information also centres around product quality, but, more specifically, food retailers cannot observe the suppliers' costs of producing high-quality goods. This private information held by suppliers determines their incentives to either compromise on quality (shirk) or uphold the required quality standards (comply) demanded by powerful buyers.

To capture the dynamics of these business relationships, where powerful retailers interact with less powerful suppliers, we depart from the models prevalent in prior GI literature, where many firms operate as price-takers. Instead, we adopt a principal-agent model that explicitly addresses the imbalance in bargaining power between buyers and sellers. In this framework, we employ a signalling model – a game setting where signalling entails the informed agent (the supplier) sending a costly signal (such as a certification decision) to inform the uninformed agent (the retailer) about its type (efficiency in producing high quality). Signalling models are structured so that the informed party (the signaller) takes actions to convey information about itself to influence the actions of the uninformed party (the receiver). Effective signalling occurs when the signaller benefits from the receiver's response, often resulting in preferential selection or improved profitability (Connelly et al., 2011). The effectiveness of signalling hinges on the signal being sufficiently costly, a concept in signalling theory indicating that some signallers are better suited to bear the associated costs, thereby distinguishing themselves effectively from those who do not use such signals (Spence, 1978).

While the empirical literature on GIs is extensive, few quantitative studies specifically examine firm-level GI adoption and its implications for supply chains. Bouamra-Mechemache and Chaaban (2010) and Bontemps et al. (2013) analyse data from the French dairy sector. The former investigates cost disparities between GI-certified and non-certified firms, focusing on PDO Brie, highlighting a 40% average increase in production costs due to raw material expenses. They also observe that PDO adoption decreases as the cost differential between PDO and non-PDO varieties widens. The latter study finds that GI certification enhances survival rates for French dairy firms, although the effect is less pronounced than that of firm size. Like our study, these authors employ propensity score matching to mitigate selection biases inherent in endogenous GI certification decisions.

López-Bayón et al. (2018) is the sole study known to us that explores the role of GIs in horizontal supply chain coordination, focusing on cooperatives and investor-owned firms in the Spanish wine sector. Their findings suggest that stricter GIs improve quality, measured by Robert Parker's ratings, thereby reducing free-riding behaviours among cooperative members. They address selection bias arising from governance choices using a Heckman-like two-step procedure but do not account for potential endogeneity in GI certification decisions. In contrast, our research investigates the potential of GIs for vertical coordination within supply chains, offering a complementary perspective to their focus on horizontal coordination.

3. A model of coordination and GI certification

In this section, we develop a theoretical model of supply-chain coordination with GI certification and derive the main theoretical results. Specifically, in Section 3.1, we delineate the model assumptions, the timing of actions and the supplier and retailer profit functions. In Section 3.2, we solve the theoretical model and derive the equilibrium transfers the retailer offers to suppliers of different sizes and certification statuses. In Section 3.3, we derive the coordination effect of GI certification and the retailer's profits from transacting with suppliers of different sizes and certification statuses, which underpins our empirical analysis.

3.1. Setup

Main assumptions. A retailer (her) aims to contract several suppliers (him) who, if the retailer places an order, produce a good that the retailer sells to final customers. Suppliers decide whether to produce a quality good or a good of low quality. Product quality is not observable to the retailer at the time of ordering. The retailer can sell any quantity of the quality good at price p ; however, revenue from any low-quality product is zero. We assume that p depends only on the quality of the product and not on its GI certification status.⁴

For each order, the supplier produces one unit. The production cost of low quality is normalised to zero for all suppliers, while suppliers are assumed to be heterogeneous regarding the costs c of producing a quality good. The production costs c are distributed uniformly as $c \sim U(\underline{c}_i, \bar{c}_i)$, which we assume to be common knowledge.⁵ The retailer cannot observe an individual supplier's production costs, creating an information asymmetry between suppliers and the retailer. This asymmetry is a crucial element of our model that motivates the need for a coordination mechanism.

A supplier's size can be large or small, $i \in \{l, s\}$, and is observable by the retailer. We assume that the expected value of the production costs for the quality good c is lower for large suppliers than for small ones. This assumption reflects the stylised fact that, on average, larger agri-food firms can produce quality goods at a lower cost due to their expertise and economies of scope (Baldwin et al., 2002; Lentz and Mortensen, 2008; Özer and Raz, 2011; Hsieh and Klenow, 2014), while accounting for the possibility that certain smaller suppliers may have lower production costs than some larger suppliers.⁶ Supplier location

⁴ Our assumption that price p depends solely on the product's quality implies that any price premium over a low-quality product reflects a preference for quality rather than the certification status itself. This perspective is supported by studies such as Castriota and Delmastro (2015) and Deselnicu et al. (2013), which demonstrate that collective reputation and price premiums of certification schemes increase with the stringency of associated quality standards. With this assumption, we maintain a neutral stance on consumer preferences, focusing on their preference for quality rather than assuming consumers are willing to pay additional premiums for GI products beyond those justified by product quality alone. However, our findings remain robust to this assumption; in fact, introducing a price premium for GI products extends the coordination effect of GI certification we identify in our theoretical model.

⁵ It is important to note that different values of c do not imply that firms are producing products of differing qualities but capture the varying efficiency of individual suppliers in producing a quality good. This holds both for GI-certified and non-certified quality goods. It is also possible that producers from GI regions benefit from a cost advantage in producing quality goods, a scenario in which the coordination effect of GI certification we identify in our theoretical model is extended.

⁶ Note that the supplier's size pertains to the scale of the operation, e.g. a company being a medium vs. a small enterprise, not the amount of the quality product ordered by the retailer, which is normalised to 1 for each supplier. These assumptions match the stylised facts of the food craft sector that we analyse empirically in Section 4, maintaining tractability. The sample

is exogenously determined and fixed, meaning suppliers in GI areas can acquire GI certification while those outside cannot. Acquiring certification in GI areas requires incurring a sunk cost c^{GI} . This cost encompasses expenditures such as time and effort to acquire the relevant information about the certification process, consultancy fees, and infrastructure modifications to meet production standards. These costs are a well-documented feature in the literature on quality certification in general and on GI certification in particular (e.g. see Swinnen, 2015; Hofmeier et al., 2023 and references therein).

Based on observable characteristics, the retailer categorises suppliers into three certification statuses for each size i : suppliers from a GI region who acquire certification ("GI-certified suppliers"), suppliers from a GI region who do not acquire certification ("non-adopters"), and non-certified suppliers without the option to certify ("non-eligible suppliers"). For each supplier category, the retailer establishes a take-it-or-leave-it framework agreement (hereafter contract) for the production of a quality good, specifying type- and size-specific transfers for each order: t_i^{GI} , t_i^{GI} , and t_i for GI-certified suppliers, non-adopters, and non-eligible suppliers, respectively. These transfers are fixed for the duration of the contract, which allows for up to two orders, with payment occurring upon each order. Suppliers who deliver a high-quality good (those who "comply") receive a second order. Suppliers who deliver a low-quality good (those who "shirk") do not receive a second order, thereby forfeiting further transfers.⁷

To capture the fact that suppliers cannot easily adapt their production methods during the relatively short period covered by the contract, we assume that suppliers' decisions on whether to comply and produce a quality product are made before delivering the first order and remain unchanged throughout the period covered by the contract. Further, for simplicity, we ignore the issue of time discounting.

All suppliers also have the outside option of selling on a spot market. Non-eligible suppliers and non-adopters earn a price normalised to zero, while GI-certified suppliers earn a price premium that allows them to recover the costs associated with producing a GI-certified quality good. Consequently, all suppliers make zero profits on the spot market.

Consistently with Addor and Grazioli (2002), Bramley et al. (2009), and Barham and Sylvander (2011), we assume the existence of effective third-party monitoring that prevents shirking by GI-certified suppliers. Hence, GI-certified suppliers who accept the contract will also comply.

Timing. Events unfold as follows:

1. Nature determines size, location (GI region or not), and production costs of individual suppliers.
2. Suppliers from GI regions decide whether to certify.
3. Retailer offers take-it-or-leave-it contracts including a first order, and pays the first transfers.
4. GI-certified suppliers decide whether to accept or decline the contract; non-adopters and non-eligible suppliers decide whether to produce a quality good for the duration of the contract ("comply") or to produce a good of low quality ("shirk").
5. Shirking is detected. Complying suppliers receive a second order and transfer and produce a quality product.

comprises companies, such as bakeries, that are either micro-, small-, or medium-sized enterprises. Any such company produces many products, but only one or a few might be delivered to a retailer. Similarly, most likely, only a subset of such a company's products are covered by GI certification. For example, a bakery in the Nuremberg area might have "Nuremberg Gingerbread" as its only GI product.

⁷ Modelling a contract with up to two orders is sufficient to capture the contractual feature that enables the retailer to penalise a supplier for delivering low quality by withholding the second order, while also keeping the model tractable.

Supplier profits. A non-eligible supplier's profits, $\pi_{i,S}(t_i)$, are:

$$\pi_{i,S}(t_i) = \begin{cases} 2(t_i - c) & \text{if non-eligible supplier complies,} \\ t_i & \text{if non-eligible supplier shirks,} \\ 0 & \text{outside option.} \end{cases}$$

A non-eligible supplier's incentive compatibility (IC) constraint, i.e. complying being more profitable for the supplier than shirking, is given by $2(t_i - c) \geq t_i$, i.e. by $t_i \geq 2c$. The individual rationality (IR) constraint, i.e. accepting the contract and complying being at least as profitable as the outside option, is given by $2(t_i - c) \geq 0$, i.e. by $t_i \geq c$.

A non-adopter's profits, $\pi_{i,S}(\bar{t}_i^{GI})$, are:

$$\pi_{i,S}(\bar{t}_i^{GI}) = \begin{cases} 2(\bar{t}_i^{GI} - c) & \text{if non-adopter complies,} \\ \bar{t}_i^{GI} & \text{if non-adopter shirks,} \\ 0 & \text{outside option.} \end{cases}$$

A non-adopter's IC and IR constraints are given by $\bar{t}_i^{GI} \geq 2c$ and $\bar{t}_i^{GI} \geq c$, respectively.

A GI-certified supplier's profits, $\pi_{i,S}^{GI}(t_i^{GI})$, are:

$$\pi_{i,S}^{GI}(t_i^{GI}) = \begin{cases} 2(t_i^{GI} - c) - c^{GI} & \text{if GI-certified supplier accepts,} \\ -c^{GI} & \text{if GI-certified supplier declines,} \\ 0 & \text{outside option,} \end{cases}$$

with $c^{GI} > 0$ the sunk costs incurred when acquiring GI certification. A GI-certified supplier's IC and IR constraints are given by $t_i^{GI} \geq c$ and $t_i^{GI} \geq c + c^{GI}/2$, respectively.

For non-eligible suppliers and non-adopters, the IC constraints are the binding constraints. For GI-certified suppliers, the IR constraint is the binding constraint.

Certification decision. The certification decision of suppliers in a GI region involves comparing the profits from certifying versus not certifying, conditional on the respective IC and IR constraints. Specifically, a supplier in a GI area evaluates the profits from certifying and accepting the contract against the profits from not certifying and complying. Formally, suppliers certify if $\pi_{i,S}^{GI}(t_i^{GI})|_{accept} \geq \pi_{i,S}(\bar{t}_i^{GI})|_{comply}$ holds, implying the following condition on the size of the transfers:

$$t_i^{GI} \geq \bar{t}_i^{GI} + \frac{1}{2}c^{GI}. \tag{1}$$

Retailer profits. Retailer profits from transacting with a non-eligible supplier of size i , $\pi_R(t_i)$, are:

$$\pi_R(t_i) = \begin{cases} 2(p - t_i) & \text{if non-eligible supplier complies,} \\ -t_i & \text{if non-eligible supplier shirks.} \end{cases}$$

Retailer profits from transacting with a non-adopter of size i , $\pi_R(\bar{t}_i^{GI})$ are:

$$\pi_R(\bar{t}_i^{GI}) = \begin{cases} 2(p - \bar{t}_i^{GI}) & \text{if non-adopter complies,} \\ -\bar{t}_i^{GI} & \text{if non-adopter shirks.} \end{cases}$$

Retailer profits from transacting with a GI-certified supplier of size i , $\pi_R^{GI}(t_i^{GI})$, are:

$$\pi_R^{GI}(t_i^{GI}) = \begin{cases} 2(p - t_i^{GI}) & \text{if GI-certified supplier accepts,} \\ 0 & \text{if GI-certified supplier declines.} \end{cases}$$

3.2. Equilibrium outcomes

Benchmark scenario. To fix ideas, we present the outcome in the absence of information asymmetries about suppliers' production costs, which motivated the analysis of GI certification as a coordination mechanism. Under the assumption that suppliers' production costs are public information, the retailer maximises her profits by offering each supplier a transfer that just fulfils his IC constraint (non-eligible suppliers and non-adopters) or IR constraint (GI-certified suppliers), thereby capturing all the profits. The corresponding transfers are:

$$t_i^* = \bar{t}_i^{GI*} = 2c, \quad t_i^{GI*} = c + \frac{1}{2}c^{GI}.$$

Two cases emerge: First, for $c^{GI} < 2c$, condition (1) does not hold, and so no supplier would find it profitable to certify. Second, for $c^{GI} \geq 2c$ we would have $t_i^{GI*} \geq t_i^* = \bar{t}_i^{GI*}$ and, consequently, for given production costs c , the transfer required by the retailer to induce a GI-certified supplier to accept the contract would be larger or equal to the transfers needed to motivate non-eligible suppliers or non-adopters to produce a quality good. The retailer would either be indifferent between transacting with suppliers of either certification status or prefer non-adopters and non-eligible suppliers over GI-certified suppliers. Hence, we conclude that in the absence of information asymmetries about suppliers' production costs, there is no scope for GI certification to add to the coordination of the supply chain.

Scenario with information asymmetry about production costs. When suppliers' production costs are unobservable to the retailer, she offers transfers based on the observable characteristics, i.e. size and certification status. The information asymmetry creates a trade-off for the retailer between offering a lower transfer (thus reducing the cost of procuring one unit) and reducing the probability of compliance (for non-certified suppliers) or acceptance of the contract (for GI-certified suppliers).

Non-eligible suppliers comply if $t_i \geq 2c$, while production costs are uniformly distributed on the interval $c \in [c_i, \bar{c}_i]$. Consequently, the probability of compliance for a randomly selected non-eligible supplier of size i offered a transfer t_i is:

$$\lambda(t_i) = \frac{t_i - 2c_i}{2(\bar{c}_i - c_i)}.$$

Given that GI certification obliges suppliers to comply once they accept a contract, only the most efficient suppliers – those capable of covering both sunk costs c^{GI} and production costs c over both periods – choose to acquire certification. We define the threshold production cost below which suppliers acquire certification, and above which they do not, as the certification threshold c_i^c . Thus, the distribution of production costs for GI-certified suppliers is $c \in [c_i^c, c_i^c]$, while for non-adopters, it is $c \in (c_i^c, \bar{c}_i^c]$.

GI-certified suppliers accept the contract if $t_i^{GI} \geq c + c^{GI}/2$. The probability of acceptance for a randomly selected GI-certified supplier of size i when offered a transfer t_i^{GI} is:

$$\lambda^{GI}(t_i^{GI}) = \frac{2t_i^{GI} - c^{GI} - 2c_i}{2(c_i^c - c_i)}.$$

Non-adopters comply if $\bar{t}_i^{GI} \geq 2c$. The probability of compliance for a randomly selected non-adopter of size i when offered a transfer \bar{t}_i^{GI} is:

$$\bar{\lambda}(\bar{t}_i^{GI}) = \frac{\bar{t}_i^{GI} - 2c_i^c}{2(\bar{c}_i - c_i^c)}.$$

The retailer's maximisation problems under information asymmetry are:

$$\max_{t_i^{GI}} \pi_R^{GI}(t_i^{GI}) = \lambda^{GI}(t_i^{GI})2(p - t_i^{GI}),$$

$$\max_{\bar{t}_i^{GI}} \pi_R(\bar{t}_i^{GI}) = \bar{\lambda}(\bar{t}_i^{GI})2(p - \bar{t}_i^{GI}) + [1 - \bar{\lambda}(\bar{t}_i^{GI})](-\bar{t}_i^{GI}),$$

$$\max_{t_i} \pi_R(t_i) = \lambda(t_i)2(p - t_i) + [1 - \lambda(t_i)](-t_i).$$

The retailer's profit maximisation and the GI certification condition (1) yield the equilibrium transfers and the equilibrium certification threshold $c_i^{c^*}$ as follows:

$$t_i^* = 2c_i - \bar{c}_i + p, \quad t_i^{GI*} = \frac{1}{2}(c_i + p) + \frac{1}{4}c^{GI}, \quad t_i^{-GI*} = \frac{1}{2}(c_i + p) - \frac{1}{4}c^{GI}, \quad (2)$$

$$c_i^{c^*} = \frac{1}{2}\bar{c}_i + \frac{1}{4}(c_i - p) - \frac{1}{8}c^{GI}, \quad (3)$$

where (3) implies that, in equilibrium, all suppliers in GI regions with production costs $c \leq c_i^{c^*}$ certify.

3.3. The coordination effect of GI certification and retailer preferences over suppliers of different certification statuses and sizes

Parameter restrictions. To formally derive the coordination effect of GI certification, we need first to restrict parameter values to rule out irrelevant cases. To this end, note that the IC constraint of non-adopters of size i ($\bar{t}_i^{GI} < 2c$), combined with the optimal transfer \bar{t}_i^{GI*} in (2), yields the shirking threshold in GI regions, $c_i^{s,GI}$:

$$c_i^{s,GI} = \frac{1}{4}(c_i + p) - \frac{1}{8}c^{GI}, \quad (4)$$

where all non-adopters from GI regions of size i with $c > c_i^{s,GI}$ shirk. We focus on the case where $c_i^{s,GI} > c_i^{c^*}$, meaning that suppliers from GI regions are split into three groups, i.e. those who certify ($c \in [c_i, c_i^c]$), those who do not certify and comply ($c \in (c_i^c, c_i^{s,GI}]$), and those who do not certify and shirk ($c \in (c_i^{s,GI}, \bar{c}_i)$). That is, we assume $p > \bar{c}_i$.⁸ Further, we assume $c_i^c \geq c_i$ to ensure that certification is profitable for at least some suppliers of size i , which, given (3), can be rewritten as $p \leq 2\bar{c}_i - 3c_i - c^{GI}/2$.

To summarise, we restrict p to lie within the following interval:

$$p \in \left(\bar{c}_i, 2\bar{c}_i - 3c_i - \frac{1}{2}c^{GI} \right], \quad (5)$$

which we will refer to as the “feasible set” of our parameters of interest.

The coordination effect of GI certification. Recall that coordination is understood as the outcome of a mechanism that improves the overall performance of the supply chain compared to a default situation. In our case, the mechanism is GI certification, and the outcome of interest is the market provision of quality goods, which can also be seen as the increase in the likelihood of complying behaviour. As we demonstrate below, GI certification increases complying beyond the level achieved by simply coordinating via procurements contract in two ways:

First, GI certification allows the retailer to select a supplier who complies with certainty. This result might seem trivial since, by assumption, a GI-certified supplier must comply. Nevertheless, this reasoning overlooks the fact that it must be an equilibrium result for a supplier to acquire GI certification and accept the contract offered by the retailer. To see why this is the case, recall first that for all suppliers in GI regions with $c \leq c_i^{c^*}$, it is profitable to certify. Further, a GI-certified supplier accepts a contract for $t_i^{GI} \geq c + c^{GI}/2$. This condition, together with the optimal transfer t_i^{GI*} in (2) yield the acceptance threshold for GI-certified suppliers, c_i^a , as:

$$c_i^a = \frac{1}{2}(c_i + p) - \frac{1}{4}c^{GI}, \quad (6)$$

where all GI-certified suppliers of size i with $c \leq c_i^a$ accept the contract. We conclude that the probability of accepting a contract given that a supplier of size i acquired certification is $\lambda^{GI}(t_i^{GI*}) = 1$, as, for all values of p in the feasible set, the acceptance threshold c_i^a lies above the certification threshold $c_i^{c^*}$.⁹ In comparison, without GI certification, a

⁸ For $p \leq \bar{c}_i$, we have $c_i^{s,GI} \leq c_i^c$, which would imply that all suppliers from GI regions of size i either certify (those with $c \leq c_i^c$) or shirk (those with $c > c_i^c$). This situation has little empirical relevance, as non-adopters would shirk with certainty and, consequently, the optimal transfer the retailer would offer is $t_i^{-GI*} = 0$.

⁹ Note that $c_i^a > c_i^{c^*}$ holds if $2c_i + 6p - 4\bar{c}_i - c^{GI} > 0$, i.e. if p lies within the feasible set. See Appendix A.1 for details.

retailer can only select a supplier randomly, leading to an equilibrium probability of compliance that is strictly lower than one (for details, see Appendix A.1).

Second, GI certification increases the range of values of c for compliance among non-adopters. To see why this is the case, recall that the shirking threshold in GI regions, $c_i^{s,GI}$, is given by (4), while the IC constraint of non-eligible suppliers ($t_i < 2c$) and the optimal transfer t_i^* in (2) yield the shirking threshold in non-GI regions, c_i^s , as:

$$c_i^s = c_i - \frac{1}{2}(\bar{c}_i - p),$$

where all non-eligible of size i with $c > c_i^s$ shirk. The shirking threshold in GI regions, $c_i^{s,GI}$, lies above the shirking threshold in non-GI regions, c_i^s .¹⁰ This result is illustrated graphically in Fig. 1. If offered a contract, all suppliers of size i from non-GI regions with production costs in the range $c \in (c_i^s, c_i^{s,GI}]$ shirk, while in GI areas, suppliers with these production costs comply despite not being GI-certified.

The mechanism behind this effect is an informational gain by the retailer, as the decision of non-adopters not to certify reveals that their production costs exceed the certification threshold, i.e. $c > c_i^c$ (otherwise, for $c \leq c_i^c$, they would acquire GI certification). Consequently, the range of production costs for non-adopters is narrower than that of non-eligible suppliers. In other words, GI certification reduces the information asymmetry between the retailer and non-adopters regarding the latter's production costs. This enables the retailer to optimally adjust offered transfers, ultimately limiting the shirking behaviour of non-adopters. The coordination effect of GI certification thus transcends the relationship between the retailer and GI-certified suppliers, as it extends to the relationship between the retailer and non-adopters.

Retailer profits by suppliers' certification statuses and sizes. Finally, we compare the equilibrium expected profits that the retailer obtains from transacting with a supplier of a given certification status and size. Without loss of generality, we normalise the lowest possible production cost to one, so that the production costs of large and small suppliers follow the uniform distributions $c_{i=l} \sim U(1, x)$ and $c_{i=s} \sim U(\beta, \beta x)$, respectively, thereby reducing the set of parameters to p , c^{GI} , β , and x (with $\beta \geq 1$, $x \geq 1$, and $\beta \leq x$). We then write the feasible set as defined in (5) as:

$$p \in \left(\beta x, 2x - 3 - \frac{1}{2}c^{GI} \right]. \quad (7)$$

Using parameter values within the feasible set defined in (7) and Monte-Carlo simulations yield two main results (see Appendices A.2 and A.3 for details).

Result 1. Given that $\beta > 1$, expected retailer profits from transacting with a GI-certified supplier of any size exceed those from transacting with a non-adopter and a non-eligible supplier of any size.

$$\pi_R^{GI}(t_i^{GI*}) > \pi_R^{-GI}(t_i^{-GI*}), \quad \pi_R^{GI}(t_i^{GI*}) > \pi_R(t_i^*), \quad \forall i \in \{l, s\}. \quad (8)$$

Result 2. For a given certification status, expected retailer profits from transacting with a larger supplier ($i = l$) exceed those from transacting with a smaller supplier ($i = s$):

$$\pi_R^{GI}(t_l^{GI*}) > \pi_R^{GI}(t_s^{GI*}), \quad \pi_R^{-GI}(t_l^{-GI*}) > \pi_R^{-GI}(t_s^{-GI*}), \quad \pi_R(t_l^*) > \pi_R(t_s^*). \quad (9)$$

4. Empirical estimation

Our empirical analysis focuses on the German food craft sector. Although there is no legal definition of the sector, practitioners generally consider it to encompass firms that utilise specialised knowledge or manual dexterity in producing food products across seven key sectors: bakery, butcher, confectioner, miller, brewer, cheese dairy, and

¹⁰ Note that $c_i^s \leq c_i^{s,GI}$ holds if $p \leq 2\bar{c}_i - 3c_i - c^{GI}/2$, i.e. if p lies within the feasible set.

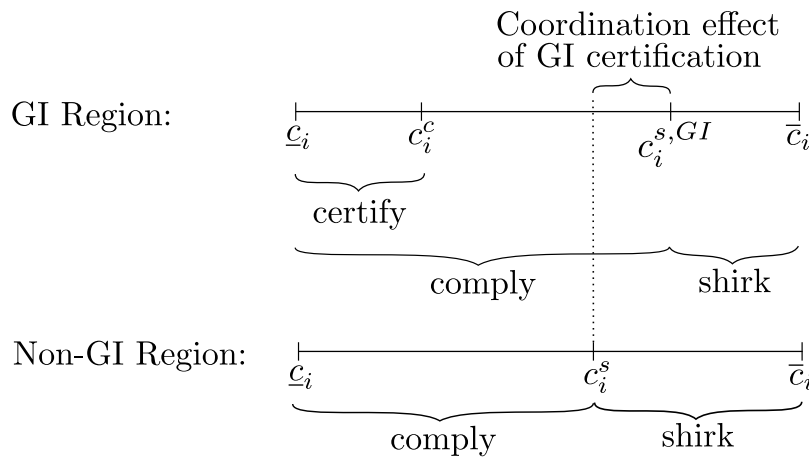


Fig. 1. Coordination effect of GI certification for non-adopters. In a “Non-GI Region”, suppliers with $c \in [c_i, c_i^s]$ comply, which represents the coordination effect of the procurement contract alone (in the absence of GI certification). In a “GI Region”, suppliers with $c \in [c_i, c_i^{s,GI}]$ comply, which represents the coordination effect of the procurement contract with GI certification. GI certification thus extends the highest value of production costs for which suppliers comply from c_i^s to $c_i^{s,GI}$.

winemaker, sectors that lend themselves well to the adoption of GI certification. Transacting with large retailer chains is a sought-after, albeit challenging, market outlet for agri-food suppliers (Hingley, 2001). These features correspond well to the characteristics of the theoretical framework outlined in Section 3.

The subsequent sections are organised as follows. We introduce our data and descriptive statistics in Section 4.1. Section 4.2 presents our econometric model and main estimation results, while Section 4.3 provides a PSM approach for robustness.

4.1. Data and descriptive statistics

Our dataset consists of survey data collected in 2020 through computer-assisted telephone interviews (CATI) with German food craft suppliers conducted by a professional market research company. Two criteria defining a food craft supplier were used to select interviewee participants. The first selection criterion was membership in one of the seven sectors that make up the food craft industry in Germany. Second, we focused on small- and medium-sized suppliers. These are - by definition - firms with fewer than 250 employees and sales revenues lower than 50 million euros (Commission of the European Union, 2003). Firms were randomly sampled from a list that included contact details on around 10,000 food craft suppliers in Germany using a stratified approach that accounts for food craft sectors and federal states. The sample comprises 476 suppliers. Descriptive statistics are reported in Table 1 and summarised next.

For each observation in the data, we know whether or not the supplier transacts with a large-scale retailer, which is the main information we use for our empirical analysis. Based on the nature of the business relationship between large-scale retailers and small-scale suppliers and the predictions of our model, we interpret such transactions as the result of the optimal behaviour of the retailer. This involves the retailer selecting the supplier and, taking into account the supplier’s optimal behaviour, offering a take-it-or-leave-it contract, which the supplier accepts. Overall, 4.41% of suppliers transact with a retailer. For suppliers, transacting with a retailer adds an additional market outlet to selling to private costumers in their own stores (95.4% of suppliers in our sample reported using this distribution channel), public institutions (14.9%), processors (14.3%), intermediaries (9.24%), or other market participants (5.25%).

We further observe the presence of a GI in the supplier’s location and sector of activity, as well as the supplier’s certification status and size. Concretely, of all suppliers in our sample, 33.19% would have the option to certify, while 7.35% actually acquired GI certification. Concerning the size of the operation, the large majority (86.56%) of

suppliers are micro- or small-sized enterprises. In our main analysis, we group micro- and small-sized suppliers and compare them to medium-sized suppliers.¹¹

Additionally, we have information on each supplier’s age, sector of activity, and location, along with a comprehensive set of data concerning perceived benefits and costs associated with GI certification. We categorise suppliers into four quartiles based on their age: lower than 30 years, between 30 and 64 years, between 65 and 100 years, and older than 100 years. The largest share of suppliers are bakeries or butchers, together accounting for 78.16% of observations (which reflects the composition of the food craft sector in Germany). While 19.96% of suppliers sell both in urban and rural areas, 43.49% of suppliers sell only in urban areas and 36.55% sell only in rural areas. 61.76% have their principal office located in West Germany.

In Figs. 2, 3 and 4, we plot the total number of observations per NUTS3 region, the number of suppliers transacting with a retailer per NUTS3 region, and the number of suppliers with GI certification per NUTS3 region, respectively. The figures show that our total set of observations is spread evenly across Germany and that there is no evident bunching of producers transacting with retailers or suppliers with GI certification at specific geographical regions.

4.2. Main estimation

Econometric model. Call $\Pi_{R,k}$ a bivariate variable capturing the transaction outcome observed in the data, where $\Pi_{R,k} = 1$ indicates that a retailer transacts with supplier k and $\Pi_{R,k} = 0$ otherwise. The transaction outcome depends on the underlying expected retailer’s profits from transacting with supplier k , denoted as $\Pi_{R,k}^*$, such that:

$$\Pi_{R,k} = \begin{cases} 1 & \text{if } \Pi_{R,k}^* > 0, \\ 0 & \text{otherwise,} \end{cases}$$

which implies that a transaction with supplier k takes place only if the expected profits are positive. As expected retailer’s profits are unobserved, we express them as a latent variable linear in covariates, as is consistent with our theoretical model:

$$\Pi_{R,k}^* = \beta' X_k + u_k,$$

where $\beta' X_k$ represents the systemic portion of the profit function determined by the observable attributes of supplier k identified in

¹¹ In Appendix A.4, we perform a robustness check in which we estimate our model including three size categories (i.e. comparing small- and medium-sized suppliers individually to micro-sized suppliers).

Table 1
Descriptive statistics of firms in the sample ($N = 476$).

Variable	Count	% of total	% of "Variable" with GI label	% of "Variable" transacting with retailer
Transacting with retailer	21	4.41	42.86	100
GI Label	35	7.35	100	25.71
GI Option	158	33.19	22.15	8.23
# employees < 10 (micro-sized)	203	42.65	3.94	1.48
# employees ∈ [10, 49] (small-sized)	209	43.91	8.13	2.87
# employees ∈ [50, 249] (medium-sized)	64	13.45	15.63	18.75
Firm age < 30	120	25.21	3.33	2.50
Firm age ∈ [30, 64]	118	24.79	6.78	1.69
Firm age ∈ [65, 100]	119	25	9.24	2.52
Firm age > 100	119	25	10.08	10.92
Bakery	184	38.66	8.7	3.26
Butcher	188	39.50	6.91	2.66
Confectioner	55	11.55	3.64	3.64
Miller	13	2.73	0	38.46
Brewer	13	2.73	23.08	7.69
Cheese dairy	13	2.73	0	15.38
Winemaker	10	2.10	10	0
Sales region: urban	207	43.49	5.80	3.38
Sales region: rural	174	36.55	5.75	2.30
Sales region: both	95	19.96	13.68	10.53
Principal office: West Germany	294	61.76	6.12	3.74
Principal office: East Germany	182	38.24	9.34	5.49

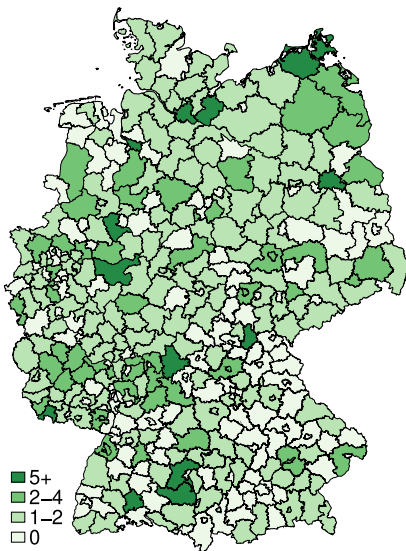


Fig. 2. Total number of suppliers per NUTS3 region.

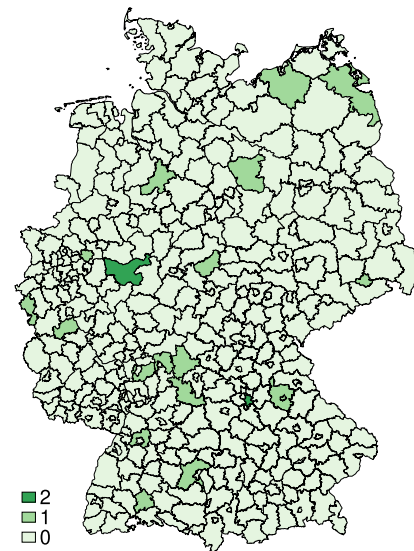


Fig. 3. Number of suppliers transacting with a retailer per NUTS3 region.

Section 3.3 (i.e. certification status and size) and other observables. u_k is a stochastic term that captures features of the supplier that are unobserved by the analyst. We thus estimate the following linear probability model (LPM):

$$P(\Pi_{R,k} = 1 | X_k) = \beta_0 + \beta_1 GI_k + \beta_2 Medium_k + \beta_3 GIOption_k + \gamma' C_k + u_k. \quad (10)$$

GI_k and $Medium_k$ are dummies indicating whether supplier k is GI-certified and whether the supplier is medium-sized (i.e. as opposed to micro- or small-sized), respectively. The corresponding parameters β_1 and β_2 capture whether, holding all other independent variables fixed, GI certification and size increase the probability of a transaction with supplier k by increasing the retailer's expected profits. Based on Results 1 and 2, respectively, we derive and empirically test the following hypotheses:

$$H_0^1 : \beta_1 \leq 0; \text{ against } H_1^1 : \beta_1 > 0, \text{ and} \quad (11)$$

$$H_0^2 : \beta_2 \leq 0; \text{ against } H_1^2 : \beta_2 > 0. \quad (12)$$

$GIOption_k$ in (10) is a dummy variable indicating whether GI certification is available for supplier k . This variable allows us to control for systematic differences among regions where certification is available and those where it is not, which could potentially affect the probability that a retailer transacts with suppliers from a given region. We acknowledge the potential collinearity problem that the inclusion of $GIOption_k$ might cause, a problem that we address by estimating a second model limited to only the subsample of suppliers who have the option to certify (see the second and fourth columns of Table 3 titled "GI Region"). C_k is a vector of controls consisting of age category dummies (younger than 30 years, between 30 and 64 years, between 65 and 100 years, older than 100 years), industry dummies (bakery, butcher, confectioner, miller, brewer, cheese dairy, winemaker), sales region dummies (rural, urban, or both), and a dummy indicating whether a

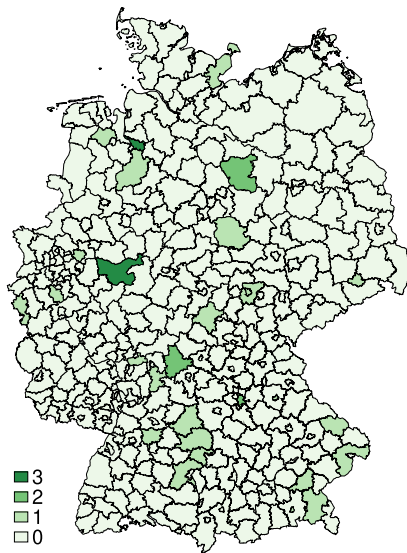


Fig. 4. Number of suppliers with GI certification per NUTS3 region.

supplier is located in West Germany. Finally, u_k is a random error term capturing the unobservable attributes of supplier k .

To control for the endogenous nature of GI_k in (10), we specify the suppliers' decisions to acquire GI certification as follows:¹²

$$GI_k = \begin{cases} 1 & \text{if } \Pi_k^{GI*} > 0, \\ 0 & \text{otherwise,} \end{cases}$$

where $\Pi_k^{GI*} = \alpha'X_k + \eta'B_k + \theta'K_k + \varepsilon_k$ represents supplier k 's profits when acquiring GI certification, with X_k being the same attributes as in (10), B_k (K_k) representing a vector of supplier k 's perceived benefits (costs) of GI certification, and ε_k being an unobservable component. $GI_k = 1$ reflects that supplier k acquired GI certification, while $GI_k = 0$ reflects that the supplier did not. We estimate the probability that a supplier acquires GI certification as follows:

$$P(GI_k = 1 | X_k, B_k, K_k) = \alpha_0 + \alpha_1 GI_{Option_k} + \alpha_2 Medium_k + \delta' C_k + \eta' B_k + \theta' K_k + \varepsilon_k. \tag{13}$$

In summary, our empirical model, consisting of Eqs. (10) and (13), forms a simultaneous equations model (SEM) (Wooldridge, 2015) that captures the decisions of two autonomous profit maximisers: the retailer's decision to transact with a given supplier and the supplier's decision to acquire GI certification.

Finally, while acknowledging the limitations of an LPM, we note that this approach is well suited to approximate partial effects of the explanatory variables (allowing us to test H_0^1 and H_0^2) when the explanatory variables are discrete and (partly) endogenous, and hence a logit model is not applicable (Angrist and Pischke, 2009; Wooldridge, 2010).

Exclusion restriction and identification. Two-stage least squares (2SLS) is a consistent and asymptotically normal estimator of the equation of interest in an SEM, provided the equation is correctly specified, and the excluded variables are exogenous (Wooldridge, 2010). In our specification of the SEM, the equation of interest is (10), and the exogenous variables are the suppliers' (perceived) benefits and costs

¹² Note that the results of Durbin-Wu-Hausman tests support the treatment of GI_k as an endogenous variable. In the full sample and in the subsample restricted to suppliers having the option to certify, we can reject the Null hypothesis that GI_k is exogenous at the 5% (p -value 0.012) and at the 10% (p -value 0.089) level, respectively.

of acquiring GI certification. It is reasonable to assume that these variables influence a supplier's decision to acquire GI certification but do not directly impact a retailer's decision of whether to transact with a particular supplier. In essence, the benefits and costs of acquiring GI certification as perceived by suppliers function as instruments for Eq. (10).

Suppliers' perceived benefits and costs of acquiring (or having acquired) certification were assessed using Likert scale questions ranging from 1 (completely agree/very high) to 5 (completely disagree/very low). Dummy variables were created to take a value of 1 if suppliers indicated complete agreement or agreement (choosing very high or high), and 0 otherwise.¹³ Concretely, suppliers were asked (i) how high the economic benefits of GI certification are (would be) for their firm, (ii) whether GI certification helps (would help) to signal high quality of their products to customers, (iii) how high the fixed costs of acquiring GI certification were (would be), and (iv) how high the variable costs of using GI certification are (would be). Answers to questions (i) and (ii) constitute the (perceived) benefits of GI certification (vector B_k in (13)), while (iii) and (iv) represent the (perceived) costs of GI certification from the point of view of suppliers (vector K_k in (13)).

As the SEM has more instruments than endogenous variables and passes the rank condition (see Table 2), our equation of interest (10) is identified.

Quality of Instruments. A concern regarding the instruments is that they might not be truly exogenous. One reason could be that the decision of a retailer to transact or not to transact with a supplier also impacts the supplier's perception of the benefits and costs of GI certification. To address this issue, we use the fact that a higher number of instruments than endogenous variables allows us to perform a test of overidentification restrictions, where the Null hypothesis is that the instruments are exogenous. Performing an overidentification test robust to heteroscedasticity results in a χ^2 value of 1.700 (p -value of 0.637) for the full sample and a χ^2 value of 3.111 (p -value of 0.375) for the sample restricted to suppliers who have the option to certify, respectively (see Table 3). Thus, we cannot reject the Null hypothesis that our instruments are exogenous. However, this result does not exclude the possibility that (at least) one of our instruments is endogenous. This could be the case if the 2SLS estimators using a full and reduced set of instruments (which are compared to test for overidentifying restrictions) are asymptotically biased in similar ways. In essence, if all instruments were correlated with $\Pi_{R,k}$ in the same magnitude and sign, we might expect similar outcomes from the full and reduced sets of instruments, thus falsely causing the test not to reject the Null hypothesis (Wooldridge, 2010). In our case, it is arguably unlikely that we encounter such a situation as our instruments capturing benefits and costs of GI certification should be, if at all, correlated in opposing directions with $\Pi_{R,k}$.

Finally, we tested whether our set of instruments is sufficiently strong using the robust test for weak instruments developed by Olea and Pflueger (2013). The Null hypothesis is that the bias relative to OLS is above 10%. To reject the Null hypothesis at the 5% significance level, an effective F statistic of at least 17.178 (14.555) is needed for

¹³ Given the ordinal nature of our data, an alternative approach would involve including a dummy variable for each of the five possible Likert scale responses across four questions used as instruments. However, the resulting large number of variables would have impaired the precision of our estimates and the statistical power of our tests (Wooldridge, 2015; Greene, 2018). Note that comparing suppliers who strongly agree or agree to the rest seems a logical choice for the purpose of explaining GI certification adoption. Additionally, in Appendix A.4, we provide a robustness analysis using non-dichotomised instruments. Further, it is sometimes argued that parametric statistics are not appropriate for the use with Likert scale data due to their ordinal nature. We refer the reader to Norman (2010) and Willits et al. (2016), who demonstrate that parametric statistics are robust to violations of the assumptions of normality (as with ordinal data).

Table 2
Verification of rank conditions.

Endogenous coefficient matrix:		$\Pi_{R,k}$	GI_k								
$\Pi_{R,k}$		-1	0.5								
GI_k		0	-1								
Exogenous coefficient matrix:											
	GI Option	Medium	Age Category	Industry	Sales Region	West Germany	Econ. Benefit	Quality	Var. Costs	Fixed Costs	
$\Pi_{R,k}$	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	Identified
GI_k	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Identified

the full (restricted) sample. In our case, as reported in Table 3, the effective F statistics are 18.586 and 32.780 for the full sample and the restricted sample, respectively. For the latter case, we can also reject the Null hypothesis that the bias relative to OLS is above 5% at the 5% significance level.

To summarise, we cannot reject the hypotheses that our instruments are exogenous and relevant, meaning that we can engage in the estimation of the SEM via 2SLS with some confidence. One issue, however, remains. As noted by Wooldridge (2010), when there are more instruments than endogenous variables and heteroscedasticity exists in the error terms, a Generalised Methods of Moments (GMM) approach might offer greater efficiency than 2SLS estimation. To test for heteroscedasticity, we use the test developed by Pagan and Hall (1983). The test strongly rejects that the error term is homoscedastic (χ^2 value of 148.135 and p -value of 0.000 for the full sample and χ^2 value of 73.916 and p -value of 0.000 for the restricted sample), indicating the necessity of presenting GMM estimates as well. However, as cautioned by Hayashi (2011), the efficient GMM estimator may have limitations in small samples. Therefore, we provide estimates from both 2SLS and GMM approaches.

Estimation results. Estimation results for the 2SLS and GMM approaches for both samples (full sample and only firms in GI regions) are reported in Table 3. Note that in a setting with a binary endogenous variable and instrumental variables, 2SLS and GMM estimates of β_1 provide a local average treatment effect (LATE) of a supplier being GI-certified on the probability of transacting with a retailer (Imbens and Angrist, 1994).¹⁴

Using the 2SLS approach, the estimated coefficient for GI_k in the full sample is significant at the 1% level and suggests that suppliers who acquired certification are, on average, 42% more likely to transact with a retailer. Medium-sized suppliers are estimated to be, on average, 12.6% more likely to transact with a retailer than micro- and small-sized suppliers. The estimated coefficient for $GIOption_k$ is not statistically significant, suggesting that regions where GI certification is available are not substantially different from regions where this is not the case.

For the restricted sample (see column “GI region”), the estimated coefficient based on 2SLS for GI_k suggests that GI-certified suppliers are, on average, 29.8% more likely to transact with a retailer. The estimated coefficient for $Medium_k$ suggests that medium-sized suppliers in GI regions are 25.9% more likely to transact with a retailer than micro- and small-sized suppliers.

The GMM estimates suggest that, in the full (restricted) sample, GI-certified suppliers are, on average, 34.7% (19.9%) more likely to

¹⁴ In analogy to randomised controlled trials, suppliers who would always acquire GI certification independently of perceived costs and benefits (assuming certification availability for their product in their region) are termed always-takers. In contrast, those who would never acquire certification are termed never-takers. The estimated LATE does not provide information about always-takers and never-takers because, by definition, the treatment status (in this case, adoption of GI certification) is not influenced by the instruments (Angrist and Pischke, 2009). In other words, the identified “treatment effects” (i.e. the estimated coefficients for GI_k) represent average effects for suppliers who can potentially change their treatment status in response to changes in the instruments (Imbens and Angrist, 1994).

transact with a retailer than non-certified suppliers, while medium-sized suppliers are estimated to be, on average, 11.7% (22.8%) more likely to transact with a retailer than micro- and small-sized suppliers.

For both estimation approaches (2SLS and GMM) and samples (full sample and only firms in GI regions), the results displayed in Table 3 allow us to reject the Null hypotheses in (11) and (12) in favour of H_1^1 and H_1^2 , respectively. Hence we can conclude that, everything else equal, GI-certified (relative to non-certified) and medium-sized (relative to small- or micro-sized) suppliers are more likely to transact with a retailer.

4.3. Propensity score matching

We now address the endogeneity of the GI certification variable using propensity score matching (PSM). Similarly to the IV approach described above, PSM effectively treats the acquisition of GI certification as a “treatment”, where assignment to treatment is non-random (Angrist and Pischke, 2009). As IV and PSM methods rely on different information and assumptions, they provide complementary information on the causal relationship between the endogenous treatment variable (the acquisition of GI certification) and the dependent variable (transacting with a retailer) (DiPrete and Gangl, 2004). By presenting PSM results, we aim to demonstrate that our previous results are not driven by the assumptions particular to the setting of an SEM linear in covariates.

Using PSM, suppliers who acquired GI certification are matched with suppliers who did not, according to observables in the data (Rosenbaum and Rubin, 1983). The observables used for matching are the same ones used as exogenous control variables in vector C_k , as well as perceived benefits and costs of acquiring GI certification used as instruments in vectors B_k and K_k . We match observations using nearest neighbour matching (NNM) with two and five nearest neighbours and kernel-based matching (KBM) with a bandwidth of 0.06 and 0.1.¹⁵

We verified the quality of matching by comparing the pseudo R^2 before and after matching, as well as the total reduction in bias induced by the matching (see Table 5). A strongly reduced R^2 and a reduction in total bias by at least 74% for all matching methods suggests that the matching was indeed appropriate. Further, the PSM method assumes that, given the observable covariates, assignment to “treatment” is ignorable. To test how strong the impact of unobservables (so-called confounding variables, measured by Γ) has to be to cast doubt on our results, we report the outcomes of the corresponding test developed by Rosenbaum (2002) in Table 4. For both NNM (2) and NNM (5), the critical level of Γ lies between 1.9 and 2.0, implying that, if suppliers with the same vector of observed characteristics differ in their odds of acquiring GI certification by 90%–100%, then the significance of the estimated effect of GI certification is questionable. Further, the effect of an unobserved confounding variable would have to induce suppliers with the same observable characteristics to be more than six times as likely to acquire certification for KBM (0.06), and more than five times as likely for KBM (0.1), to cast doubt on the significance of the results.

¹⁵ As we have a relatively low number of “treated” individuals (those who acquired GI certification), we chose the baseline specifications such that no observation was off support, meaning that all suppliers with GI certification were matched with a non-certified counterpart.

Table 3
Estimated coefficients from 2SLS and GMM estimations.

	2SLS		GMM	
	Full	GI Region	Full	GI Region
GI_k	0.420*** (0.127)	0.298*** (0.116)	0.347*** (0.109)	0.199** (0.090)
$Medium_k$	0.126*** (0.042)	0.259*** (0.088)	0.117*** (0.041)	0.228*** (0.090)
$GIOption_k$	-0.028 (0.026)		-0.015 (0.023)	
Constant	-0.004 (0.022)	-0.021 (0.072)	-0.002 (0.022)	-0.010 (0.069)
Age category dummies	Yes	Yes	Yes	Yes
Sales region dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
West Germany dummy	Yes	Yes	Yes	Yes
N	476	158	476	158
Effective F-statistic	18.586	32.780	18.586	32.780
Robust Overid. Res. Test (χ^2)	1.700	3.111	1.700	1.379
Robust Overid. Res. Test (p-value)	0.637	0.375	0.637	0.711

Robust standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01
Reported significance levels are based on one-sided z tests.

Table 4
Rosenbaum bounds for different matching algorithms.

Matching algorithm	Γ	p-critical (p^+)	Matching algorithm	Γ	p-critical (p^+)
NNM (2)	1	0.013	NNM (5)	1	0.006
	1.1	0.018		1.1	0.010
	1.2	0.025		1.2	0.015
	1.3	0.032		1.3	0.022
	1.4	0.042		1.4	0.031
	1.5	0.052		1.5	0.040
	1.6	0.063		1.6	0.052
	1.7	0.074		1.7	0.064
	1.8	0.086		1.8	0.080
	1.9	0.100		1.9	0.093
2.0	0.112	2.0	0.109		
KBM (0.06)	1	<0.001	KBM (0.1)	1	<0.001
	2	<0.001		2	<0.001
	3	0.002		3	0.003
	4	0.013		4	0.020
	5	0.042		5	0.050
	6	0.091		6	0.105
	7	0.157			

With that in mind, note that based on PSM, we are estimating the average treatment effect on the treated (ATT), which implies that the estimated effects of acquiring GI certification apply to a broader population than the IV results, which are estimates of the LATE.¹⁶ The estimates of the ATT presented in Table 6 suggest throughout that GI certification exerts a positive and significant impact on the probability of a supplier transacting with a retailer. Concretely, the estimates based on the different matching methods suggest that the probability of transacting with a retailer is 25.7%–26.5% higher for a GI-certified supplier than for a non-certified supplier, a finding that allows to reject hypothesis H_0^1 in (11).

5. Concluding remarks

This article illustrates the role of GIs as a tool to support coordination in agri-food supply chains. The context we explore involves the relationship between large-scale retailers and small-scale suppliers who

¹⁶ The ATT is the estimated average effect for all suppliers who acquired GI certification, which, different from the LATE, includes “always-takers”.

face a coordination issue concerning the provision of quality goods due to information asymmetries.

While the literature on the role of GIs for quality provision in agri-food markets is extensive (see Menapace and Moschini, 2024 for a recent encompassing review), our contribution is the first to model the role of GIs as a quality signal in procurement contracts, demonstrating that a signalling function of GIs can exist independently of any price premium paid by consumers. Our theoretical contribution is based on a principal–agent model, which effectively captures the strong imbalance of bargaining power between large-scale retailers and small-scale suppliers. In this context, we interpret GI certification as a costly signal that allows suppliers with a more favourable cost structure to indicate their type, thereby reducing information asymmetries.

We demonstrate that GI certification adds to the coordination in agri-food supply chains (i.e. fosters the provision of quality goods) through two mechanisms: First, it is possible for the retailer to select optimised contract terms so that acquiring GI certification and accepting the contract is optimal for some suppliers from GI regions, where the retailer is assured that each order placed with GI-certified suppliers will be fulfilled with high quality. Second, the reduction in information asymmetry from GI certification extends to producers in GI regions who do not certify (referred to as non-adopters). Indeed, the retailer can motivate a wider range of suppliers (that is, suppliers over a wider range of production costs) to deliver high-quality goods in GI regions compared to outside GI regions. The coordination effect of GIs therefore extends beyond GI-certified suppliers.

In addition to describing the mechanisms for coordination that GIs activate, the model yields two results concerning the influence of GI certification and supplier size on retailer profits that lend themselves to testable hypotheses addressed in the empirical analysis: All else equal, expected retailer profits are larger when transacting with (i) GI-certified suppliers relative to non-certified suppliers, and (ii) larger suppliers relative to smaller suppliers.

The data for our empirical analysis come from a survey among small- and medium-sized enterprises in the German food craft sector, a context where the characteristics closely resemble the business relationships highlighted in our model. In this setting, we interpret the retailer equilibrium profit equation as the underlying latent process that yields the binary outcome (transaction between a retailer and a supplier or no transaction), which we observe in the data. Additionally, our data provides information on each supplier’s perceived benefits and costs of GI certification, which allows us to specify a system of structural

Table 5
PSM quality indicators before and after matching.

Matching algorithm	Pseudo R^2 before matching	Pseudo R^2 after matching	$p > \chi^2$ before matching	$p > \chi^2$ after matching	Mean std. bias before matching	Mean std. bias after matching	(Total) % bias reduction
NNM (2)	0.445	0.230	0.000	0.441	40.5	10.5	74.074
NNM (5)	0.445	0.047	0.000	1.000	40.5	7.1	82.469
KBM (0.06)	0.445	0.074	0.000	0.999	40.5	9.4	76.790
KBM (0.1)	0.445	0.091	0.000	0.994	40.5	10	75.309

Table 6
Estimated ATT from PSM.

Matching algorithm	ATT	Number of treated	Control
NNM (2)	0.257** (0.092)	35	441
NNM (5)	0.257** (0.087)	35	441
KBM (0.06)	0.265*** (0.085)	35	441
KBM (0.1)	0.257*** (0.085)	35	441

Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

equations that defines the retailers’ optimised decisions of which suppliers to transact with and suppliers’ optimised decisions of whether to acquire GI certification. Through this structural approach, we are able to address the endogeneity of the acquisition of GI certification in the retailer equation by estimating the system using an IV approach.

Our estimates provide evidence that, all else equal, both (i) GI certification and (ii) larger size increase the probability of a supplier transacting with a retailer. These results hold consistently across different estimators (2SLS, GMM) and samples (full sample, firms only in GI regions), as well as in a PSM approach implemented as an alternative method to address the endogeneity issue associated with the certification status.

While our evidence cannot be considered conclusive regarding the extent to which GIs contribute to addressing potential market failures in supply chain relationships characterised by strong imbalances in bargaining power and asymmetric information, it is suggestive of such a role. Our findings, derived from different empirical approaches, consistently align with the result from our theoretical model. Therefore, we conclude that GIs likely play a role in extending the coordination effect of procurement contracts. However, factors such as the specific type of GI, its organisational structure, regional supply chain constraints, and demand conditions may also influence retailers’ decisions to transact with suppliers of different certification statuses, as well as suppliers’ decisions to acquire certification. Further research is thus warranted to fully understand the scope of the impact of GI certification on the coordination between large-scale retailers and small-scale agri-food suppliers in different market contexts.

CRedit authorship contribution statement

Jakob Rackl: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Luisa Menapace:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

A.1. Equilibrium probabilities of accepting and complying

GI-certified suppliers. The equilibrium certification threshold, c_i^{c*} , and the equilibrium acceptance threshold of GI-certified suppliers, c_i^a , are given by (3) and (6), respectively. GI-certified suppliers accept with certainty if the acceptance threshold lies above the certification threshold, i.e. if $c_i^a > c_i^{c*}$. This holds for $2\underline{c}_i + 6p - 4\bar{c}_i - c^{GI} > 0$. Solving this condition for p gives

$$p > \frac{2}{3}\bar{c}_i - \frac{1}{3}\underline{c}_i + \frac{1}{6}c^{GI}. \tag{14}$$

From the feasible set defined in (5), we know that $p > \bar{c}_i$ holds. We can thus infer that, if the right-hand-side of (14) is smaller than \bar{c}_i , (14) holds, which is the case if:

$$\frac{1}{2}c^{GI} < \bar{c}_i + \underline{c}_i. \tag{15}$$

Finally, for the upper bound of the feasible set in (5) lying above its lower bound, $2\bar{c}_i - 3\underline{c}_i - \frac{1}{2}c^{GI} > \bar{c}_i$ has to hold, which can be expressed as

$$\frac{1}{2}c^{GI} < \bar{c}_i - 3\underline{c}_i. \tag{16}$$

It is immediate to see that if (16) holds, (15), (14), and, consequently, $c_i^a > c_i^{c*}$ hold. Since the acceptance threshold c_i^a lies above the certification threshold c_i^{c*} , the probability that a certified supplier accepts the contract when offered the optimal transfer t_i^{GI*} is equal to $\lambda(t_i^{GI*}) = 1$.

Non-eligible suppliers and non-adopters. The equilibrium transfers the retailer offers to non-eligible suppliers and non-adopters, respectively, are given by $t_i^* = 2\underline{c}_i - \bar{c}_i + p$ and $t_i^{-GI*} = (\underline{c}_i + p)/2 - c^{GI}/4$. The equilibrium certification threshold is given by $c_i^{c*} = \bar{c}_i/2 + (\underline{c}_i - p)/4 - c^{GI}/8$. Given these results, equilibrium probabilities of complying of non-eligible suppliers and non-adopters, respectively, are given by

$$\lambda(t_i^*) = \frac{p - \bar{c}_i}{2(\bar{c}_i - \underline{c}_i)}, \quad \bar{\lambda}(t_i^{-GI*}) = \frac{4(p - \bar{c}_i)}{4\bar{c}_i + 2(p - \underline{c}_i) + c^{GI}}.$$

$\pi_R^{GI}(t_l^{GI*}) = p - \frac{1}{2}c^{GI} - 1,$ $\pi_R(\bar{t}_l^{GI*}) = \frac{4c^{GI}p - 8p - 4c^{GI} - 32px + (c^{GI})^2 + 20p^2 + 4}{4(c^{GI} + 2p + 4x - 2)},$ $\pi_R(t_l^*) = \frac{x^2 + 4 - 4x - 2px + p^2}{2(x - 1)},$	$\pi_R^{GI}(t_s^{GI*}) = p - \frac{1}{2}c^{GI} - \beta,$ $\pi_R(\bar{t}_s^{GI*}) = \frac{4c^{GI}p - 8\beta p - 4\beta c^{GI} - 32\beta px + (c^{GI})^2 + 20p^2 + 4\beta^2}{4(c^{GI} - 2\beta + 2p + 4\beta x)},$ $\pi_R(t_s^*) = \frac{\beta^2 x^2 + 4\beta^2 - 4\beta^2 x - 2\beta px + p^2}{2\beta(x - 1)}.$
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Box I.

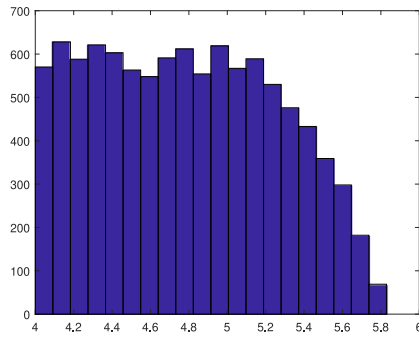


Fig. 5. Distribution of results of Monte-Carlo simulation of Δ_1^1 .

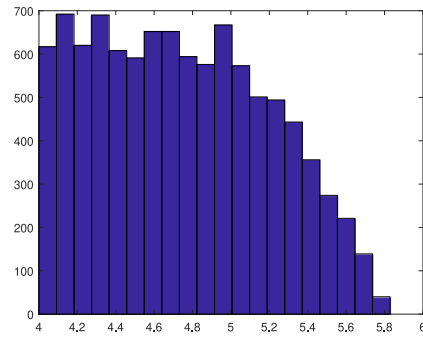


Fig. 6. Distribution of results of Monte-Carlo simulation of Δ_4^2 .

To show that the equilibrium probabilities of complying for non-eligible suppliers and non-adopters are smaller than the equilibrium probability of GI-certified suppliers accepting a contract (i.e. $\lambda(t_l^*) < 1$ and $\bar{\lambda}(\bar{t}_l^{GI*}) < 1$), we need:

$$p - \bar{c}_i < 2(\bar{c}_i - \underline{c}_i), \quad \text{for non-eligible suppliers, and} \quad (17)$$

$$4(p - \bar{c}_i) < 4\bar{c}_i + 2(p - \underline{c}_i) + c^{GI}, \quad \text{for non-adopters.} \quad (18)$$

(17) holds for $p < 3\bar{c}_i - 2\underline{c}_i$. Recall that if p lies within the feasible set, $p \leq 2\bar{c}_i - c^{GI} - 3\underline{c}_i$ has to hold. This implies that if $2\bar{c}_i - c^{GI} - 3\underline{c}_i < 3\bar{c}_i - 2\underline{c}_i$ holds, (17) holds as well. Simplifying yields $c^{GI} + \bar{c}_i + \underline{c}_i > 0$, which holds with certainty as all parameters are positive by assumption. We thus have $\lambda(t_l^*) < 1$. Further, as $p > \bar{c}_i$ if p lies within the feasible set, we have $\bar{\lambda}(\bar{t}_l^{GI*}) > 0$.

(18) holds for $p < 4\bar{c}_i - \underline{c}_i + c^{GI}/2$, so if $2\bar{c}_i - c^{GI}/2 - 3\underline{c}_i < 4\bar{c}_i - \underline{c}_i + c^{GI}/2$ holds. Simplifying gives $c^{GI} + 2\bar{c}_i + 2\underline{c}_i > 0$, which also holds as all parameters are positive by assumption. Further, as $p > \bar{c}_i$ if p lies within the feasible set, we have $\bar{\lambda}(\bar{t}_l^{GI*}) > 0$.

We therefore showed that $0 < \lambda(t_l^*) < 1$ and $0 < \bar{\lambda}(\bar{t}_l^{GI*}) < 1$ hold as long as p lies within the feasible set.

A.2. Retailer preferences over suppliers of different certification statuses

With production costs of large suppliers being uniformly distributed as $c_{l=l} \sim U(1, x)$, and production costs of small suppliers being uniformly distributed as $c_{l=s} \sim U(\beta, \beta x)$, equilibrium retailer profits from transacting with GI-certified suppliers, non-adopters, and non-eligible suppliers of sizes l and s , respectively, are given by (see the equations in Box I).

To come to a conclusion about the rankings of retailer profits, we define the following functions:

$$\begin{aligned} \Delta_l^1 &= \pi_R^{GI}(t_l^{GI*}) - \pi_R(\bar{t}_l^{GI*}), & \Delta_l^2 &= \pi_R^{GI}(t_l^{GI*}) - \pi_R(t_l^*), \\ \Delta_l^3 &= \pi_R^{GI}(t_l^{GI*}) - \pi_R(\bar{t}_s^{GI*}), & \Delta_l^4 &= \pi_R^{GI}(t_l^{GI*}) - \pi_R(t_s^*), \\ \Delta_s^1 &= \pi_R^{GI}(t_s^{GI*}) - \pi_R(\bar{t}_l^{GI*}), & \Delta_s^2 &= \pi_R^{GI}(t_s^{GI*}) - \pi_R(t_l^*), \\ \Delta_s^3 &= \pi_R^{GI}(t_s^{GI*}) - \pi_R(\bar{t}_s^{GI*}), & \Delta_s^4 &= \pi_R^{GI}(t_s^{GI*}) - \pi_R(t_s^*). \end{aligned}$$

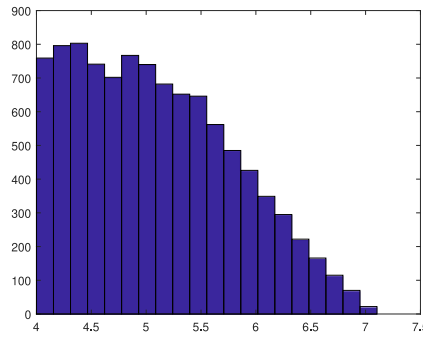


Fig. 7. Distribution of results of Monte-Carlo simulation of Δ_4^3 .

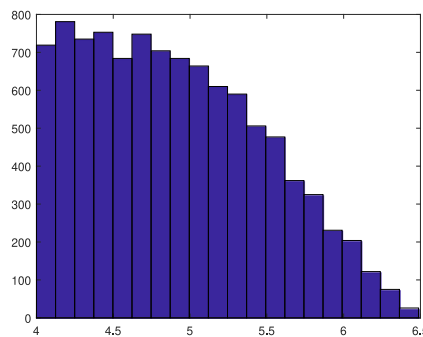


Fig. 8. Distribution of results of Monte-Carlo simulation of Δ_4^4 .

If the functions Δ_l^j and Δ_s^j with $j \in \{1, 2, 3, 4\}$ are positive, expected retailer profits from transacting with GI-certified suppliers (of both sizes) are larger than from transacting with suppliers of any other certification status of both sizes. To this end, we performed Monte-Carlo simulations to determine whether this is indeed the case. We drew 10,000 sets of parameter values for p , c^{GI} , β , and x , where we imposed restrictions such that all parameters lie within the feasible set

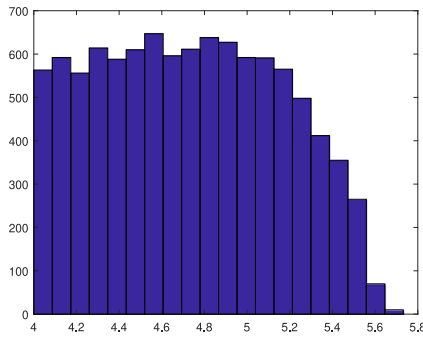


Fig. 9. Distribution of results of Monte-Carlo simulation of Δ_l^1 .

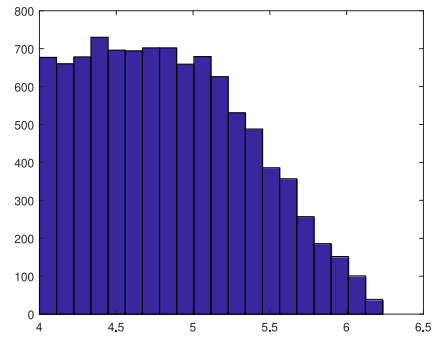


Fig. 12. Distribution of results of Monte-Carlo simulation of Δ_s^1 .

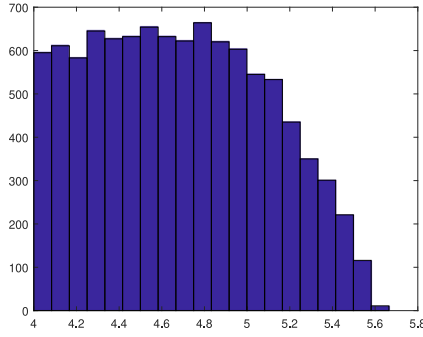


Fig. 10. Distribution of results of Monte-Carlo simulation of Δ_l^2 .

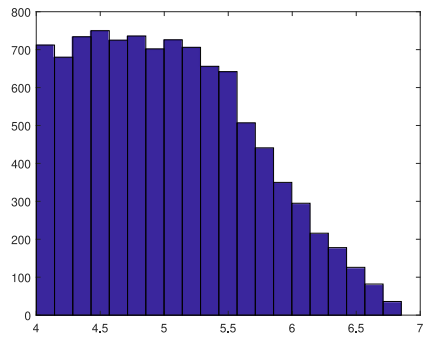


Fig. 11. Distribution of results of Monte-Carlo simulation of Δ_s^3 .

as defined in (7). We then computed the explicit values of functions Δ_l^j and Δ_s^j . Results are reported in Figs. 5–12 below. For all 10,000 sets, Δ_l^j and Δ_s^j resulted in positive values. We can thus state that, for parameter values within the feasible set, expected retailer profits from transacting with GI-certified suppliers (of both sizes) are indeed larger than from transacting with suppliers of any other certification status of both sizes.

A.3. Retailer preferences over suppliers of different sizes with the same certification statuses

With production costs of large suppliers being uniformly distributed as $c_{i=l} \sim U(1, x)$, and production costs of small suppliers being uniformly distributed as $c_{i=s} \sim U(\beta, \beta x)$, optimal transfers and probabilities of complying are given as follows. For GI-certified suppliers of size l and s :

$$\begin{aligned} t_l^{GI*} &= \frac{1}{2}(1+p) + \frac{1}{4}c^{GI}, & t_s^{GI*} &= \frac{1}{2}(\beta+p) + \frac{1}{4}c^{GI}, \\ \lambda(t_l^{GI*}) &= 1, & \lambda(t_s^{GI*}) &= 1. \end{aligned}$$

For non-adopters of size l and s (including the optimal certification threshold c_i^{c*}):

$$\begin{aligned} \bar{t}_l^{GI*} &= \frac{1}{2}(1+p) - \frac{1}{4}c^{GI}, & \bar{t}_s^{GI*} &= \frac{1}{2}(\beta+p) - \frac{1}{4}c^{GI}, \\ c_l^{c*} &= \frac{1}{2}x + \frac{1}{4} - \frac{1}{4}p - \frac{1}{8}c^{GI}, & c_s^{c*} &= \left(\frac{1}{2}x + \frac{1}{4}\right)\beta - \frac{1}{4}p - \frac{1}{8}c^{GI}, \\ \lambda(\bar{t}_l^{GI*}) &= \frac{4p-4x}{c^{GI} + 2p + 4x - 2}, & \lambda(\bar{t}_s^{GI*}) &= \frac{4p-4\beta x}{c^{GI} - 2\beta + 2p + 4\beta x}. \end{aligned}$$

For non-eligible suppliers of size l and s :

$$\begin{aligned} t_l^* &= 2-x+p, & t_s^* &= (2-x)\beta+p, \\ \lambda(t_l^*) &= \frac{p-x}{2(x-1)}, & \lambda(t_s^*) &= \frac{p-x\beta}{2\beta(x-1)}. \end{aligned}$$

The rankings of transfers and probabilities of complying for suppliers of the same certification statuses and different sizes are then given by:

$$\begin{aligned} t_l^{GI*} &< t_s^{GI*}, & \lambda^{GI}(t_l^{GI*}) &= \lambda^{GI}(t_s^{GI*}), & \text{for GI-certified suppliers,} \\ \bar{t}_l^{GI*} &< \bar{t}_s^{GI*}, & \bar{\lambda}(\bar{t}_l^{GI*}) &> \bar{\lambda}(\bar{t}_s^{GI*}), & \text{for non-adopters,} \\ t_l^* &< t_s^*, & \lambda(t_l^*) &> \lambda(t_s^*), & \text{for non-eligible suppliers.} \end{aligned}$$

Note that these rankings hold for $\beta > 1$, which is the case by assumption.

For a given certification status, equilibrium transfers are lower, and probabilities of complying are higher when the retailer transacts with larger suppliers relative to smaller suppliers, implying that expected retailer profits are higher from transacting with larger than with smaller suppliers:

$$\pi_R^{GI}(t_l^{GI*}) > \pi_R^{GI}(t_s^{GI*}), \quad \pi_R(\bar{t}_l^{GI*}) > \pi_R(\bar{t}_s^{GI*}), \quad \pi_R(t_l^*) > \pi_R(t_s^*). \quad (19)$$

A.4. Robustness

Three size categories. In Table 7, we report the outcomes of estimating (10) with three size categories instead of two, i.e. comparing small and medium suppliers individually to micro suppliers. We find no significant difference between small and micro suppliers in terms of their probability of transacting with a retailer in all specifications. Further, the estimated coefficients for GI_k and $Medium_k$ are close to the estimated coefficients in the main estimation with two size categories and allow us to reject H_0^1 and H_0^2 in (11) and (12) at the 1% significance level for all specifications except the GMM estimation of the “GI Region” sample, where we reject H_0^1 at the 5% significance level. Our main results are thus robust to the definition of the size variable in two or three categories.

Non-dichotomised instruments. In Table 8, we report outcomes of estimating (10) with non-dichotomised instruments (i.e. including a dummy for each of the five possible answers for each of the four questions regarding benefits and costs of acquiring GI certification used

Table 7
Regression outputs with three size categories.

	2SLS		GMM	
	Full	GI Region	Full	GI Region
GI_k	0.414*** (0.127)	0.297*** (0.116)	0.342*** (0.108)	0.200** (0.091)
$Small_k$	0.017 (0.017)	-0.005 (0.029)	0.024 (0.015)	-0.029 (0.035)
$Medium_k$	0.139*** (0.045)	0.256*** (0.089)	0.137*** (0.044)	0.206** (0.095)
$GIOption_k$	-0.025 (0.026)		-0.012 (0.023)	
<i>Constant</i>	-0.012 (0.022)	-0.019 (0.073)	-0.014 (0.022)	0.003 (0.069)
<i>N</i>	476	158	476	158
Effective F-statistic	18.399	32.305	18.399	32.305
Robust Overid. Res. Test (χ^2)	1.681	3.131	1.681	1.503
Robust Overid. Res. Test (p-value)	0.641	0.372	0.641	0.682

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Reported significance levels are based on one-sided z tests.

Table 8
Regression outputs with non-dichotomised instruments.

	2SLS		GMM	
	Full	GI Region	Full	GI Region
GI_k	0.359*** (0.109)	0.244*** (0.100)	0.232*** (0.080)	0.092** (0.052)
$Medium_k$	0.127*** (0.043)	0.261*** (0.089)	0.090*** (0.036)	0.214*** (0.073)
$GIOption_k$	-0.015 (0.022)		0.003 (0.014)	
<i>Constant</i>	-0.004 (0.022)	-0.012 (0.072)	-0.002 (0.016)	-0.000 (0.002)
<i>N</i>	476	158	476	158
Effective F-statistic	9.793	11.644	9.079	11.644
Robust Overid. Res. Test (χ^2)	13.678	17.785	19.122	17.607
Robust Overid. Res. Test (p-value)	0.550	0.470	0.449	0.482

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Reported significance levels are based on one-sided z tests.

as instruments). The results allow us to reject H_0^1 and H_0^2 in (11) and (12) at the 1% significance level for all specifications except the GMM estimation of the “GI Region” sample, where we reject H_0^1 at the 5% significance level. Our main results are thus robust to the use of dichotomised or non-dichotomised instruments.

Data availability

Data will be made available on request.

References

Addor, F., Grazioli, A., 2002. Geographical Indications beyond wines and spirits: A roadmap for a better protection for Geographical Indications in the WTO/TRIPS agreement. *J. World Intellect. Prop.* 5, 865.
 Akerlof, G.A., 1978. The market for “lemons”: Quality uncertainty and the market mechanism. In: *Uncertainty in Economics*. Elsevier, pp. 235–251.
 Albrecht, M., 2009. Supply Chain Coordination Mechanisms: New Approaches for Collaborative Planning. Vol. 628, Springer Science & Business Media.
 Angrist, J., Pischke, J.-S., 2009. *Mostly Harmless Econometrics: An Empiricist’s Companion*. Princeton University Press.
 Arshinder, Kanda, A., Deshmukh, S., 2008. Supply chain coordination: Perspectives, empirical studies and research directions. *Int. J. Prod. Econ.* 115 (2), 316–335.

Baldwin, J.R., Jarmin, R.S., Tang, J., 2002. The Trend to Smaller Producers in Manufacturing: A Canada/US Comparison. In: *Statistics Canada, Analytical Studies-Economic Analysis, Series 1F0027MIE(003)*.
 Barathova, K., Cacchiarelli, L., Di Fonzo, A., Lai, M., Lee, H., Menapace, L., Pokrivcak, J., Rahbauer, S., Rajcaniova, M., Russo, C., 2020. *Pass-Through of Unfair Trading Practices in EU Food Supply Chains: Methodology and Empirical Application*. Publications Office of the European Union.
 Barham, E., Sylvander, B., 2011. *Labels of Origin for Food: Local Development, Global Recognition*. Cabi.
 Belaya, V., Hanf, J.H., 2016. The dark and the bright side of power: implications for the management of business-to-business relationships. *Agric. Food Econ.* 4 (1), 1–17.
 Bontemps, C., Bouamra-Mechemache, Z., Simioni, M., 2013. Quality labels and firm survival: some first empirical evidence. *Eur. Rev. Agric. Econ.* 40 (3), 413–439.
 Bouamra-Mechemache, Z., Chaaban, J., 2010. Protected designation of origin revisited. *J. Agric. Food Ind. Organ.* 8 (1).
 Boyer, M., Porrini, D., 2002. The choice of instruments for environmental policy: Liability or regulation? In: *An Introduction to the Law and Economics of Environmental Policy: Issues in Institutional Design*. Emerald Group Publishing Limited, pp. 245–267.
 Bramley, C., Biénabe, E., Kirsten, J., 2009. The economics of Geographical Indications: Towards a conceptual framework for Geographical Indication research in developing countries. *Econ. Intellect. Prop.* 1, 109–149.
 Bundesministerium für Ernährung und Landwirtschaft, 2023. *Ernährungshandwerk*. from <https://www.bmel-statistik.de/ernaehrung/ernaehrungsgewerbe/ernaehrungshandwerk>. (Retrieved 13 June 2024).
 Cachon, G.P., 2003. Supply chain coordination with contracts. *Handbooks Oper. Res. Management Sci.* 11, 227–339.
 Caprice, S., Rey, P., 2015. Buyer power from joint listing decision. *Econ. J.* 125 (589), 1677–1704.
 Castriota, S., Delmastro, M., 2015. The economics of collective reputation: Evidence from the wine industry. *Am. J. Agric. Econ.* 97 (2), 469–489.
 Commission of the European Union, 2003. Recommendation of the commission dated 6 may 2003 concerning the definition of small and medium-sized enterprises.
 Connelly, B.L., Certo, S.T., Ireland, R.D., Reutzel, C.R., 2011. Signaling theory: A review and assessment. *J. Manag.* 37 (1), 39–67.
 Crescenzi, R., De Filippis, F., Giua, M., Vaquero-Piñeiro, C., 2022. Geographical Indications and local development: The strength of territorial embeddedness. *Reg. Stud.* 56 (3), 381–393.
 Deconinck, K., Swinnen, J., 2021. The size of terroir: A theoretical note on economics and politics of Geographical Indications. *J. Agric. Econ.* 72 (1), 321–328.
 Deselnicu, O.C., Costanigro, M., Souza-Monteiro, D.M., McPadden, D.T., 2013. A meta-analysis of Geographical Indication food valuation studies: What drives the premium for origin-based labels? *J. Agric. Resour. Econ.* 204–219.
 Desquilbet, M., Monier-Dilhan, S., 2015. Are Geographical Indications a worthy quality label? A framework with endogenous quality choice. *Eur. Rev. Agric. Econ.* 42 (1), 129–150.
 DiPrete, T.A., Gangl, M., 2004. 7. Assessing bias in the estimation of causal effects: Rosenbaum bounds on matching estimators and instrumental variables estimation with imperfect instruments. *Sociol. Methodol.* 34 (1), 271–310.
 Duvalaix, S., Emlinger, C., Gaigné, C., Latouche, K., 2021. Geographical Indications and trade: Firm-level evidence from the French cheese industry. *Food Policy* 102, 102118.
 Greene, W., 2018. *Econometric Analysis*. Pearson.
 Handayati, Y., Simatupang, T.M., Perdana, T., 2015. Agri-food supply chain coordination: The state-of-the-art and recent developments. *Logist. Res.* 8, 1–15.
 Hayashi, F., 2011. *Econometrics*. Princeton University Press.
 Hernandez, M.A., Espinoza, A., Berrospi, M.L., Deconinck, K., Swinnen, J., Vos, R., 2023. The Role of Market Concentration in the Agrifood Industry. Vol. 2168, International Food Policy Research Institute.
 Hingley, M., 2001. Relationship management in the supply chain. *Int. J. Logist. Manag.* 12 (2), 57–71.
 Hobbs, J.E., 2006. Liability and traceability in agri-food supply chains. *Frontis* 85–100.
 Hofmeier, M., Menapace, L., Rahbauer, S., 2023. Adoption of Geographical Indications and origin-related food labels by SMEs—A systematic literature review. *Clean. Circ. Bioecon.* 4.
 Hsieh, C.-T., Klenow, P.J., 2014. The life cycle of plants in India and Mexico. *Q. J. Econ.* 129 (3), 1035–1084.
 ifo Institute, 2020. *Strukturmerkmale ernährungshandwerk*. from <https://www.ifo.de/sites/default/files/2020-10/Strukturmerkmale-Ernaehrungshandwerk-20200918.pdf>. (Retrieved 13 June 2024).
 Imbens, G.W., Angrist, J.D., 1994. Identification and estimation of local average treatment effects. *Econometrica*: *J. Econom. Soc.* 467–475.
 Lence, S.H., Marette, S., Hayes, D.J., Foster, W., 2007. Collective marketing arrangements for geographically differentiated agricultural products: Welfare impacts and policy implications. *Am. J. Agric. Econ.* 89 (4), 947–963.
 Lentz, R., Mortensen, D.T., 2008. An empirical model of growth through product innovation. *Econometrica* 76 (6), 1317–1373.
 López-Bayón, S., González-Díaz, M., Solís-Rodríguez, V., Fernández-Barcala, M., 2018. Governance decisions in the supply chain and quality performance: The synergistic effect of Geographical Indications and ownership structure. *Int. J. Prod. Econ.* 197, 1–12.

- Malone, T.W., Crowston, K., 1994. The interdisciplinary study of coordination. *ACM Comput. Surv.* 26 (1), 87–119.
- Menapace, L., Moschini, G., 2012. Quality certification by Geographical Indications, trademarks and firm reputation. *Eur. Rev. Agric. Econ.* 39 (4), 539–566.
- Menapace, L., Moschini, G., 2024. The economics of Geographical Indications: An update. *Annu. Rev. Resour. Econ.* 16.
- Ménard, C., Valceschini, E., 2005. New institutions for governing the agri-food industry. *Eur. Rev. Agric. Econ.* 32 (3), 421–440.
- Mérel, P., 2009. On the deadweight cost of production requirements for geographically differentiated agricultural products. *Am. J. Agric. Econ.* 91 (3), 642–655.
- Mérel, P., Sexton, R.J., 2012. Will Geographical Indications supply excessive quality? *Eur. Rev. Agric. Econ.* 39 (4), 567–587.
- Moschini, G., Menapace, L., Pick, D., 2008. Geographical Indications and the competitive provision of quality in agricultural markets. *Am. J. Agric. Econ.* 90 (3), 794–812.
- Mussa, M., Rosen, S., 1978. Monopoly and product quality. *J. Econ. Theory* 18 (2), 301–317.
- Nelson, P., 1970. Information and consumer behavior. *J. Political Econ.* 78 (2), 311–329.
- Norman, G., 2010. Likert scales, levels of measurement and the “laws” of statistics. *Adv. Health Sci. Educ.* 15, 625–632.
- Norrman, A., Naslund, D., 2019. Supply chain incentive alignment: The gap between perceived importance and actual practice. *Oper. Supply Chain Manag.: Int. J.* 12 (3), 129–142.
- Olea, J.L.M., Pflueger, C., 2013. A robust test for weak instruments. *J. Bus. Econom. Statist.* 31 (3), 358–369.
- Özer, Ö., Raz, G., 2011. Supply chain sourcing under asymmetric information. *Prod. Oper. Manage.* 20 (1), 92–115.
- Pagan, A.R., Hall, A.D., 1983. Diagnostic tests as residual analysis. *Econometric Rev.* 2 (2), 159–218.
- Raimondi, V., Falco, C., Curzi, D., Olper, A., 2020. Trade effects of Geographical Indication policy: The EU case. *J. Agric. Econ.* 71 (2), 330–356.
- Rosenbaum, P.R., 2002. *Observational Studies*. Springer.
- Rosenbaum, P.R., Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70 (1), 41–55.
- Shapiro, C., 1983. Premiums for high quality products as returns to reputations. *Q. J. Econ.* 98 (4), 659–679.
- Shen, B., Choi, T.-M., Minner, S., 2019. A review on supply chain contracting with information considerations: Information updating and information asymmetry. *Int. J. Prod. Res.* 57 (15–16), 4898–4936.
- Spence, M., 1978. Job market signaling. In: *Uncertainty in Economics*. Elsevier, pp. 281–306.
- Swinnen, J., 2015. *Quality Standards, Value Chains, and International Development: Economic and Political Theory*. Cambridge University Press.
- TRIPS, 1994. Agreement on Trade-Related Aspects of Intellectual Property Rights. Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299, 33 I.L.M. 1197.
- Vosooghizajji, M., Taghipour, A., Canel-Depitre, B., 2020. Supply chain coordination under information asymmetry: A review. *Int. J. Prod. Res.* 58 (6), 1805–1834.
- Willits, F.K., Theodori, G.L., Luloff, A., 2016. Another look at likert scales. *J. Rural Soc. Sci.* 31 (3), 6.
- Wooldridge, J.M., 2010. *Econometric Analysis of Cross Section and Panel Data*. MIT Press.
- Wooldridge, J.M., 2015. *Introductory Econometrics: A Modern Approach*. Cengage learning.
- Yu, J., Bouamra-Mechemache, Z., Zago, A., 2018. What is in a name? Information, heterogeneity, and quality in a theory of nested names. *Am. J. Agric. Econ.* 100 (1), 286–310.
- Zhao, G., Liu, S., Lopez, C., Chen, H., Lu, H., Mangla, S.K., Elgueta, S., 2020. Risk analysis of the agri-food supply chain: A multi-method approach. *Int. J. Prod. Res.* 58 (16), 4851–4876.