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ABSTRACT

Does "Network Closure" Beef up Import Premium?*

We investigate whether network closure in the supply chain can explain the heterogeneity observed in import premia. Using unique panel data on trade flows among beef farms in the Italian region of Piedmont, we analyze a purely sequential supply chain characterized by the co-existence of two competing production systems: domestic cattle, of lower quality and less risky, and imported cattle, of higher quality and exposed to higher risks. Our findings indicate that trust and mutual cooperation, computed in terms of network closure, are associated with increasing gains from imports and may promote the use and investment in inputs of superior quality.

JEL Classification: D22, D85, F10, F14, L14, O13

Keywords: import premium, network closure, sequential supply chain

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1 Introduction

Imported intermediate inputs have been recognized as one of the main sources of technological diffusion and, consequently, of productivity growth (Coe and Helpman, 1995; Keller, 2002; Grossman and Helpman, 1993). Recently, empirical investigations based on micro data have confirmed that the use of foreign intermediate inputs increases firm productivity (Amiti and Konings, 2007; Kasahara and Rodrigue, 2008; Topalova and Khandelwal, 2011; Bas and Strauss-Kahn, 2014). While the literature has made progress in decomposing the import effect in two main mechanisms, one related to the higher quality of imported inputs and the other one to complementarities from the combination of foreign and domestic inputs, much less is known about "which firms gain most and how the effect depends on the economic environment" (Halpern *et al.*, 2015).[1] In this paper we concentrate on the quality channel and we study the role of firm-to-firm linkages in explaining its heterogeneity.

The recent research on firm-to-firm trade has shown the importance of the structure of the production network for explaining both firm-level outcomes and aggregate outcomes (Chaney, 2016; Bernard and Moxnes, 2018). This literature has emphasized the importance of having more and better suppliers for the performance of downstream firms both in domestic and international production networks (Chaney, 2018; Bernard *et al.*, 2015; Oberfield, 2018). The interdependence between economic agents along the supply chain implies that a firm's productivity is affected not only by variations in the efficiency of its direct input providers but also by indirect (higher order) connections. Because of this, firms can be exposed to foreign intermediates also indirectly, that is, through domestic suppliers which use foreign inputs (Tintelnot *et al.*, 2017).

This paper analyzes how the performance of firms using foreign intermediate inputs, either directly sourced abroad or indirectly used through supply chain linkages, is affected by the structure of the domestic production network in which they are embedded. By studying the benefits of the diffusion of more productive foreign breeds in Italian cattle industry, we show that a local characteristic of the network, the proportion of "supported" links (i.e., links whose ends share a common contact), augments the productivity advantage of importers (i.e., the so-called *import premium*). This network feature, commonly encompassed by the term "network closure" and associated with trust in relationship networks (Jackson *et al.*, 2017), is found to be relevant only for production units which use the more productive foreign intermediate inputs, for which uncertainty is higher and problems of asymmetric information, unobserved quality and relation-specific costs are higher. This result is robust to taking into account other local/micro and global/macro features

[1] Halpern *et al.* (2015) allow differences in the efficiency of import use by ownership status and estimate that the import effect is 24 percent higher for foreign owned with respect to domestic firms. Some studies on foreign direct investments (FDI) (Smarzynska Javorcik, 2004; Newman *et al.*, 2015) have emphasized how, through input-output linkages, the availability of advanced intermediate goods originated by foreign and foreign-owned firms affects not only direct users but may also produce positive externalities and spillover effects favoring technology adoption and increasing other firms' productivity (Eslava *et al.*, 2015; Fieler *et al.*, 2018).

of the network and possible agglomeration effects.

Beef farming is an excellent case study to analyze the presence and impact of high quality foreign inputs in the production network and investigate how the characteristics of the network may favor an efficient integration of foreign inputs into the production process. Indeed, even if commonly considered a traditional sector, beef farming has undergone major changes in the last century (Field, 2017). Recent improvements in genomics and in breeding techniques have fostered the development of breeds that clearly outperform the traditional ones.[2] In Italy, 46% of bovines raised for meat production are imported from countries, e.g. France, that have historically exhibited a comparative advantage in selecting and reproducing highly-performing breeds (Rama, 2008, 2009, 2010, 2011, 2012).[3] However, native breeds better fit local conditions such as climate, food and local diseases, as a result of a selection process over hundreds of years and, additionally, traditional beef farming is usually more integrated with local agricultural production and may then be undertaken using a relatively old and established technology. Bovines raised for meat production usually travel across different farms during their lifetime and each of them constitutes a different production stage. The plain sequentiality of this supply chain allows us to follow the foreign input downstream across all production/fattening stages up to the slaughtering, and to attribute the measured efficiency advantage of (direct and indirect) importers to the higher quality of the (imported) breed used.

The convenience for farmers to substitute local bovines with imported ones depends on the trade-off between the higher technical efficiency of the foreign breed (e.g. the ability to grow faster) and the higher uncertainty associated with their adoption. On the one hand, the cost of imported animals is higher and subjected to larger price fluctuations (Rama, 2008, 2009, 2010, 2011, 2012, 2014; Sarzeaud *et al.*, 2008), and these external factors lead to a time-observed variability in the proportion of foreign bovines reared in a farm. On the other hand, though the two production systems are compatible and can co-exist, foreign cattle is a biological asset whose superior performance requires specific know-how and the provision of adequate housing conditions.[4] This production customization to specific traits requires cooperation along the production chain among different farmers and, therefore, constitutes an interdependent (sunk) investment which may be hampered by classical hold-up problems. Due to the higher complexity and the lower familiarity with this

[2]Breeds characterized by a higher ability of transforming feed intake into pounds of animal weight, a.k.a. *feed conversion ratio*. This advantage guarantees faster growth rates and better achievements in terms of mass weight at slaughter age (Rama, 2008, 2009, 2010, 2011, 2012; Field, 2017). Selected breeds also display a better distribution of intramuscular fat which improves the tenderness of the meat (Field, 2017).

[3]A crucial aspect is that of subsidies given to farmers, corresponding to specific production phases. It is the case of France with respect to the first phases of the animals' lives. In general, "member states [of the European Union] can opt for keeping up to 100% of the "suckler cow premium" and up to 40% of the "slaughter premium" for adult bovine animals' coupled." In particular, "France decided to leave the whole suckler cow premium and 40% of the slaughter premium coupled." (Sarzeaud *et al.*, 2008)

[4]The direct (re)production of foreign cattle is not typically attempted by farms, as this would require drastic investments in capital and technology.

production paradigm, trades among production units using foreign inputs are less standardized (Rauch, 2001). These exchanges are characterized by higher relation-specific costs, connected to the customization of the advanced intermediate input, and by problems of unobserved quality and asymmetric information.[5] In such a context of contract incompleteness, trust between parties turns out to be an important factor to stimulate more cooperative and efficient behaviors.

We frame our findings by exploiting an extension of the Jackson *et al.* (2012) model where, in the presence of incomplete contracts, clustered patterns of links increase trust and promote cooperation among the users of high-quality imported intermediate goods.[6] In this context, link formation is limited by frictions, as in Tintelnot *et al.* (2017), Bernard *et al.* (2014), Bernard *et al.* (2015) and Carvalho and Voigtländer (2014), because firm-to-firm connections entail relation-specific costs related to product customization and contract negotiations. Our findings, thus, indicate that "network closure", a phenomenon typically analyzed in social networks, has an important role also in production networks.

In Section 2 we model trade exchanges as a network where, in presence of frictions and risks, more profitable links can be established endogenously only when trust among firms is sustained by network closure. Section 3 describes the data in detail. In section 4, by taking advantage of information about the owners of each production structure, we are able to analyze the social network of owners and to econometrically study clustering configurations and plant-level performance.

2 A Model of Production of an Imported Good

The sociological literature (Granovetter, 1985; Putnam, 2000; Coleman, 2000) has long argued that particular social network structures play a key role in building and maintaining trust among agents. Trust, in turn, fosters cooperative and efficient behaviors that end up positively affecting economic outcomes. This line of reasoning has been applied effectively in social contexts where interactions among agents are assumed to be repeated over time and occurring without formal contracts (Board, 2011; Dall'Asta *et al.*, 2012). Specifically, it has been shown that the main structural characteristic related to trust is network "closure" (Ali and Miller, 2016; Karlan *et al.*, 2009).

Drawing on this literature, we build a model based on a variation of the one in Jackson *et al.* (2012), where agents who decide to produce using foreign inputs do so only if the supply chain in which they are embedded is structured in "closely knit"/clustered local connections, able to

[5] For example, animals often suffer from diseases that are latent for long time but that can heavily affect their growth and, ultimately, their weight at slaughter age (Field, 2017).

[6] This result is in line with the empirical findings of Allcott *et al.* (2007) and Karlan *et al.* (2009). Allcott *et al.* (2007) study data from surveys in American Schools, that include self–reported friendship networks, and show how a measure of clustering called *closure* is correlated with pro-social attitudes in a survey. Karlan *et al.* (2009) study data from two shantytowns in Peru, including self–reported friendship and money borrowing relations, and show that more money is borrowed between links that are supported by common friends.

ensure the right incentives to sustain sunk investments and relation-specific costs necessary for the production of the high quality (imported) good.

Specifically, firms are producers of a domestic good (i.e. cattle) and are part of a network defined by their trade relationships (i.e. supplier-client or input-output linkages). Such a network is considered pre-existing and exogenously given. In addition, a firm can choose to use imported inputs (i.e. foreign breeds), with the assumption that these are of higher quality, more profitable but also more complex to deal with. Such firms are named *importers*.[7] To become importers, firms have to pay a sunk cost which represents the breed-specific investments needed to treat the foreign good, such as adequate housing, knowledge of breed-specific raising techniques and so forth.[8] Firms who decide not to become importers remain active only in the production network of the domestic good, and being a non-importer is formalized as a no-risk outside option which always yields a net profit normalized to 0. This is considered to be a less risky choice which requires less investments both in terms of physical assets and in terms of learning/acquiring breed-specific know-how.

We now focus our attention to the description of the importers. While the foreign input is potentially more productive and profitable, it is also riskier and more complex to adopt and produce. Once a firm has paid the sunk cost for importing, then she has access to a broader set of business opportunities given by the possibility of producing the high quality good. However, the complexity of the imported good, the specialization in (breed- and) age-specific housing and investments and, ultimately, the sequentiality of cattle raising production, make collaboration among different importers in the production chain necessary to enjoy the higher productivity yielded by foreign breeds.

In particular, when an importer i is presented with a business opportunity, she needs the cooperation of another importer j to catch it, for example because j is downstream in the production chain with respect to i and i needs to ensure j's demand. This is formalized as a relation-specific investment paid by j, corresponding to customization costs of j to i's inputs.[9] In the end, i is able to enjoy the benefit yielded by the production of the high-quality good only if j has borne this relation-specific cost. Notice that j is also an importer so, symmetrically, there may well occur a situation in a successive time period where j may ask i to reciprocate the investment for an opportunity she has been presented.

Crucially, however, problems due to incomplete contracts are pervasive, because no binding agreement can be used to force firm i to reciprocate. Also, monitoring the partner may be a concern, since the quality of the traded foreign good and the effort exerted in raising the animals are both unobservable. In a context like this, trust and reputation are important to sustain collaboration

[7]We indicate by importers not only those producers who directly import the foreign cattle, but also those who participate in the production chain of a cattle which was born abroad.

[8]Fixed or sunk cost of importing are a common feature in the literature (Kasahara and Rodrigue, 2008; Kasahara and Lapham, 2013; Halpern *et al.*, 2015).

[9]Relation-specific costs are also present in Carvalho and Voigtländer (2014) and Bernard *et al.* (2015).

and j's response to i's refusal to reciprocate is formalized as the cut of their trade relationship.

The main features of this model can be summarized as follows (we will be more precise on the timing of the game below, when the model is introduced formally):

- Firms have a sunk cost $s > 0$ to pay to become importers.[10] Moreover, each firm has a specific discount factor δ_i over time. Time is assumed to be discrete in $\{0, 1, 2, ...\}$.

- Importing is a risky but profitable activity: with some probability, an importing firm faces a business opportunity but is able to catch it only if she can share it with an importer partner who, in turn, is asked for a (relation-specific) investment. More precisely: if i and j are linked (and they are both importers), then there is a probability p_{ij} that i is presented an opportunity that can be shared with j. Time periods are assumed small enough so that at most one business opportunity can arise in each time period across all firms, i.e. $p_{ij} \leq \frac{1}{n(n-1)}$ for all $i, j \in N$.

- In response to this event/opportunity, j can choose either to reject it or to accept it: if rejection is chosen, no benefit is enjoyed nor cost incurred, but the relationship is severed.[11] Instead, if j accepts the offer, then j bears a cost $c_{ji} > 0$ for the investment and i enjoys a benefit of $v_{ij} > c_{ji}$, which abstractly represents the intensity and profitability of the trade relationship between i and j.[12] Moreover, in case of j's acceptance, the relationship ij is maintained and future opportunities for the two firms can arise again.

- If a firm decides not to become an importer (i.e. it does not pay the sunk cost s), then it does not have access to any business opportunities involving foreign goods, so it keeps its relations with non-importer partners in place and enjoys a payoff of 0 in perpetuity.[13]

In this framework, on the one hand it is ex-ante Pareto optimal for importers to invest in each others' business opportunities over time but, on the other hand, in absence of binding agreements firms could free-ride by not reciprocating the investment. The punishment for free riding, i.e. the deletion of the trade relationship, can have negative cascade effects to other relationships and is then able to ensure the right incentives and high levels of trust among the firms that, in turn, sustain the optimal equilibrium achieved thanks to collaboration.

From a network perspective, maintaining links with other importers is costly but guarantees access to a possibly superior payoff obtained with the more productive input. Importing firms who achieve a sufficiently high degree of collaboration with other importers manage to compensate the

[10] This cost may be randomly distributed across firms in an interval or in a discrete set, e.g. in a finite set of low and high costs $\{s_L, s_H\}$. In general, it can be firm specific and the analysis remains the same.

[11] And it can never be resuscitated (at least in the short-run).

[12] Heterogeneity in trade relationships is allowed and also considered in the empirical analysis of Section 4. Notice, however, that for tractability reasons in the model the intensity v_{ij} of the relationship ij is constant over time.

[13] It is assumed that trade relationships among non-importing firms yield a net payoff normalized to 0.

sunk cost paid and can enjoy higher payoffs, whereas those who cannot will find it more convenient to keep their production restricted to the low-performing domestic good.

2.1 The Game

A finite set of firms $N = \{1, ..., n\}$ is placed on a network represented by a graph g, where $N_i(g)$ is the set of neighbors of firm i in the network and $d_i(g) = |N_i(g)|$ is i's degree in g. A link between two firms is present if they have a trade relationship. A link is said to be *supported* if there exists a third firm who is a common neighbor.[14]

At the beginning, the parameters s, δ_i, p_{ij}, c_{ij} and v_{ij} for all firms i, j are given and the network g is in place. In all generality, these parameters are specific to relationships and, in addition, may also depend on the network structure g, so they can be of the form $p_{ij}(g)$, $c_{ij}(g)$ and $v_{ij}(g)$. A society is described by $(N, s, \{\delta_i\}_{i\in N}, \{p_{ij}\}_{i,j\in N}, \{c_{ij}\}_{i,j\in N}, \{v_{ij}\}_{i,j\in N}, g)$.

A 2-stage game with complete information then begins, where the first stage is one-shot while the second stage evolves over discrete times, $t \in \{0, 1, ...\}$.[15]

Stage 1 (One-shot import decision)

Each firm decides whether to become an importer or not:

- if firm i decides to be an importer, then it pays the sunk cost s and has access to the following stage of the game;
- otherwise, no cost is paid nor benefit enjoyed. So, a non-importer remains part of the trade network g, thus interacting with other non-importers. She will not get any additional benefit thus obtaining a net payoff normalized to 0.

Let us denote by $N^I \subseteq N$ the subset of firms who are importers and, correspondingly, by $g^I = g|_{N^I}$ the subnetwork of g induced by the importers. We call $d_i(g^I)$ the degree of node i in the subnetwork g^I.[16]

Stage 2 (Import with collaborations)

Importing firms choose the other importers they want to be linked to or, rather, the collaborations with other importers they want to maintain, while knowing that collaboration among importers is costly but valuable.

- At time $t = 0$, the network g is in place and, hence, the subnetwork of importers $g_0 = g^I$ is taken as starting point;

[14] That is, the link ij is supported in g if there exists $k \neq i, j$ such that $k \in N_i(g) \cap N_j(g)$.

[15] We assume that a firm knows the (cap)abilities of her trading partners and, particularly, knows whether they can raise imported cattle, both in terms of physical assets and in terms of know-how (i.e. a firm knows which of her neighbors has paid the sunk cost to become an importer).

[16] For a subset $S \subseteq N$, we denote by $g|_S$ the subgraph of g induced by S, that is, the graph whose vertices are in S and whose links ij are present if and only if both i and j belong to S.

– time is discrete, and period t begins with (sub)network $g_{t-1} \subseteq g_0$ in place. Nodes of g_{t-1} announce the links they want to retain and the resulting network $g'_t \subseteq g_0$ is formed, where links are present only if mutually announced. Formally, for $i \in g_{t-1}$, let $L(i) \subseteq N_i(g_{t-1})$ be the set of i's neighbors that i announces. Then, $g'_t \subseteq g_{t-1}$ is defined by taking only the links $ij \in g_{t-1}$ such that $i \in L(j)$ and $j \in L(i)$;

– according to the distribution $\{p_{ij}\}_{i,j}$, the (directed) link ij is selected with probability p_{ij}. If $ij \notin g'_t$, then nothing happens and time t ends with network g'_t in place. Otherwise, i is presented an opportunity and asks j to invest in it. Then:

  * if j rejects, no cost and no benefit are incurred and the resulting network at time t is $g'_t - ij$;[17]
  * if j accepts, i enjoys the benefit v_{ij} while j pays the investment cost c_{ji}, and the resulting network is g'_t.

The initial network of importers g_0 is a subnetwork of the given exogenous trade network g, and the same holds for the equilibrium subnetwork of importers resulting from the game. Also, notice that we are assuming that trade relationships cannot resuscitate once cut. This is a reasonable assumption if one considers that trust among partners is usually established through interactions occurring over several years. Moreover, our data span around 6 years and since each stage of cattle production typically lasts few months, this limits the number of possible interactions that farmers could have had in this time period. Crucially, this also limits the possibility of re-establishing a closed relationship (that is, the possibility of forgiving a free rider) in what is a relatively short-time horizon.

Lastly, notice that consistently with the market considered here, in this model the production of the local good is assumed to be less complex and, hence, to imply less restrictions on the trade partners. This is formalized by the generality of the exogenously given network g.

2.2 Solution of the Game and Testable Predictions

The 2-stage game can be solved by backward induction, as done in Jackson *et al.* (2012): the second stage has a solution, based on the concept of *renegotiation–proof* equilibrium, such that the equilibrium subnetworks of importers are those where all their links are supported, i.e. where all links between two importers are supported by another importer. Then, a firm decides to be an importer in the first stage only if it anticipates that the benefits obtained by collaborating with other importers in the equilibrium network will exceed its sunk cost.

Since, by construction, the non-importers get the outside-option payoff of 0, in what follows we focus on the network structures among importers that result in equilibrium and in their payoffs. We show that the import premium obtained by the importers is increasing in the number of supported

[17] If $ij \in g$ is a link of g, we indicate by $g - ij$ the network g without that link.

relationships (with other importers) that they are able to sustain in equilibrium and, hence, in their involvement in importing. From the network-theory perspective, the interesting cases arise when a single link between two importers is not sustainable in isolation, that is, when

$$c_{ji} > \delta_i \frac{p_{ij}v_{ij} - p_{ji}c_{ji}}{1-\delta_i}, \tag{1}$$

for all importers $i, j \in N^I$.

Proposition 1. *Let* $(N, s, \{\delta_i\}_{i\in N}, \{p_{ij}\}_{i,j\in N}, \{c_{ij}\}_{i,j\in N}, \{v_{ij}\}_{i,j\in N}, g)$ *be a society such that equation (1) is satisfied. Then, in equilibrium, the subset of importers* $N^I \subseteq N$ *and the induced subnetwork* $g^I \subseteq g$ *are such that:*

- *non-importing firms in* $N \setminus N^I$ *get a payoff of 0, by construction;*
- *if* $i \in N^I$ *is an importer then she gets an equilibrium payoff of* $u_i(g^I) \geq s > 0$*, given by*

$$u_i\left(g^I\right) = \frac{\sum_{j\in N_i(g^I)}\left(p_{ij}v_{ij} - p_{ji}c_{ji}\right)}{1-\delta_i}. \tag{2}$$

- g^I *is such that all its links are supported in* g^I*.*

Proposition 1 follows from Theorem 3 in Jackson *et al.* (2012). It is worth remembering that a link between two agents is supported when there is a third agent, in contact with both, who can guarantee one's good behavior with the other. This mechanism is used to enforce pro-social behaviors and sustain high-achieving collaborative outcomes.

Next result is a corollary of that, and comes from the fact that the payoff in equilibrium (2) is linear with the number of importer neighbors $d_i(g^I)$. Recall that $d_i(g)$ is the "exogenous" degree of node i in network g and that $d_i(g^I)$ is the "endogenous" degree of node i in the equilibrium subnetwork $g^I \subseteq g$. For a non-isolated node $i \in N$, we define the *relative degree* as the fraction of i's neighbors that are importers, $\theta_i(g^I) := d_i(g^I)/d_i(g)$, with the convention that $d_i(g^I) = 0$ if $i \notin N^I$.

Proposition 2 (Productivity and "Relative" Degree).
Given a network g*, if* $p_{ij}v_{ij} \geq p_{ji}c_{ji}$*, for all* $i, j \in N^I$*, then importers' payoffs are increasing in the relative share* $\theta_i(g^I)$ *of* i*.*

Our model represents a stylized and simplified scenario with stark predictions. This theoretical benchmark will be used to guide our empirical analysis.

A first important prediction is that, consistently with the literature on importing and productivity, the higher a firm's involvement in importing is, the higher her payoff will be. In the model the degree of participation of a firm in importing can be described by the share of its relations with other importing firms, i.e. the relative degree. The relative degree, which takes into account the extensive margin of a firm's trades, is a sufficient statistics to pin-down the "internationalization intensity" of a firm.[18] However, in order to exploit all the information available in the data and for comparability with the extant literature on importing (see for example Kasahara and Rodrigue (2008) and Tintelnot *et al.* (2017)), in the empirical part of the paper our preferred proxy of the degree of involvement of a firm in importing will be the share of imported bovines in the total number of bovines used in production, which takes into account both the extensive and the intensive margins a firm's trades. In the robustness checks in Section 4.3 we show that the main results are robust to using the relative (in)degree.[19]

The second crucial prediction of the model that we aim to test is related to the role of "network closure". On the one hand, in equilibrium importers establish a network of trade linkages among them characterized by being "supported", because only supported links guarantee non-negative payoffs. Moreover, each link between two importers is supported by another importer. On the other hand, the degree of closure of the relations involving domestic inputs is not relevant to determine the payoffs. In practice, in the data we observe that, although the links between importers are much more supported than those among non-importers, not all links among importers are supported. Following the main message of the model, we expect that the payoffs stemming from importing will be increasing in the percentage of an importer's links that are supported and, instead, the percentage of supported links of a non importer will be not relevant for determining her performance.

In this light, the aim of the empirical section will be to test the following main qualitative predictions of the model:

(P1) the higher is a farm involvement in importing, as proxied by the share of imported bovines, the higher will be its productivity (from Proposition 2);

(P2) the effect of importing on productivity is heterogeneous and positively depends on the proportion of supported links of the farm (from Proposition 1);

(P3) the proportion of supported links of a farm is not a relevant determinant of productivity for farms that use only traditional domestic bovines (from Proposition 1).

3 Background and Data Description

The data on the movements of bovines are provided by the Italian National Animal Identification and Registration Database (*Anagrafe Bovina*) managed by the Italian Ministry of Health. The Registration Database was developed after the introduction of the EEC-issued Council Directive

[18] In the model, c_{ij} and v_{ij} describe the differences in costs and quantity traded for importing firms. However, there is not enough information about intensive margins because for tractability reasons the payoffs deriving from trade in domestic intermediate inputs are normalized to 0.

[19] The use of the indegree instead of the degree is due to the mechanical correlation with the dependent variable used, as explained in Section 4.1.

92/102/EEC in 1992. This Directive aimed at regulating beef cattle movements and guaranteeing their traceability after the outbreak of bovine spongiform encephalopathy (a.k.a. mad cow disease).

The dataset tracks the movements of each bovine from birth until slaughtering. Incoming animals from foreign countries are also registered in the database. Each animal is assigned a unique identification code and, moreover, the dates and the geographical locations of origin and destination of each of its movements are recorded in the database. The data, thus, enable the identification of the links between all possible animal holdings and, in particular, between animal husbandry or farms and slaughterhouses. Given the epidemiological interest in identifying all potential channels of infection, the dataset defines a *holding* as a closed structure where animals are somehow isolated from other livestock.

Structures identified as animal husbandries or farms can thus be considered as single production units. Stables, for efficiency reasons, usually house bovines of the same age and breed. Independently of the breed, beef production is roughly divided in three stages (cow-calf stage, stock-calf stage, feedlot stage) (Field, 2017), so the transfer of bovines from one farm to another (or to a slaughterhouse) can be seen as the completion of a production stage. In this context, the number of bovines exiting from a farm, conditional on the number of past inflows, can be used as a measure of productivity, reflecting the survival, especially at earlier ages, of the reared animal and its ability to grow. Indeed, inflows of bovines into a farm do not necessarily translate into outflows if the fattening stage is not successfully conducted and the animal is not matched with adequate environmental conditions. Bad conditions and/or stress suffered by the bovine may considerably hamper its growth or even lead to the development of diseases (Field, 2017).[20] Holdings registered as farms will thus represent the main unit of analysis in our empirical investigation and movements from farms towards other farms or slaughterhouses will be used to infer differences in technical productivity of premises. It is worth noting that our measure of efficiency is based on the actual quantities traded by firms and is not revenue-based.

Additional information about the breed of each animal allows us to restrict our sample only to breeds that can be used for meat production; cattle for dairy production are excluded from the sample, whereas dual-purpose meat-milk breeds and cattle classified as crossbreeds are included.

We focus our analysis on cattle movements in the Piedmont region. Together with Veneto and Lombardy, Piedmont is one of the main producers of beef in Italy (Sarzeaud *et al.*, 2008; Rama, 2008, 2009, 2010, 2011, 2012). Differently from the other northern regions, which are mainly specialized in fattening imported calves, beef farming in Piedmont is characterized by a diversified

[20]To minimize health problems, the optimal environmental conditions present in each holding should be highly breed- and age-specific, such as heating, ventilation, specific dietary requirements, sanitary conditions, space allotment, etc. Specific "financial losses related to health issues account to 62% due to death loss, 21% due to performance losses in sick cattle, and 17% for the expense of treatment" and "[t]he average sick animal shrinks 10-20%" (Field, 2017).

productive system.[21] On the one hand, local farmers raise native breeds (i.e. the Piedmontese), thus maintaining active a local suckler-cow system. On the other hand, Piedmont imports 53% of livestock, which means that several farmers are also involved in fattening foreign breeds. The proximity to the French border facilitates the imports. For farms located farther from the border the choice of importing bovines from foreign countries is heavily affected by problems related to the stress induced by the longer transport. These problems include the development of diseases and reduced growth (or even death) of the animal in the receiving fattening farms. Long transport is also more costly since, due to the current European legislation, bovines cannot be transported for more than eight hours. Long movements of animals, especially from foreign countries, are thus required to transit through specific holdings, called staging point, to give rest to the animals for at least 24 hours. Due to the shorter distance from the border, transits through staging point is a limited phenomenon for receiving farms located in Piedmont, and this simplifies both the identification of connections between farms and also the analysis of the determinants of the adoption of foreign breeds.

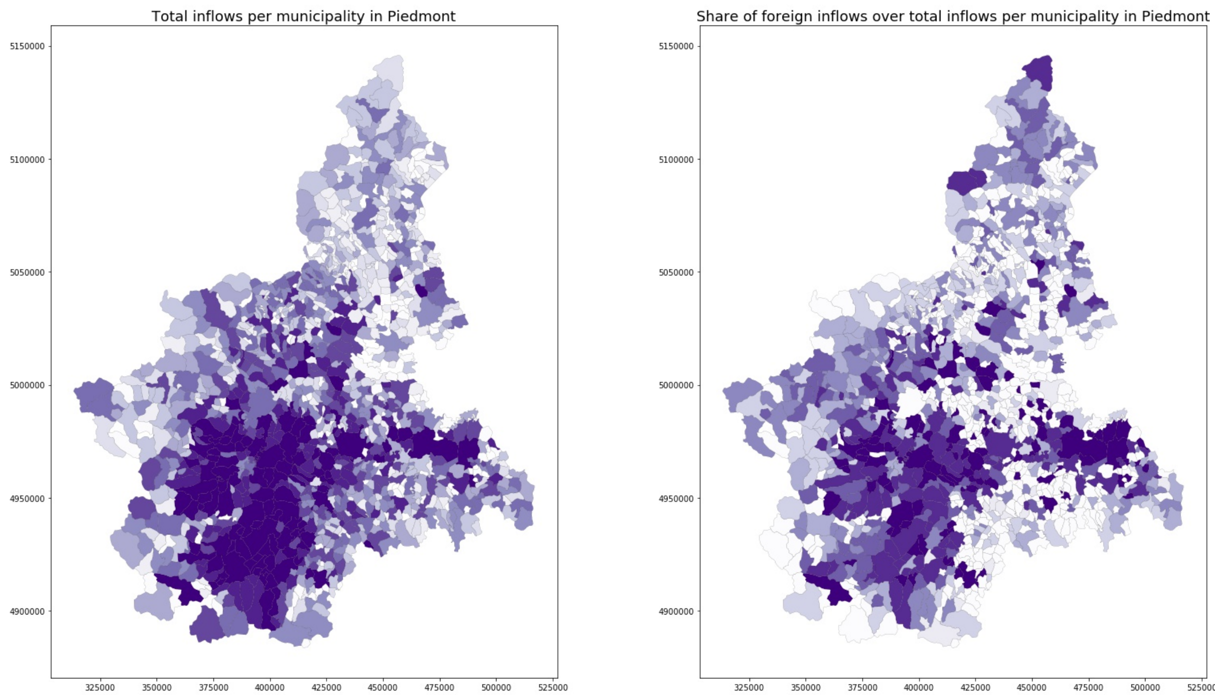
In order to construct the network statistics describing the social network of owners, we use both information on movements between holdings and information on farms' ownership. The data contains information on how much time an owner has kept a given number of bovines in each farm. The structures/holdings registered in the database cannot be considered directly as nodes of the ownership network, because two or more stages of production can be implemented in farms all belonging to the same owner.

Figure 2 illustrates this with an example. The lines represent transfers of bovines between farms and, in particular, the dashed line is a transfer between farm 1 and 2, both belonging to owner A. The network depicted in panel (a) of Figure 2 is the production network constructed using only connections among holdings. If one were to consider structures 1 and 2 as being two different nodes, then one would misidentify the transitivity in the relations among owners A, B and C (i.e. triples of owners all trading with each other) and, consequently, miscalculate their supported links. Instead, we consider connected structures belonging to the same owner as a unique node. In other words, all the farms belonging to the same owner are grouped in the same node. Connections between two different nodes/owners will still be determined by the movements from and to the structures/farm belonging to the two owners. With these definitions of nodes and connections we can obtain the graph described in panel (b), where each of the three owners has two supported links. In Figure 3 we provide a visual representation of how we have reduced the network, aggregating nodes and corresponding links, when they belong to the same owner.

Similarly, by focusing on ownership, we can detect connections between supply chains that

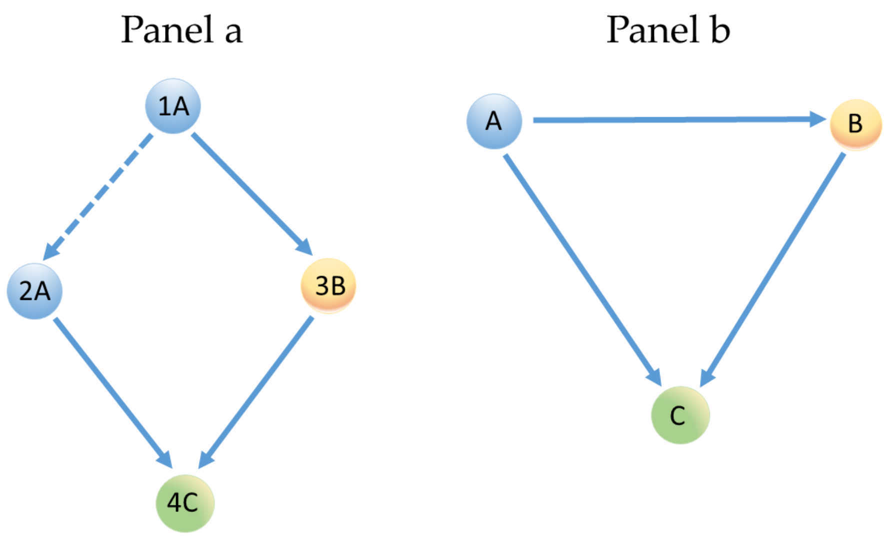
[21] In Piedmont, cattle industry is composed by many relatively small and independently-owned farms. These farms are mainly family-owned businesses where labor can be considered as a fixed input. The average farm has 580 livestock units in Piedmont, whereas in a somewhat comparable region, such as Veneto, the average value is 1250 (Rama (2012), section 4.1).

Figure 1: Piedmont and cattle inflows



Piedmont is a region located in the north-western part of Italy and shares its western borders with France. The figure on the left shows the total inflows in each municipality and the one on the right the share of these inflows that are of foreign cattle. Darker areas correspond to larger inflows on the left and larger foreign shares on the right, respectively.

Figure 2: Construction of the network



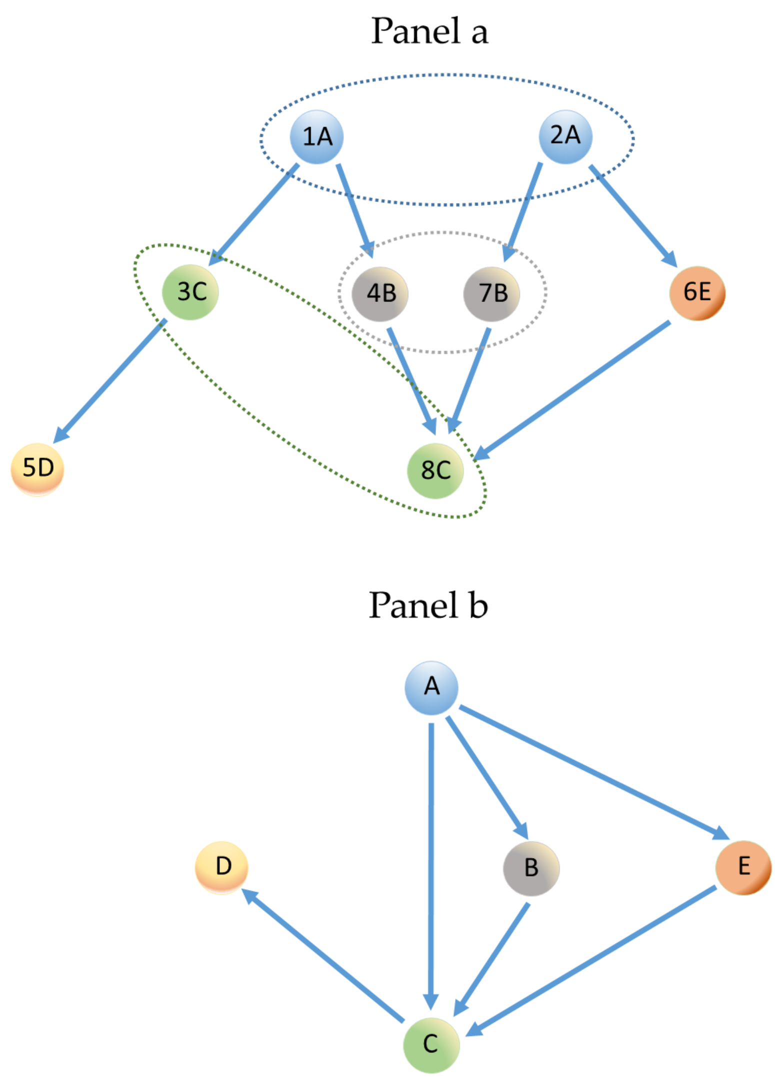
Note: Figure in panel (a) displays the connections determined by movements of bovines between holdings (i.e. farms). Numbers identifies the holdings whereas capital letters identify the owners of the farm. In panel (b) the nodes represent owners (denoted by letters): the connections of each node are determined by the connections of all the farms belonging to that owner (shown in panel a).

could not be identified if we were using structures/farms as unit of analysis. Panel (a) of Figure 3 represents a case where: individual A owns farms 1 and 2, individual B owns 4 and 7 and individual C owns 3 and 8. There is no movement of bovines between any two structures belonging to the same owner. The network structure based on ownership in panel (b), where holding 1 and 2 (as well as 4 and 7 and 3 and 8) are grouped in a unique node, allows us to identify two closed triangles (A,B,C) and (A,E,C). The latter could not be identified had nodes 1 and 2 be considered as separate structures. If a farm hosts simultaneously bovines of different owners, then we assign the links corresponding to this holding to each of the owners present in that structure.

Our final network is thus characterized by owner-specific nodes. For each node we compute several ego/local-network measures such as degree, proportion of supported links, centrality, clustering, betweenness, and so on. For the computation of these measures we have used the universe of farms and owners in Italy. Then, these owner-specific network measures are assigned to the corresponding farm which will be the unit of analysis in our empirical investigation. When more owners coexist in the same farm, we assign to that holding the maximum of the given network measure. In almost all of the cases this maximum value belongs to the owner with the highest number of bovines in the farm.

Our dataset is constructed using the information available for the 2006-2013 period. We have

Figure 3: Construction of the ownership network from complex supply chains



Note: Figure in panel (a) displays the connections determined by movements of bovines between holdings (i.e. farms). Numbers identifies the holdings whereas capital letters identify the owners of the farm. In panel (b) the nodes represent owners (denoted by letters): the connections of each node are determined by the connections of all the farms belonging to that owner (shown in panel a).

implemented some trimming procedures since some holdings, although classified as farms, display anomalous values of flows and stocks that suggest that they could be used as assembly centers and/or staging points. For these reasons we dropped all observations with a value of the stock and of the number of suppliers greater than the corresponding 99th percentile.[22] Finally, we excluded farms that have exceeded a value of flows greater than 211 (corresponding to the 99th percentile) at least once in the 2006-2013 period. Again, the rationale of this selection is to retain only structures whose (production) capacity is compatible with the farming activity and to exclude premises used as assembly centers and/or staging points.[23]

4 Econometric analysis

This section presents our empirical analysis to test the main predictions of the theoretical model derived in subsection 2.2: a farm's performance is an increasing function of its involvement in importing; the performance of a farm that uses only traditional domestic bovines is not affected by the proportion of supported links; the effect of importing on productivity positively depends on the proportion of supported links. In subsection 4.1, we present our empirical model and describe the variables used in the analysis. In subsection 4.2 the main results are commented and then, in subsection 4.3, we test the robustness of these results to confounding mechanisms related to the network structure, to externalities/spillovers connected to farm location and to alternative measures of involvement in importing and of network closure.

4.1 Empirical Framework

Our empirical analysis uses the exact information on the number of bovines exiting from a registered farm to estimate a plant-level production function, thus avoiding omitted price bias and optimally using information at the highest level of disaggregation (Van Beveren, 2012). The following regression equation is estimated to assess the advantages of using foreign bovines and the role of the network structure in amplifying the import premium:

$$\begin{aligned} \text{OutFlow}_{it} = {} & \beta_0 + \beta_1 \,\text{InFlow}_{i,[t-4,t-1]} + \beta_2 \,\text{Foreign}_{i,[t-4,t-1]} + \\ & + \beta_3 \,\text{Support}_{i,s,[t-4,t-1]} + \beta_4 \left(\text{Foreign}_{i,[t-4,t-1]} \times \text{Support}_{i,s,[t-4,t-1]}\right) + \\ & + \boldsymbol{X}_{i,[t-4,t-1]} \cdot \boldsymbol{\beta_5} + \theta_t + v_i + \varepsilon_{it}, \end{aligned} \tag{3}$$

for all farm $i = 1, \ldots, N$, quarter $t = 1, \ldots, T$ and owner $s = 1, \ldots, S$.

[22] The 99th percentile of the stock is equal to 763 bovines, whereas the median and the 75th percentiles are 41 and 101 respectively. The 99th percentile for the number of suppliers (the variable Indegree that we will later use as a control in the regression) is equal to 34. The median and the 75th percentile are 1 and 3 , respectively.

[23] The 99th percentile is approximately 10 times the 90th percentile (22 animals) and almost four times the 95th percentile (58 bovines). The empirical results of the paper do not change if we apply more restrictive selection criteria.

Our dependent variable, OutFlow_{it}, is the number of bovines exiting in quarter t from farm i and directed to other farms or slaughterhouses. As mentioned in Section 3, this outflow of bovines from a farm can be considered as the completion of a production stage.[24]

The variable $\text{InFlow}_{i,[t-4,t-1]}$ measures the total number of bovines entering in farm i in the year preceding t (i.e. from quarter $t-4$ to quarter $t-1$ included). We retain in the sample only farms which have been active from $t-4$ to $t-1$, i.e. have been receiving a positive amount of animals in the previous year. The variable $\text{Foreign}_{i,[t-4,t-1]}$, which represents the percentage of foreign livestock over the total inflow of bovines entered in the same period, is our main proxy of the degree of a farm's involvement in importing. As mentioned in subsection 2.2, this variable is a more refined and a more standard proxy of the "internationalization intensity" of a firm with respect to the proportion of connected farms which are importers (i.e. relative degree), that is the variable on which Proposition 2 provides a prediction. Nonetheless, in subsection 4.3 we show that the results are robust to using the relative indegree, which is the ratio between the number of connected providers of farm i that use foreign bovines over the total number of its providers during the year preceding t.[25] Notice that in the empirical analysis we use indegree and relative indegree instead of degree and relative degree, respectively, because the portion of degree due to outdegree (i.e. the number of outgoing links) is endogenous, being mechanically correlated with the number of exiting bovines, our dependent variable.

The choice of measuring all regressors in a one-year time window is supported by the goodness-of-fit indexes and is also motivated by the need to encompass production/fattening stages of different length (from 3 to 12 months). The different time windows chosen for the measurement of the dependent and independent variables explicitly exclude fattening stages shorter than 3 months, because these represent a tiny portion of total fattening stages (Field, 2017).

In line with Jackson *et al.* (2012), the variable $\text{Support}_{i,s,[t-4,t-1]}$ measures the proportion of supported links of the owner s of farm i, i.e. the ratio between the number of links of s with owners that share a common neighbor over the total number of links of s. As explained in Section 3, this index is constructed using the ownership network and thus represents a measure specific to owner s of farm i. When farm i hosts simultaneously bovines of different owners, the above variable takes the maximum value of the proportion of supported links across the different owners of bovines in farm i. The interaction between the share of foreign bovines and the measure of support is introduced to test the importance of closed and transitive relationships for importers. We compute a support index for all importers and non-importers (as opposed to creating a specific measure for the two groups or to the subgroup of importers). Since in the majority of the cases the links among importers are supported by other importers, this "global" support index is a good proxy

[24] Even if the transfer of livestock occurs between two holdings belonging to the same owner.

[25] The relative indegree is computed consistently with the definition done in the model and used in Proposition 2: the number of connections with other importers (independently of the origin of the cattle traded) divided by the total number of connections that one has.

of the support index computed using only the subnetwork of importers. Indeed, in the prediction of our stylized model of Section 2, the support measure which is relevant for the performance of importers is that computed only within the subnetwork of importers, while having supported links of any kind is not affecting the efficiency with which domestic inputs are used.[26]

The control variables $\boldsymbol{X}_{i,[t-4,t-1]}$ include the average age of bovines entered in farm i which implicitly indicates the position of the production stage within the supply chain. The estimations also control for size dummies constructed using the information on the stock of bovines measured at $t-4$ before any inflow or outflow of bovines in that quarter. Additional network measures are included and discussed at the end of this section.

Lastly, v_i captures farm-specific fixed effects, i.e. time invariant unobserved attributes related to the production structure such as geographic location or owner-specific attributes, while θ_t captures time dummies measured on a quarterly basis from 2007Q1 to 2013Q4.

In our basic specification the error term ε_{it} includes omitted inputs such as labor, capital and managerial skills. These components may, in principle, vary over time and be correlated with the included regressors and and with unobserved factors affecting productivity. Beef farming system in Piedmont is, however, characterized by labor almost entirely provided by the family (Sarzeaud *et al.*, 2008; Rama, 2008, 2009, 2010, 2011, 2012). Similarly, the other fixed costs represented by facilities and equipment, although not negligible in absolute terms, represent a minor portion of total costs. The purchase cost of the animal and feeding cost represent the greater portion of total expenses (Sarzeaud *et al.*, 2008; Rama, 2008, 2009, 2010, 2011, 2012). In the period under analysis, these two cost items have been subjected to wide fluctuations determined by variations in the price of feed, in the purchase cost of imported weaners and in weather conditions affecting the production of home-grown feed (Rama, 2008, 2009, 2010, 2011, 2012). Hence, most of the variations in the number of bovines entering in each holding and in the relative proportion of imported animals, are determined by unanticipated shocks in input prices. By focusing on highly disaggregated structures with a given level of production capacity, we can consider the amount of fixed capital and family labor used in each farm as time-invariant and we can assume that the contribution of these omitted inputs is captured by structure-specific fixed effects. With most of within variation in the regressors being determined by unpredictable shocks we can assume, as conventionally done in the context of the estimation of a production function of an agricultural product (Aguirregabiria, 2009), that the assumptions of fixed effect regressions are satisfied.

The main driver of changes in productivity that, if unobserved, would potentially create simultaneity bias, is the investment in inputs characterized by higher marginal productivity. The inclusion as a regressor of the proportion of foreign bovines aims at controlling for this innovation in the production system. The interaction of this measure of import intensity with the percentage

[26] Indeed, a generic link between two importers is supported by a generic firm or by another importer in 41.29% or 38.4% of the times, respectively. Whereas a link between two non-importers is supported (by any firm) only 15.95% of the times.

Table 1: Descriptive statistics

	(1)	(2)	(3)
	Foreign = 0	Foreign > 0	Total
Outflow	5.594	25.65	9.408
	(10.29)	(32.91)	(18.80)
Foreign	0	76.40	14.53
	(0)	(32.27)	(33.12)
Relative Indegree	0.138	0.769	0.258
	(0.284)	(0.307)	(0.380)
InFlow	14.12	103.0	31.03
	(29.15)	(118.5)	(67.65)
Mean Age	15.30	18.05	15.82
	(23.85)	(18.27)	(22.92)
Size $\leq$ 30	0.495	0.225	0.444
	(0.500)	(0.417)	(0.497)
30 < Size $\leq$ 100	0.328	0.382	0.339
	(0.470)	(0.486)	(0.473)
Size > 100	0.177	0.393	0.218
	(0.381)	(0.488)	(0.413)
Support	0.175	0.300	0.199
	(0.303)	(0.398)	(0.327)
Transitivity	0.0383	0.0645	0.0433
	(0.136)	(0.189)	(0.148)
Eigen Centrality	0.00112	0.00351	0.00157
	(0.0115)	(0.0284)	(0.0162)
Betweenness	364336.9	895497.4	465349.7
	(3476988.3)	(4637422.3)	(3731416.4)
Closeness	0.110	0.0897	0.106
	(0.0306)	(0.0643)	(0.0401)
Indegree	2.011	3.481	2.291
	(4.639)	(7.603)	(5.362)
Indegree$_s$	3.609	3.952	3.674
	(4.502)	(5.276)	(4.661)
Number of observations	105820	24850	130670

Descriptive statistics on the final sample used for estimation. Means and Standard errors in parenthesis. Column 1 reports the descriptive statistics for farms who are not using foreign bovines. Column 2 refers to farms that received at least one foreign bovine. Column 3 reports the statistics for the entire sample used for estimations. In two-tailed tests for the difference between the means in 1 and 2, the equality of the means is rejected for all the variables with p-values < 0.001. The statistics for the variable Outflow refer to time t, whereas all the other descriptive statistics on the independent variables are computed on a yearly basis in the quarters $[t-4, t-1]$. Indegree is the indegree index in the network constructed using the information on ownership. Indegree$_s$ is the number of holdings (structures) sending bovines to farm i. Closeness (computed as in Newman 2003) is multiplied by 10^9 for scaling purposes.

Table 2: Correlation among main variables

	Foreign	Relative Indegree	Support	Transitivity
Foreign	1			
Relative Indegree	0.686	1		
Support	0.098	0.090	1	
Transitivity	0.046	0.050	0.520	1

Correlations are calculated for the sample used in the main analysis (the number of observations is 130670).

of supported links captures the heterogeneity in productivity gains which is potentially associated with the effect of network closure.

Table 1 reports some descriptive statistics (i.e. average and standard deviation) of the dependent and independent variables used in the analysis, for the subsample of farms using only livestock born in Italy (column 1), structures receiving at least one foreign bovine (column 2) and the entire sample of farms (column 3). Holdings breeding foreign livestock are larger than farms housing only domestic bovines. There are not marked differences in the mean age of cattle transiting through the two different types of premises. Farms receiving imported animals display, however, inflows and outflows that are much larger than the corresponding values for the other holdings. These results are in line with the literature showing that importers are larger and exhibit significant performance premia relative to non-importing firms (Bernard *et al.*, 2009; Castellani *et al.*, 2010). Together with the proportion of supported links, which is 30% for farms using foreign breeds and 17% for holdings using domestic animals, these variables are used in the baseline specification (i.e. equation 3) whose estimates are presented in subsection 4.2.

In addition to support, other local network characteristics of the node are described using the four main concepts of centrality (Jackson *et al.*, 2017): (direct) "connectivity", the number of direct links of a node, which we measure with the indegree of a node; "closeness", the reciprocal of the sum of the length of the shortest paths from the node to all other nodes, which describes the easiness to reach information flows both directly and indirectly; "intermediation" (a.k.a. the betweenness), the number of shortest paths between any two nodes passing through the owner of farm i; and "having well-connected neighbors", which we measure using the eigenvector centrality. These statistics are used as additional explanatory variables in the robustness checks presented in subsection 4.3 together with an alternative measure of clustering, transitivity, which is defined as the number of existing edges between the neighbors of node i divided by the number of all the possible edges between the neighbors of node i.[27] As shown in Table 1, with the exception of the closeness index, the other networks measures (support, transitivity, eigenvector centrality, betweenness and indegrees) exhibit higher values for farms breeding foreign livestock, thus indicating that importing

[27] All these statistics are computed on a yearly basis in the period $[t-4, t-1]$.

firms also tend be better connected within the production network, both in terms of centrality and clustering measures. Finally, we also report the average value of the relative indegree (the ratio between the number of connected providers of farm i that use foreign bovines over the total number of its providers during the year preceding t) which is, as expected, relatively higher for farms using foreign bovines. Indeed, this alternative proxy of involvement in importing is highly correlated with the variable Foreign (i.e. the Pearson correlation coefficient is 0.686, as shown in Table 2).[28]

4.2 Main results

In this section we present the empirical results obtained by estimating equation 3 with different sets of control variables and for different samples.

In the first column of Table 3, we report the results for a specification in which we control for: the total number of bovines entering in farm i during the year preceding t (i.e. from quarter $t-4$ to quarter $t-1$ included), quarter fixed effects and production-unit fixed effects.

For a farm with no supported links, we estimate that an increase of 10 points in the percentage of foreign livestock (over the total inflow of bovines entered in the same period) is associated with a rise in the number of bovines exiting the farm of approximately 0.16 which, compared with the observed average of the dependent variable (i.e., 9.4), corresponds to an economically (and statistically) significant effect of 1.7%. By looking at the estimated coefficient associated with the interaction between the support index and the share of foreign cattle, it is apparent that network closure is a fundamental determinant of the heterogeneity of the import effect. In fact, for a production unit whose links are all supported (i.e. the Support variable is 1), the effect of an increase of 10 points in the percentage of foreign livestock is estimated to be around 4.1%. This evidence is consistent with our model (Prediction 1 at page 10), and with the literature finding a positive effect of imported inputs on firms' performance, but it also suggests that such effect is heterogeneous depending on the closure of the network in which production units are embedded (Prediction 2). Moreover, consistently with our stylized model (Prediction 3), the support index, which is a proxy of trust between firms, has no statistically significant effect for firms using only domestic intermediate inputs, as shown by the estimated coefficient for the support index when not interacted.

In the second column of Table 3, we additionally control for the average age of bovines entered in farm i to take into account that farms are specialized in different stages of the production chain (which are defined by specific age of the bovines) characterized by different fattening times. The results shown in the third column (of Table 3) are obtained by introducing in the previous specification also size dummies (defined using the observed stock of bovines at the beginning of $t-4$)

[28] If the relative degree were computed by counting only the links involving the trade of foreign breeds over the total number of links that one has (see Note 25 for the actual definition), this would result in an even higher correlation coefficient with the proportion of foreign cattle used in production (i.e. 0.94)

Table 3: Main Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	0.016***	0.016***	0.016***	0.014***	0.012***	0.020***	0.017***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
InFlow	0.108***	0.108***	0.108***	0.113***	0.109***	0.114***	0.110***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Support	-0.164	-0.155	-0.150	-0.068	-0.014	-0.048	0.012
	(0.115)	(0.114)	(0.114)	(0.112)	(0.175)	(0.118)	(0.189)
Support $\times$ Foreign	0.023***	0.023***	0.023***	0.021***	0.013**	0.023***	0.014**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Mean Age		-0.005***	-0.005***	-0.004***	-0.003*	-0.005***	-0.004*
		(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
$30 < \text{Size} \leq 100$			0.312***	0.299***	0.361***	0.294***	0.343***
			(0.086)	(0.086)	(0.119)	(0.092)	(0.131)
Size > 100			0.674***	0.650***	1.182***	0.675***	1.264***
			(0.136)	(0.137)	(0.195)	(0.148)	(0.217)
Indegree_s				-0.137***	-0.091**	-0.131***	-0.077**
				(0.029)	(0.036)	(0.030)	(0.037)
Constant	5.208***	5.271***	5.026***	5.459***	6.481***	5.418***	6.484***
	(0.225)	(0.223)	(0.230)	(0.224)	(0.351)	(0.237)	(0.380)
Adj. R^2	0.740	0.740	0.740	0.741	0.771	0.742	0.772
N	130670	130670	130670	130670	76844	122013	70114

All specifications include quarterly dummies and farm fixed effects. Clustered standard errors at the farm level in parenthesis. *** significant at 1%; **significant at 5%; *significant at 10%. Indegree_s is the number of holdings (structures) sending bovines to farm i.

in order to take into account possible economies of scale related to the use of imported bovines. In the fourth column, we present the estimates obtained by additionally controlling for the number of holdings (including structures different from farms) providing bovines to farm i (during the periods $t-4$ to $t-1$). We expect that the higher the number of providers the more complex will be for farmers to adjust their production techniques to the needs of the bovines. The results of these additional specifications confirm the findings of the first column.

In the last three columns we report the estimates obtained when using the specification employed in the fourth column but with a changed sample. In the fifth column we repeat our analysis by restricting the sample to farms whose inflows of bovines have an average age equal or greater than 6 months. This is motivated by the fact that the movements of foreign bovines may occur at different ages than domestic animals because, by definition, animals are not observed before import. Moreover, we verify whether our results are driven by peculiarities in the earlier stages of production (i.e. weaning or fattening of calves). In the sixth column, we retain in the sample only farms that are classified as meat producers. In the last column we combine these sample restrictions. The main results are still robust to these different sample definitions.

4.3 Robustness Checks and Alternative Explanations

Both in the theoretical section and in the baseline regressions we have underlined the importance of a local pattern of the network, the support index, in favoring cooperation and trust. In the following empirical analyses we consider other possible mechanisms that could foster firm efficiency and are related to the network structure and farm location (see Table 4). Moreover, we show that the results are robust to using the relative indegree, instead of the the share of foreign cattle, as proxy of a farm's involvement in importing (see Table 5).

Although we control for time-constant unobservable farm characteristics (together with relevant time-varying observables), in principle it is still possible that firms increasing their involvement in importing do so because they invest in the necessary know-how and that these firms tend to increase also their clustering by interacting more with each other. In order to take into account this possible confounding mechanism, we introduce as additional explanatory variable the transitivity (a.k.a. clustering) coefficient, which is an alternative measure of network closure around node i. It is worth recalling that the basic difference between the transitivity coefficient and support index (Jackson *et al.*, 2012) is that the former describes the extent to which contacts of node i are also in contact with each other, thus capturing both the intensity of interconnections in i's neighborhood and the closure of triplets originating from i, whereas the latter isolates only the closure aspect connected to trust between agents since it counts the neighbors that share at least one neighbor with i. As expected, the two network statistics are positively correlated at 68.6%, as shown in Table 2. In the first column of Table 4 we substitute the support index (and its interaction with import share) with the transitivity coefficient (and its interaction with import share). In the second column, we include both the support index and the transitivity coefficient (and their interaction with the import share). We do not find any statistically and/or economically relevant effect of the transitivity coefficient (column 1) and, most importantly, the previous results about the support index and its interaction with the share of foreign bovines continue to hold (column 2). Therefore, only the closure aspect of connections is important for enhancing the performances of importers, while how much their neighbors actually connect to each other is irrelevant. These findings suggest that the detected positive effect of the support index on importers' performance cannot be ascribed to omitted variables, such as increases in knowledge or productivity, which could simultaneously determine an increase in the import share and in the clustering of highly productive firms.

A possible alternative explanation that is worth testing is whether it is the position of the owner in the input-output network to be the driver of the augmented performance and the observed heterogeneity in the gains from import. To test for this hypothesis, we control for several local measures of centrality of the owner and for the corresponding interaction of these variables with the share of foreign bovines.[29] In the third column of Table 4 we report the estimates from this robustness check. The previous results remain unaltered, and all forms of centrality are statistically non-significant. This suggests that it can be safely excluded that firms' performances are relevantly determined by other information-related mechanisms, such as knowledge spreading or information flowing in the network, or nodes acting as gatekeepers in intermediation with others.

In the fourth column of Table 4 we take into account also the possible role of Marshallian externalities by controlling for the specialization of the municipality in the cattle industry as proxied by the share of bovines traded in the municipality over the total number of bovines traded in Piedmont (per quarter) (i.e. the variable Spec Mun). In the fifth column we consider possible spillovers between importers by adding a proxy for the specialization of the municipality in foreign cattle: the share of farms using foreign bovines in the municipality over the total number of farms using foreign bovines in Piedmont (per quarter) (i.e. the variable Spec Imp Mun). Moreover, the introduction of this explanatory variable allows us to control, at least at the local level, for unobserved factors which may have simultaneously fostered the adoption of foreign breeds and affected the structure of the production network. Finally, in the sixth column we introduce municipality-by-quarter fixed effects, which pick up all the productivity and demand shocks common to the firms located in the same municipality, such as weather conditions, infectious diseases, input prices, knowledge flows, consumers' preferences and so on. Also in this case the basic results remain unaltered.

Lastly, using the same specifications presented in Table 4, in Table 5 we report the results obtained by substituting the percentage of foreign bovines (i.e. the variable Foreign) with the ratio between the number of connected providers of farm i that use foreign bovines over the total number of its providers (i.e. the variable Relative Indegree). As explained in the subsections 2.2 and 4.1,

[29] Given farm i, the centrality of its owner(s) is computed in the network of owners, that is the ownership network shown in Figures 2 and 3.

the relative indegree is the measure of importing activities suggested by our theoretical model in which only the extensive margin of importing matter (i.e. the number of trade partners that are importing). The results of Table 5 are very similar to those obtained in Table 4. According to the most demanding specification (column 6, with municipality by quarter fixed effects), for a farm with no supported links a rise of 0.10 in the proportion of connected providers that use foreign bovines is associated with an increase in the number of bovines exiting the farm of approximately 0.07. Compared with the observed average of the dependent variable (i.e. 9.4), this figure corresponds to an economically (and statistically) significant effect of 0.8%. For a production unit whose links are all supported (i.e. the Support variable is 1), the effect of an increase of 0.10 in the relative indegree is estimated to be around 2%. Also this measure confirms that a farm's performance is increasing in its degree of involvement in importing and that this import effect positively depends on the fraction of its supported links.

5 Conclusions

This paper shows that import gains are higher for firms whose supply chain exhibits higher network closure. This, in turn, shows the importance of trust for promoting the adoption of innovative or efficient technologies and behaviors in an production networks.

These findings are consistent with previous studies indicating that social networks, especially in contexts where well-functioning formal institutions are absent, are often used to enforce informal contracts and to enhance cooperation, which can ultimately lead to higher economic achievements (Chandrasekhar *et al.*, 2016). In particular, other analyses, mainly conducted in traditional sectors of developing economies, have already found that specific network characteristics can help explaining the adoption of more productive technologies or inputs (Conley and Udry, 2010; Foster and Rosenzweig, 2010; Krishnan and Patnam, 2013; Munshi, 2004; Bandiera and Rasul, 2006). For example, in Gehrke and Grimm (2018), the authors show that limited access to information may constitute part of the entry costs that hamper the diffusion of modern cattle breeds in rural areas of India despite their higher returns.

Our case study shows that in a developed economy, where institutions should not be a major obstacle to access information and services (also related to customization costs associated with investments in modern breeds), local characteristics of the network structure related to trust are a key factor in explaining the benefits of adopting an advanced imported input. Analyzing the heterogeneity of local features of the network of firms within the supply chain, thus, proves to be an extremely important tool to understand the distribution of productivity gains in the economy.

For the sector under analysis, our findings clearly indicate to policy makers that interventions aimed at improving productivity should mainly promote the adoption of high quality inputs in areas characterized by high levels of network closure.

Table 4: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
Foreign	0.021***	0.016***	0.011***	0.002	0.005	0.014***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
InFlow	0.109***	0.108***	0.112***	0.110***	0.112***	0.110***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Transitivity	-0.273	-0.156	-0.301	-0.378	-0.312	-0.194
	(0.201)	(0.285)	(0.286)	(0.286)	(0.286)	(0.321)
Transitivity × Foreign	-0.004	-0.017	-0.018	-0.016	-0.018	-0.018
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Mean Age	-0.005***	-0.005***	-0.005***	-0.004***	-0.005***	-0.005**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
$30 < \text{Size} \leq 100$	0.312***	0.313***	0.298***	0.297***	0.298***	0.323***
	(0.086)	(0.086)	(0.086)	(0.087)	(0.086)	(0.103)
Size > 100	0.673***	0.675***	0.651***	0.650***	0.650***	0.692***
	(0.136)	(0.136)	(0.136)	(0.136)	(0.136)	(0.151)
Support		-0.105	0.071	0.113	0.082	-0.058
		(0.162)	(0.159)	(0.160)	(0.159)	(0.182)
Support × Foreign		0.026***	0.019***	0.017**	0.018***	0.017**
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Eigen Centrality			-4.023	-4.977	-4.074	-4.489
			(6.003)	(6.005)	(6.004)	(6.663)
Eigen Centrality × Foreign			0.031	0.037	0.031	0.037
			(0.239)	(0.238)	(0.238)	(0.256)
Betweenness			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Betweenness × Foreign			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Closeness			0.773	1.244	0.929	0.841
			(1.023)	(1.028)	(1.022)	(1.232)
Closeness × Foreign			-0.016	-0.033	-0.020	-0.002
			(0.042)	(0.042)	(0.042)	(0.046)
Indegree			0.006	0.006	0.005	0.014
			(0.029)	(0.028)	(0.029)	(0.031)
Indegree × Foreign			0.002*	0.002*	0.002*	0.002
			(0.001)	(0.001)	(0.001)	(0.001)
Indegree_s			-0.143***	-0.135***	-0.141***	-0.150***
			(0.029)	(0.029)	(0.029)	(0.032)
Indegree_s × Foreign			0.000	0.000	0.000	0.000
			(0.002)	(0.002)	(0.002)	(0.002)
Spec Mun				415.234***		
				(37.667)		
Spec Mun × Foreign				2.210***		
				(0.507)		
Spec Imp Mun					13.306	
					(33.070)	
Spec Imp Mun × Foreign					1.021**	
					(0.405)	
Constant	4.998***	5.017***	5.385***	2.672***	5.278***	
	(0.232)	(0.231)	(0.233)	(0.329)	(0.287)	
Adj. R^2	0.052	0.053	0.054	0.059	0.054	0.725
N	130670	130670	130670	130670	130670	123927

Specifications (1)-(5) include quarterly dummies and farm fixed effects. Specification (6) contains municipality-by-quarter fixed effects and farm fixed effects. Indegree is the indegree index in the network constructed using the information on ownership. Indegree_s is the number of holdings (structures) sending bovines to farm i. Clustered standard errors at the farm level in parenthesis. *** significant at 1%; **significant at 5%; *significant at 10%.

Table 5: Additional Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
Relative Indegree	0.433***	0.237**	0.725***	0.365	0.591**	0.702**
	(0.123)	(0.109)	(0.246)	(0.257)	(0.260)	(0.288)
InFlow	0.111***	0.110***	0.116***	0.115***	0.116***	0.114***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Transitivity	-0.212	-0.145	-0.207	-0.265	-0.211	-0.032
	(0.211)	(0.307)	(0.310)	(0.310)	(0.310)	(0.358)
Transitivity × Relative Indegree	-0.385	-1.212	-1.182	-1.088	-1.174	-1.358
	(0.885)	(1.020)	(1.009)	(1.001)	(1.009)	(1.074)
Mean Age	-0.004***	-0.004***	-0.004**	-0.004**	-0.004***	-0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
$30 < \text{Size} \leq 100$	0.315***	0.316***	0.300***	0.302***	0.301***	0.324***
	(0.086)	(0.086)	(0.087)	(0.087)	(0.087)	(0.103)
Size > 100	0.686***	0.686***	0.653***	0.654***	0.652***	0.693***
	(0.137)	(0.137)	(0.137)	(0.136)	(0.137)	(0.151)
Support		-0.052	-0.008	0.008	-0.007	-0.164
		(0.189)	(0.187)	(0.186)	(0.186)	(0.213)
Support × Relative Indegree		1.257***	1.148**	1.070**	1.126**	1.161**
		(0.470)	(0.467)	(0.467)	(0.467)	(0.523)
Eigen Centrality			-4.777	-6.062	-4.905	-3.434
			(7.562)	(7.570)	(7.558)	(8.578)
Eigen Centrality × Relative Indegree			7.958	9.032	8.199	5.224
			(17.124)	(17.082)	(17.137)	(18.398)
Betweenness			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Betweenness × Relative Indegree			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Closeness			1.260	1.496	1.418	1.089
			(1.665)	(1.667)	(1.656)	(2.010)
Closeness × Relative Indegree			0.281	0.381	0.273	1.138
			(2.623)	(2.634)	(2.626)	(3.119)
Indegree			0.052*	0.053*	0.052*	0.058*
			(0.030)	(0.030)	(0.030)	(0.033)
Indegree × Relative Indegree			-0.034	-0.038	-0.036	-0.034
			(0.050)	(0.050)	(0.050)	(0.055)
Indegree_s			-0.107***	-0.104***	-0.106***	-0.112***
			(0.028)	(0.028)	(0.028)	(0.031)
Indegree_s × Relative Indegree			-0.354***	-0.352***	-0.359***	-0.397***
			(0.115)	(0.114)	(0.115)	(0.124)
Spec Mun				439.135***		
				(38.586)		
Spec Mun × Relative Indegree				68.531***		
				(17.945)		
Spec Imp Mun					51.959	
					(33.811)	
Spec Imp Mun × Relative Indegree					27.901	
					(18.491)	
Constant	5.147***	5.147***	5.299***	2.544***	5.023***	
	(0.232)	(0.231)	(0.264)	(0.361)	(0.318)	
Adj. R^2	0.052	0.052	0.053	0.057	0.053	0.724
N	130670	130670	130670	130670	130670	123927

Specifications (1)-(5) include quarterly dummies and farm fixed effects. Specification (6) contains municipality-by-quarter fixed effects and farm fixed effects. Indegree is the indegree index in the network constructed using the information on ownership. Indegree_s is the number of holdings (structures) sending bovines to farm i. Clustered standard errors at the farm level in parenthesis. *** significant at 1%; **significant at 5%; *significant at 10%.

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