The Dynamic Welfare Consequences of Trade Restrictions

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Abstract

Food exporting countries often restrict exports when faced with international price increases. The goal of such measures is to redistribute income from exporters to consumers. What is the effect of such policy on the exporting countries? I study that question in the context of restrictions on the exports of beef in Argentina in the period 2006-2015. I construct a novel county-level dataset of yearly cattle stock disaggregated by variety, and use it to inform a structural model of land use that incorporates the dynamic problem of cattle raising. Quantitative analysis shows the policy to be blunt; it loses most of the welfare it is trying to redistribute, and it has negative spillovers for domestic producers. The dynamics are perverse; effects are strongest in the short run, but as exporters adjust to the policy, consumer gains dwindle and the burden of the policy is shifted to domestic producers. This may explain why these policies tend to be short-lived.

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1 Introduction

International food price increases are often met with a wave of export restrictions in the developing world. Most recently, during the Ukraine 2022 crisis, 34 countries took 74 policy measures restricting exports, 20 of which were full export bans [Espitia et al., 2022]. This policy response has been a source of concern for economic multilateral agencies, from the WTO to the IMF [Bounds, 2022] [Rother et al., 2022] [Malpass, 2022], as it magnifies the initial shock [Giordani et al., 2016], especially hurting food-importing low-income countries. On the exporter side, the intended goal of the policy is to distribute income from exporters to domestic consumers. However, exporters do not exist in isolation. Their contraction may hurt their suppliers, as well as benefit other firms who compete for their inputs.

This paper studies the distributional consequences of export bans by focusing on an episode of export restrictions on Argentine beef in the early 2000s. I construct a novel yearly panel of agricultural land shares and cattle stocks, and a time series of slaughter and prices. I write down a dynamic structural model incorporating two types of ranchers, one that sells a domestic variety and another that produces an export variety, and agricultural producers who compete with cattle producers for land. I find that domestic producers lose three times as much as exporters due to the restrictions, and almost half of the total income captured from producers is not transferred to consumers or agricultural producers, but lost. The effects of the ban are concentrated in the short run; as time passes, consumer gains dwindle, and the burden of the ban is passed to domestic producers.

The specific episode studied is the effect of export restrictions on the Argentine market for cattle from 2006 to 2015. In the early 2000s, inflation reached double digits with price increases in beef doubling the average inflation rate. Policymakers were greatly concerned about beef prices, because beef is a staple in Argentina, where per capita beef consumption is 100 lbs/year – the largest in the world. This means that prices of beef not only greatly affect real income, but also are very salient to consumers. The government aimed to curb the price increase with increasingly stronger restrictions on exports. As a result, total exports fell by 75% from 2005 to 2015.

To analyze the episode, I construct a novel data set combining yearly county-level data on cattle stocks and soybean output, country-level prices and slaughter and exports, and the universe of cattle transactions. I document four facts that guide the modeling approach.

The first fact is that the cattle market is segmented across age and sex. Females are kept for giving birth to more cattle, being slaughtered at the end of their reproductive life. Males are slaughtered at different stages of their physical development depending on consumer preferences, since the age of the animal changes the characteristics of the meat. For males, the development stages from youngest to oldest are: steer calf (breastfeeding), young steer (non-breastfeeding but not fully matured), and (old) steer (fully matured). This paper will focus on young and old steers, from now on simply young and old. These categories composed 46% of total slaughter during the period in heads and 51% by weight, on average.

The second fact is that the sources of demand for each variety are different: Foreign buys old while Home buys both old and young. As exports are restricted, the stock of old collapses. The most important trading partner in this period was the European Union, with over 50% of all purchases overall, and over 90% in chilled beef, which is of higher quality. The transaction-level data reveal that the European Union concentrates its demand for beef almost exclusively on the old variety. Domestic demand, on the other hand, purchases both varieties. At the end of the period, the stock of old falls from 6.5M heads to only 2.7M heads, almost 60%. In the model, I will assume that foreign purchases the old variety exclusively.

The third fact is that cattle contraction was mirrored by soybean expansion. During the period, as stocks of old cattle collapsed, I observe a great expansion in the land use by soybeans. This holds not only at the national level but also at the county level: in counties where cattle stocks fell, soybeans expanded. This suggests either an indirect effect of the ban on agriculture, or agriculture as an additional factor leading to the reduction in cattle stocks. In any case, it highlights the interaction of cattle and agriculture as being of first-order importance during the period.

The fourth fact is that cattle prices vary greatly across time, but barely across space. Using the transaction-level data, I control prices by age, sex, and breed of the animal as well as time. Once controlling for age, sex, breed of the animal, and time, standard demand shifters such as population density or distance to ports show no correlation with price. Moreover, once the fixed effects are used, there is very little residual variation in prices. On the time dimension, however, I observe great variability. I relate this variation to the imposition of the ban, as well as weather shocks, most importantly the 2008-9 drought. This will lead me to consider the market to be integrated nationally, with both agriculture and cattle having time-varying productivity.

Informed by these facts, I build a dynamic structural model. The necessity of a dynamic model arises from the nature of the market under study. Firstly, since the export variety is simply the not-slaughtered variety in the future, accounting itself necessitates keeping track of time. Secondly, while agriculture requires a few months from the growth decision to harvest, cattle are long-lived: females are kept until above 10 years of age and males until 3. This requires ranchers to consider not only this year's prices, but to form expectations about prices in future years.

A relevant example is the effect of a drought. While a drought leads to temporarily lower agricultural output and therefore a temporary increase in prices, it has the opposite effect on the cattle market. During a drought, ranchers cull their animals, as they would rather have them die at the slaughterhouse than starve in their fields. Increased culling means more meat available, which leads to a temporary *reduction* in prices. Once the drought is over, cattle scarcity leads prices to increase, creating incentives for cattle ranchers to increase their cattle stock. A static framework would lead to a completely incorrect identification of productivity, and therefore the teasing out of the effects of the ban would also be incorrect.

Having justified our modeling choice broadly, I present the model in more detail. On the demand side, the representative consumer in Home has CES preferences over two varieties of cattle: young and old. Foreign has quasilinear preferences for old only. Policy affects the competitive solution by restricting the amount foreign may buy from the domestic market.

On the supply side, in each geographical location (county) there is a continuum of plots. Each plot has a Fréchet productivity draw for each use, which includes cattle raising and agriculture. For agriculture, the problem is static: revenue is simply price times productivity. For cattle, the rancher has revenue equal to the expected appreciation of the cattle stock it can feed on that land. All things equal, fields with higher cattle productivity will see farmers choosing to raise cattle. To accommodate weather variation, I make average land productivity random over time. This merges the canonical linear dynamic problem of cattle raising in [Rosen, 1987] with the land share use model of [Costinot et al., 2016].

To deliver a quantitative analysis, values for three key elasticities are needed: Foreign's price elasticity of demand governing the effect of the ban on prices, Home's elasticity of substitution across young and old governing the spillover of the ban to domestic producers, and the supply elasticity between cattle and soybeans governing the effect of the ban on agriculture. I use the [Feenstra, 1994] method improved upon by [Soderbery, 2015] to obtain Foreign's price elasticity of demand. I use time-series variation to obtain Home's elasticity of substitution, obtaining a high degree of substitutability across varieties as in [Aadland, 2004]. Given the identical spatial setting and similar time period, I take the supply elasticity from [Dominguez-Iino, 2021].

Finally, with estimates and the data, I invert the model to obtain the productivity shocks. The model points to strong negative productivity shocks in the years of a historically strong drought (2008-09). Across space, the productivities that the model finds are correlated with external measures of productivity from the Food and Agriculture Organization (FAO).

With these estimates and our data on exports, stocks, slaughter, and prices per variety, I can compute counterfactuals.

In the first counterfactual, I analyze the effects of the ban removing the shocks to demand and productivity. I call this counterfactual an ex-ante analysis, because the policymaker could not have anticipated a once-in-a-lifetime drought interacting with its policy. This helps us understand the mechanisms of the restrictions in the cleanest way possible.

The analysis shows that the ban has the intended effect in the short run. Exporters chose their stock without foreseeing a ban, and must liquidate their stock domestically, incurring losses and depressing prices. Domestic producers are also hurt since the varieties are close substitutes, but less so. Consumers are the clear winners, seeing lower prices of both domestic and exported varieties.

In the long run, exporters will reduce their investment, by buying fewer young to turn into old. This depresses demand for young further, and improves the price of the exported variety since the quantity supplied falls. By lowering their investment, exporters are able to pass the burden of the ban to domestic producers, as well as reducing consumer surplus. In the end, most of the burden is paid by domestic producers, not exporters, and consumer gains exist but are severely mitigated in the long run.

In the second counterfactual, I analyze the effects of the ban while keeping all the shocks. I call this counterfactual the ex-post analysis, since it asks how the economy would have looked like without export restrictions given the realization of supply and demand shocks. The analysis reveals that demand would have led to higher prices for both varieties but not much higher stocks. This is explained by increases in agricultural productivity over the period. During the drought, the ban would have had the least effect, since domestic prices would have been so high that the comparative advantage of Argentina would have been dampened greatly.

However, the overall picture remains consistent. Over the period, the ban reduces rancher surplus by almost 6.5 Bn pesos of 2000[1], with almost 5 Bn or 75% of these losses borne by domestic producers. Consumers gain less than 3 Bn, resulting in total welfare losses of approximately 50%. Export losses amount to $6 Bn USD, more than 20% of Argentina's foreign exchange reserves at the end of the period.

This paper contributes to four different branches of the literature. First, it contributes to the literature on the distributional impact of trade [Porto, 2006] [Topalova, 2010] [Nicita et al., 2014] [Fajgelbaum and Khandelwal, 2016] [Cravino and Sotelo, 2019] [Borusyak and Jaravel, 2021] [Adão et al., 2022] [Galle et al., 2023] and the effects of food price spikes in particular [Martin and Anderson, 2012] [Do et al., 2014] [Martin and Ivanic, 2016] [Giordani et al., 2016]. I contribute by studying the distri-

[1] In the year 2000, the exchange rate of the peso was fixed to be 1 USD. Therefore, PPP differences aside, they can be considered equivalent to USD

butional impact over time, focusing on a critical industry.

Second, it contributes to the literature on agricultural economics. We merge the literature on the dynamics in animal economies [Jarvis, 1974] [Rosen, 1987] [Favaro, 1990] [Rosen et al., 1994] [Aadland, 2004] as well as static agricultural models of land use [Costinot et al., 2016], [Sotelo, 2020], and closest to us [Dominguez-Iino, 2021]. It contributes to the former by explicitly considering the effect of agriculture in a disaggregated manner and to the latter by incorporating cattle, the main user of land, into the empirical analysis. While there is a growing literature incorporating dynamics into agriculture [Vance and Geoghegan, 2002], [Scott, 2014], [Farrokhi et al., 2023], they do not incorporate the dynamic nature of cattle markets, which account for two thirds of land use.

Finally, this paper contributes to a growing literature on the interaction between trade and capital accumulation [Anderson et al., 2015], [Alvarez, 2017], [Ravikumar et al., 2019]. Cattle are a capital good: females can be "saved" for reproduction, and closer to our setting, males can be "saved" to let their body mass increase to produce a larger quantity and a different quality of meat. Since I study a specific market, I am able to measure capital in physical units and do not need to employ aggregates of heterogeneous elements.

This paper is organized as follows. In the next section, I present the data sources and the main stylized facts that inform our modeling choices. After that, I present the model itself. In Section 4, I present the estimation of the main parameters and invert the model to obtain the shocks. In Section 5, I present the counterfactuals. Finally, I conclude.

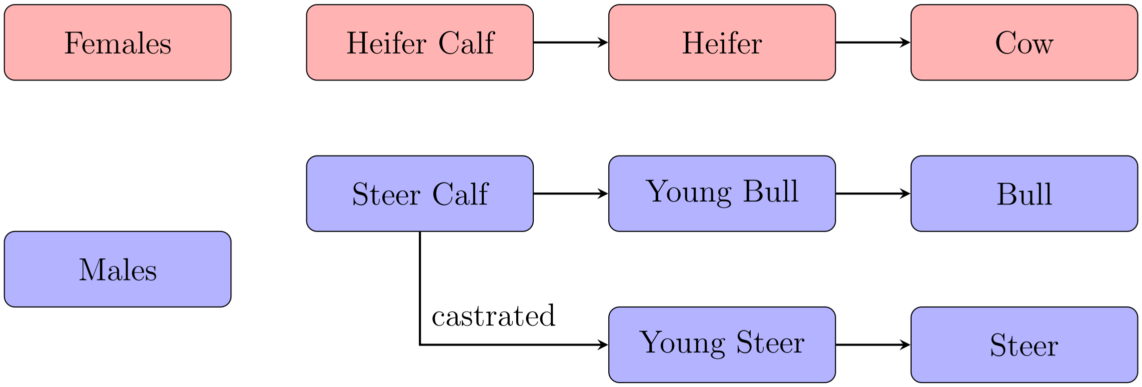
2 Data

In this section, I explain the main data sources that I will use, the main facts that arise from them, and how they will inform the modeling and the counterfactuals.

The main data source is the Argentine National Service of Agricultural Food and Animal Quality and Health (SENASA), which is similar to the US Food and Drug Administration. I construct a panel of cattle stocks per animal category by merging two datasets from SENASA: one from (universal) vaccinations, and the other from stocks proper. I observe 407 out of the 505 Argentine counties for 2005-2015.[2] From SENASA, I also obtained yearly data on total slaughter, from the years 2000-2020. Additionally, I observe the universe of cattle transactions for the period 2018-2022, amounting to a total of 8 million transactions.

[2]The missing data comes from the limitations of the vaccination program, which ignored remote regions such as Patagonia. Thankfully for us, these regions are irrelevant for the aggregate cattle stock.

Figure 1: Cattle Categories



The figure shows the different categories present for cattle. Females in red, males in blue. Categories are ordered from left to right in increasing age.

To obtain data on prices for each category, I scraped the website of the central cattle market of Argentina, the MAG (*Mercado AgroGanadero*, Agricultural and Cattle Market). I constructed a daily time series per age-sex category for the years 2000-2020.

Finally, agricultural data come from the Argentine Secretary of Bioeconomy. I construct a panel of soybean output and land shares for the period 2005-2015 across 505 counties. I also obtain a yearly series of post-tax soybean prices for the same time period.

The **first fact** arising from the data is that **the market for live cattle is segmented by sex and age**. I present a simple description of these categories in Figure (1).

The first major division is by sex. Females are kept for giving birth to more cattle, being slaughtered at the end of their reproductive life (8-12 years of age). For females the development stages from youngest to oldest are: heifer calf (breastfeeding), heifer, and cow (given birth).

Males are slaughtered at different stages of their physical development depending on consumer preferences, as the age of the animal changes the characteristics of the meat. Ranchers may also decide whether to castrate a male or not. An uncastrated male can be used for reproduction, but is harder to handle, as castration increases tameness. Since farmers can choose to artificially inseminate their cows, or if they decide to have traditional insemination the male to female ratio is 1 to 20, so most males are castrated[3]. Like females, reproductive males are kept alive until the end of their reproductive life, but castrated ones are slaughtered much earlier, at the latest

[3] Uncastrated males also develop more muscular mass, giving different meat characteristics. As such the Argentine Ministry of Agriculture through Resolution 4906/2010 created the category Whole Young Male *macho entero joven*, a rebranding of young bull destined to slaughter. I exclude them as they are dwarfed in numbers compared to the main categories.

when they reach maturity (3 years of age). If castrated, the development stages from youngest to oldest are: steer calf (breastfeeding), young steer (non-breastfeeding but not fully matured), and (old) steer (fully matured). If uncastrated, the steer calf turns into a young steer (non-breastfeeding but not fully matured), and later into a bull.

Given their relationship with international trade, this paper will study the markets for young steers, from now on simply "young", and steers, from now on simply "old". There are no hard-set cutoffs between the categories; criteria are usually set with variables that correlate with physical development, such as age, weight, or number of teeth. Calves stop being breastfed around 9 months of age. SENASA's resolution 879/2002 sets the cutoff between young and old at 2 years of age. As such, for our model, I will assume that young steers are 2 years old, and steers 3 years old.

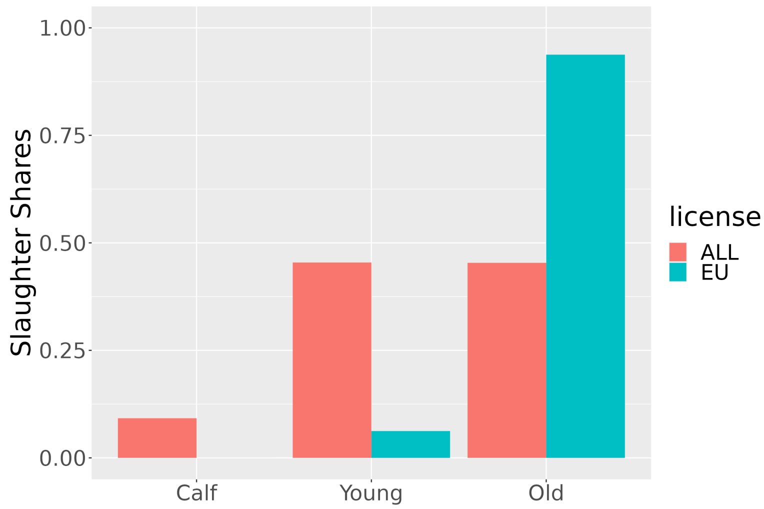
Having explained the different categories, I now match them to export status. The **second fact**, arising from the transaction-level data, is that **foreign demand has a strong preference for the old variety, and as the ban was implemented, the stocks of the export variety fell**. The way I infer this from the data is by looking at licensing to export. Since these data come from a sanitary agency, it includes whether each transaction has the sanitary requirements to be exported to the European Union. While having passed all the sanitary requirements to export to the European Union is a necessary but not a sufficient condition to export to the EU (and the majority of licensed cattle is actually not exported[4]) these data do provide a very clear idea of what cattle varieties are not exported by the European Union.

We observe in Figure 2 the distribution of slaughter of male cattle across age categories, comparing cattle with an EU export license to all cattle. What we observe is that cattle with no EU export license are overall balanced between young and old. Cattle that have an EU export license, however, are almost exclusively old. Given this strong result, and the fact that age categories are always fuzzy (what may appear to be a mature animal for the slaughterhouse may not perfectly coincide with the definition of the sanitary agency at the time), I will make the simplifying assumption in the data that Foreign demands this category exclusively.

Following the ban, we observe changes in stocks across varieties consistent with the EU demanding solely old: as the export market became increasingly closed, the stock of old fell. I present that evolution in Figure 3. The difference is very clear. While the

[4]The reason for this being that the license is not costly for ranchers, so the slaughterhouse requests it in case it secures an export sale. The reason for the license being not costly is, first, the bureaucratic procedure is relatively simple. Second, the actual requirements are fulfilled by most cattle in Argentina. The main requirement is not using any growth hormones (SENASA Res 53/2017) which are both prohibited from being produced and imported into Argentina. Reading in between the regulatory lines, the European regulation aims to forbid the import of cattle being raised under the most extreme practices of US factory farming (corn-fed cattle densely packed in feedlots), which is the diametrically opposite to the way of raising cattle in Argentina (grass-fed cattle spread in fields).

Figure 2: Distribution of EU Export Licensing in Male Cattle Conditional on Age



The figure shows the distribution of licensing to export to the European Union in male cattle, depending on the age category: calves which are breastfeeding males, young steers, which I call simply young and are non-breastfeeding males but not yet fully developed, and steers which I call old and are mature males steers. In red, I show the distribution of slaughter for all cattle. In green, I show the distribution of slaughter that has a European Union export license. The figure shows that EU demand is sharply concentrated on the oldest category: 92% of all male cattle slaughtered with an EU export license were old. Overall demand is actually much more balanced, with young and old being slaughtered at similar rates.

stocks of other categories do experience ups and downs across the years (mainly due to weather), they end in 2015 at a similar level identical to what they were in 2005. The stocks of old monotonically fall after the ban, finishing almost 60% below their initial level.

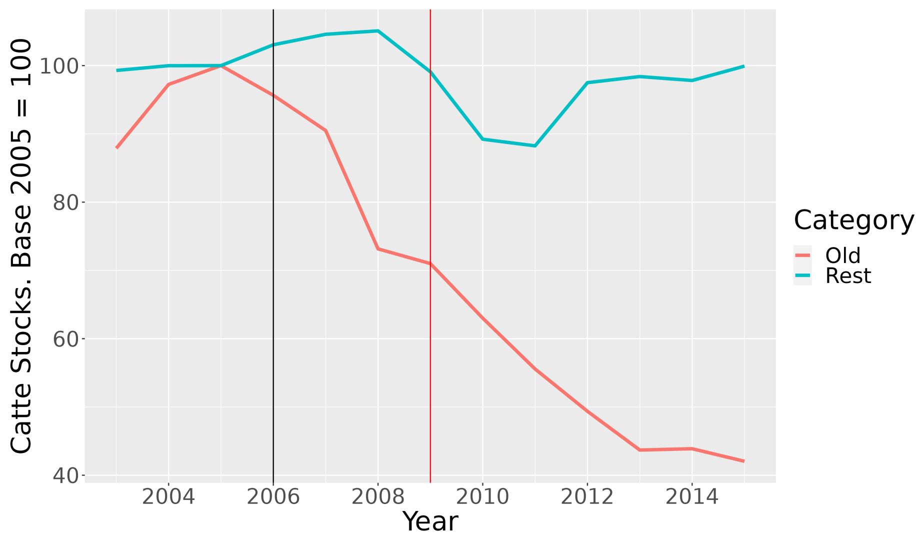
The **third fact** regards the evolution of the main crop in Argentina, soybeans. What the data show is that **as cattle stocks collapsed, soybean cultivation expanded**. I present the time series of aggregate land area sowed in Figure 4. The increase is significant both in relative terms, at approximately 50%, as well as in aggregate terms, adding 5 million hectares.

To relate this variation to the collapse of cattle stocks, I leverage the county-level disaggregation to show that this relationship also holds at this fine level of disaggregation. I present regressions at the year-county level in Table 1. The specification controlling for both time and county fixed effect shows that for each hectare that went to soybeans, the county lost 0.17 units of cattle, on average.

The final stylized fact that will inform the model regards prices. To do so, I leverage both the long time series obtained from the central cattle market in Buenos Aires and the cross section of prices obtained from SENASA in 2018.

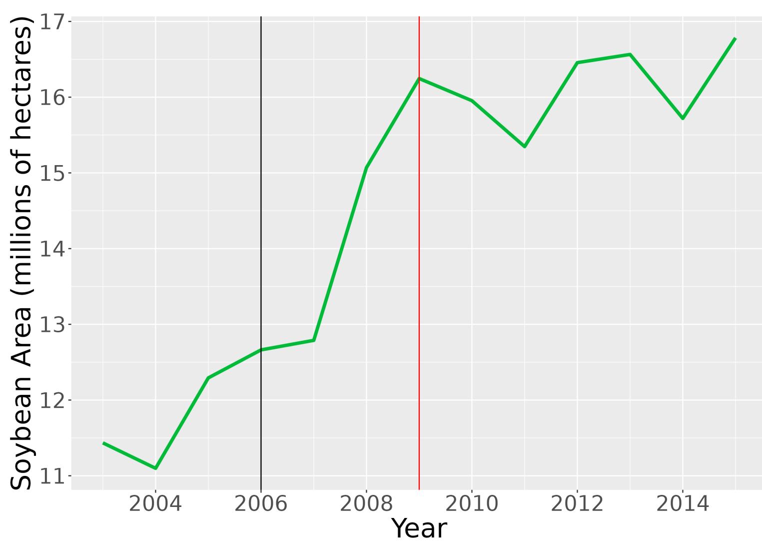
The **fourth fact** is that **prices vary greatly across time are homogeneous**

Figure 3: Evolution of Cattle Stocks



The figure shows a time series of the stock of old, the export category (in green), compared to the stock of other the categories (in red). The vertical line shows the beginning of the export restrictions. Cattle stocks are measured in heads, and 2005, the last year before the restrictions, is taken as a base year.

Figure 4: Soybean Boom



The figure shows the time series of total soybean area sowed per year in Argentina, in hectares. As the cattle stock was contracting, the soybean sector was expanding significantly. The expansion is significant in relative terms, 50%, and in absolute terms, adding 5 million hectares.

Table 1: Cattle Contraction and Soybean Expansion

	DV: Old Stock		
Soybean Area	0.0065***	-0.214***	-0.171***
	(0.004)	(0.008)	(0.007)
Obs	2861	2861	2861
R squared	0.082	0.834	0.859
County FE	NO	YES	YES
Time FE	NO	NO	YES

The table shows the regression of the stock of old cattle (in heads) on soybean area (in hectares), at the year-county level. The first column corresponds to the simple OLS regression. The last specification shows that for each hectare that went to soybeans, the county lost 0.17 units of cattle, on average. Standard errors in parentheses. Statistically significant at *10% **5% ***1%.

across space. Figure 5 shows the average monthly prices per live kg in real pesos of 2000 for young and old. The range of the y axis shows that prices are very volatile, they vary in real terms across the sample by a factor of two. Moreover, prices are very highly correlated with each other. We can also observe a downward trend in prices after the ban was implemented. There is also a collapse in prices during the drought, as farmers had to cull their animals, and an increase in prices once the drought ended and cattle stocks were depleted.

Having shown how prices of different categories vary over time, I now move to explore the spatial variation. To do so, I use the transactional-level data, which include the county of origin of the transaction. I run fixed effects regressions of log prices on breed b, animal Category a, time t, and the covariate of interest X_i that varies only at the county level i.

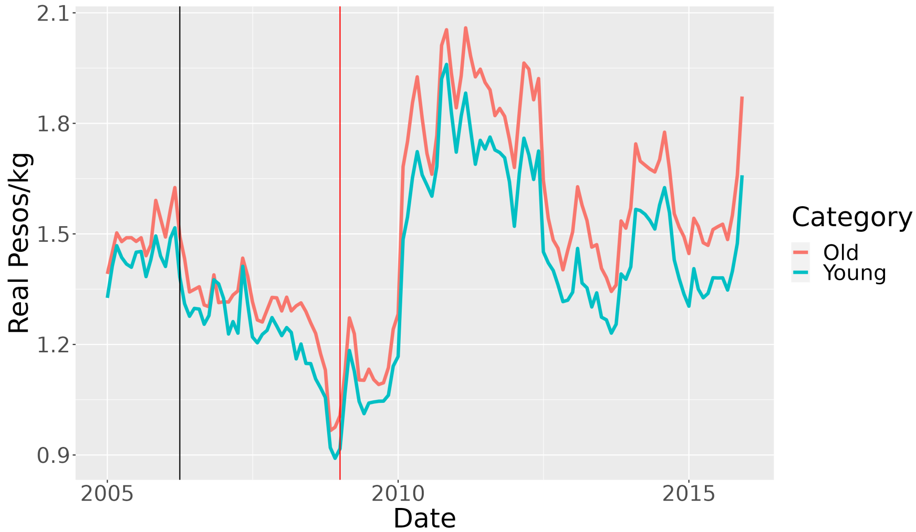
$$\ln P_{ibsa} = \beta X_{it} + \delta_b + \delta_s + \delta_a + \delta_t + \epsilon_{ibsa} \quad (1)$$

I choose to show one result graphically: the relationship between prices and population density. To do so, I save the residuals from the fixed-effects regression without population density as a covariate, and plot a bin scatter of the variable against population density[5] in Figure 6.

The graph shows there is very little variation across space, with deviations of at most 10%. Such variation is not correlated with population density. I take this result to imply that prices are homogeneous across space.

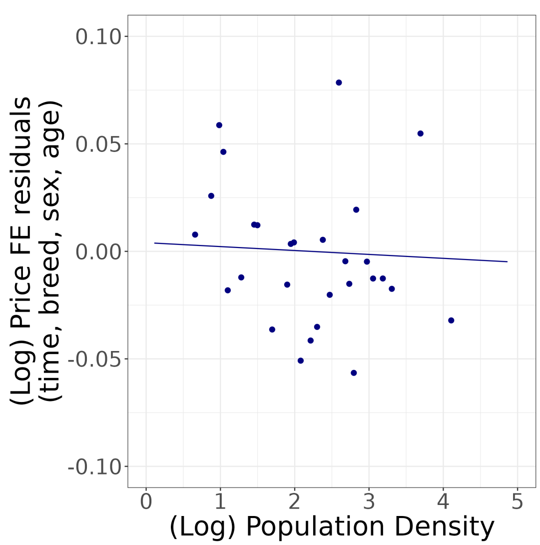
[5]The exact equivalence would be to present the regression of the residuals of price on the dummies on the residuals of population density of the dummies themselves, but I wished to show an informative X axis at the expense of accuracy. In any case, the coefficient can be seen in Table 7

Figure 5: Evolution of Cattle Prices



The figure shows the time series of prices for young and old, from the central Buenos Aires market. The unit is pesos of January 2000 per kilogram of live cattle. The Y axis reveals significant time variation, by an order of two. The black vertical line indicates the beginning of the ban. Prices fell immediately after the ban was implemented. The red vertical line indicates the drought. Prices also collapse during the drought as farmers cull their cattle, and then recover greatly as the cattle stock is depleted and high prices are needed to induce farmers to increase it.

Figure 6: (No) Relationship between Price Residuals and Population Density



The figure shows the relationship between the residuals of a regression of log prices on fixed effects on time, breed and animal category on log population density coming from the transactional dataset SIO Carnes. If trade costs were high, we would expect, on average, more densely populated counties to have higher cattle prices, as demand increases. While we observe a large variation on the X axis, with population density varying by four orders of magnitude, the residuals vary very little, by at most 10%. When we look at the linear fit, the coefficient is not statistically significant. This leads us to think that prices are mostly homogeneous across space.

3 Model

3.1 Environment

Time is discrete, indexed by $t = 1, ...$ There are two countries: Home and Foreign. Home has multiple regions indexed by $i \in \mathcal{I} = \{1, ..., I\}$. There are two varieties of cattle, young, denoted by the subscript y, and old, denoted by the subscript x. In each region and period there is an endowment of young K_{yit}, and an endowment of land. Within each region there is a continuum of plots indexed by $\omega \in [0, 1]$. Each plot can be used to produce two goods indexed by $k \in \mathcal{K} = \{a, x\}$, where a represents agriculture (soybeans).

3.2 Demand

There is (static) domestic representative consumer[6] with exogenous expenditure on cattle m_t. I assume there is a CES utility function with elasticity σ, that depends on consumption C and taste shocks a:

$$U(C_{xt}, C_{yt}) = \left((a_{xt})^{\frac{1}{\sigma}} C_{xt}^{\frac{\sigma-1}{\sigma}} + (a_{yt})^{\frac{1}{\sigma}} C_{yt}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

Which yields the standard CES demand system

$$C_{yt} = a_{yt} \frac{p_{yt}^{-\sigma}}{P_t^{1-\sigma}} \tag{3}$$

$$C_{xt} = a_{xt} \frac{p_{xt}^{-\sigma}}{P_t^{1-\sigma}} \tag{4}$$

Additionally, there is a foreign representative consumer who has quasilinear preferences over his consumption of young and old:

$$U^*(C^*, C_x^*) = C^* + \frac{\eta}{\eta - 1} (a_{xt}^*)^{\frac{1}{\eta}} (C_{xt}^*)^{\frac{\eta-1}{\eta}} \tag{5}$$

This yields an isoelastic foreign demand for old, with a price elasticity of demand η.

$$C_{xt}^* = a_{xt}^* p_{xt}^{-\eta} \tag{6}$$

The foreign consumer faces the policy restriction, his demand is limited by policy $\bar{C}_t^* \geq 0$.

[6] Consumers could be dynamic by buying beef and storing it in freezers, for example. For a yearly time frequency, this seems highly implausible.

$$C^*_{xt} = \min(a^*_{xt} P_{xt}^{-\eta}, \bar{C}^*_t) \tag{7}$$

Note that the good under consideration is live cattle. As in [Dominguez-Iino, 2021] the "consumers" under consideration are the purchasers of the live animals, that is, the slaughterhouses. The extent to which consumers will actually obtain the wins/losses from changes in prices will depend on the degree of passthrough that slaughterhouses have, which in turn depends on their market power. As specified in the data section, given the low market concentration of slaughterhouses in general and exporting slaughterhouses in particular, I do not believe there to be significant market power.

3.3 Supply

I use the Fréchet abstraction created by [Eaton and Kortum, 2002] and applied to agriculture by [Costinot et al., 2016], extending it to a dynamic setting.

In each county i, there is a continuum of plots indexed by ω. In each plot, a farmer faces a discrete choice problem: whether to use the plot to raise young into old, or to grow crops. For each option k, there is a productivity $\zeta_{kit}(\omega) \sim F(Z_{kit}, \theta)$.

I can express the profit-maximization problem of the firm in the following value function.

$$\begin{aligned} v\left[k_{xi}(\omega), \zeta_{xi}(\omega), \zeta_{ai}(\omega)\right] = {} & P_x k_{xi}(\omega) + \\ & \max\Bigg\{ P_a \zeta_{ai}(\omega) + \frac{1}{1+r} v\left[0, \zeta'_{xi}(\omega), \zeta'_{ai}(\omega)\right], \\ & - P_y \zeta_{xi}(\omega) + \frac{1}{1+r} v\left[\zeta_{xi}(\omega), \zeta'_{xi}(\omega), \zeta'_{ai}(\omega)\right] \Bigg\} \end{aligned} \tag{8}$$

Equation (8) can be interpreted as follows. The value of a plot ω depends on three state variables: the amount of old that it inherits from the past $k_{xi}(\omega)$ and its realized productivities for cattle $\zeta_{xi}(\omega)$ and agriculture $\zeta_{ai}(\omega)$. Its exact value is the total revenue that can be obtained from selling the old (a sunk benefit) plus the result of the firm's discrete choice. One choice is agriculture, which leads to obtaining crop revenue $P_a \zeta_{ai}(\omega)$ today, but a value function with zero old tomorrow. The other choice is cattle raising, which leads to having a negative cash flow today by buying young up to the maximum that the plot will allow, based on its productivity $\zeta_{xi}(\omega)$, but having a value function tomorrow with $\zeta_{xi}(\omega)$ units of old.

The farmer will decide to raise cattle instead of agriculture if and only if the expected cattle appreciation that the land productivity allows is greater than the agricultural revenue:

$$\left(\frac{E_t P_{x,t+1}}{1+r} - P_{y,t}\right)\zeta_{xit}(\omega) > P_a \zeta_{ait}(\omega) \tag{9}$$

The solution to the problem is analogous to those in the cattle literature [Rosen, 1987], [Rosen et al., 1994]. In those models ranchers trade off cattle stock appreciation, the benefit of not slaughtering arising from an increase in prices or the number of heads, with the holding cost, the cost incurred in keeping the cattle alive. The model serves as a microfoundation of that exogenous holding cost as the opportunity cost of the land, in our case, the revenue that the rancher could get from growing crops.

This means that, even if prices are equal across all plots, plots with relatively high cattle productivity will select into raising cattle, since the price difference will be multiplied by a larger number, and those with relatively high agricultural productivity will select into agriculture.

I use our distributional assumptions on productivity to come to a closed form solution for county-level aggregates. Assume $\zeta_{kit}(\omega)$ is a Fréchet with scale parameter $\tilde{Z}_{kit}$, and shape parameter θ. Call $Z_{kit} = \left[\Gamma(1-\frac{1}{\theta})\right]^{-1}\tilde{Z}_{kit}$. Given properties of the Fréchet distribution, the total amount of cattle raised to old age and crops produced are:

$$K_{x,i,t+1} = \frac{\left(\frac{E_t P_{x,t+1}}{1+r} - P_{y,t}\right)^{\theta-1}(Z_{xit})^{\theta}}{\phi_{it}^{\frac{\theta-1}{\theta}}} \tag{10}$$

$$Q_{a,i,t} = \frac{(P_{at})^{\theta-1}(Z_{ait})^{\theta}}{\phi_{it}^{\frac{\theta-1}{\theta}}} \tag{11}$$

And the land shares used for cattle and agriculture are:

$$\pi_{x,i,t} = \frac{\left[\left(\frac{E_t P_{x,t+1}}{1+r} - P_{y,t}\right)Z_{xit}\right]^{\theta}}{\phi_{it}} \tag{12}$$

$$\pi_{a,i,t} = \frac{(P_{at}Z_{ait})^{\theta}}{\phi_{it}} \tag{13}$$

where

$$\phi_{it} = \left[\left(\frac{E_t P_{x,t+1}}{1+r} - P_{s,t}\right)Z_{xit}\right]^{\theta} + (P_{at}Z_{ait})^{\theta} \tag{14}$$

I finalize the discussion of the problem of the firm by clarifying what I mean by expectations. In the data we observe behavior that is inconsistent with perfect foresight. Namely, in years of drought there is sudden capital liquidation, leading to initially low prices of beef, followed by years of high prices. If agents had perfect foresight, they would not liquidate their capital suddenly. By doing so, they are selling most of their capital at a low price. Instead, knowing a drought was on the way, they would smooth the liquidation so as to flatten the price dynamics.

To rationalize this in a computationally simple fashion, I assume that for each county there is an average productivity vector that firms observe across time, $(\bar{Z}_{ai}, \bar{Z}_{xi})$. When forming expectations about the values of future productivity, I assume firms think that in the following periods the productivity will be at the average forever. They do observe current productivity though, so they know for certain in each plot how many animals can be fed / how much the agricultural output will be. For the rest of the time-varying variables, I assume static expectations.

3.4 Equilibrium

Three conditions close the model. The sum of all old raised in all plots in all counties must equal the total country stock tomorrow. Old at moment t must be consumed, either by foreign or domestic consumers. Young arrive exogenously in each period, and can be consumed by domestic consumers, or can be saved so that the become old one period in the future.

In equation form, market clearing implies:

$$K_{x,t+1} = \sum_i \int k_{x,i,t+1}(\omega) d\omega \tag{15}$$

$$w_{x,t} = C_x(P_{x,t}, P_{y,t}) + C_x^*(P_{x,t}, P_{y,t}) \tag{16}$$

$$K_{x,t+1} = K_{y,t} - C_y(P_{x,t}, P_{y,t}) \tag{17}$$

Having laid out demand, supply and market clearing, we are ready to define the equilibrium of the model.

Given the real interest rate r, the Frechet shape parameter θ, home's elasticity of substitution across cattle varieties σ, foreign's demand price elasticity η, the initial level of old capital K_{x0}, and Exogenous sequences of: domestic expenditures on cattle $\{X_{Ct}\}_{t=0}^{\infty}$, foreign's consumption of other goods $\{C_t^*\}_{t=0}^{\infty}$, policy restrictions $\{\bar{C}_x^*\}_{t=0}^{\infty}$, young steer endowments $\{K_{yt}\}_{t=0}^{\infty}$, foreign demand shocks $\{a_{xt}^*\}_{t=0}^{\infty}$, agricultural prices $\{P_{at}\}_{t=0}^{\infty}$, old mean productivities $\{\bar{Z}_{xi}\}_{t=0}^{\infty}$, agricultural mean productivities $\{\bar{Z}_{at}\}_{t=0}^{\infty}$, and the resulting time-variant Fréchet distribution of productivities for old $\zeta_{xit} \sim F(Z_{xit}, \theta)$ and agriculture $\zeta_{ait} \sim F(Z_{ait}, \theta)$; an equilibrium in the model is a sequence of prices of young and old $\{(P_{yt}, P_{xt})\}_{t=0}^{\infty}$, domestic consumptions of old and young $\{(C_{yt}, C_{xt})\}_{t=0}^{\infty}$, foreign consumption of old $\{C_{xt}^*\}_{t=0}^{\infty}$, distributions of

Table 2: Parameter Values

Parameter	Description	Value	Source
η	Demand Elasticity Foreign	2.825	panel IV
σ	Demand Elasticity Home	7.851	time-series IV
θ	Supply Elasticity	2.116	[Dominguez-Iino, 2021]
r	Real Interest Rate	0.01	
a^*_{xt}	Demand Shocks Foreign	–	inversion eq. (6)
$(a_{xt},\, a_{yt})$	Demand Shocks Home	–	inversion eqs. (3) (4)
$(Z_{ait},\, Z_{xit})$	Productivity Shocks	–	inversion eqs. (10) (11)

The table shows the parameter values and their sources that I use for the quantitative analysis.

plot-level capital of old $\{k_{xit}(\omega)\}_{t=1}^{\infty}$, and the resulting distribution of county-level capital of old $\{K_{xit}\}_{t=1}^{\infty}$, and national-level capital of old $\{K_{xt}\}_{t=1}^{\infty}$, such that: the consumption sequence of home for young and old $\{(C_{yt}, C_{xt})\}_{t=0}^{\infty}$ solves the static utility-maximization problem, the consumption sequence for foreign of old solves the static utility-maximization problem, for each plot $\omega \in [0,1]$ the firm solves the dynamic profit maximization problem and markets clear.

4 Estimation

In this section, I take the model to the data. Values for the three elasticities are needed first: Foreign's demand elasticity η, home's demand elasticity between young and old σ, and home's supply elasticity across land uses θ. Having obtained the values, the model can be inverted to obtain the unobserved exogenous variables: the demand shocks for home (a_{xt}, a_{yt}), the demand shocks for foreign a^*_{xt}, and the average county-level productivities for both cattle and soybeans (Z_{xit}, Z_{ait}).

I present the results in Table 2 and proceed to elaborate on how I obtained the values for the elasticities first, briefly describe the inversion procedure second, and finalize the section by providing evidence of external validity for the inversion results.

4.1 Elasticities

Foreign's Demand Elasticity η

To estimate η I use the panel of the European Union's trade in beef from COMTRADE, and the [Feenstra, 1994] method with the later modification of [Soderbery, 2015]. I describe the methodology briefly below. For a full exposition, the reader may consult [Leamer, 1981], [Feenstra, 1994], [Broda and Weinstein, 2006], and finally [Soderbery, 2015].

A representative (European) consumer has CES preferences over foreign and domestic goods and varieties, where like in the [Armington, 1969] model, each sourcing country c is a variety.

$$\sum_c (a^*_{ct})^{\frac{1}{\eta}} q_{ct}^{\frac{\eta-1}{\eta}} \tag{18}$$

This implies that the EU's share of expenditure of beef of country c relative to all beef consumption is given by

$$s_{ct} = b^*_{ct} \frac{p_{ct}^{1-\eta}}{P_t^{1-\eta}} \tag{19}$$

Note that under the small country assumption[7], the price elasticity of demand is equivalent to the elasticity of substitution, so our expression in (19) is equivalent to our previous assumption of quasilinear demand where $(a^*_{xt})^{\eta} = \frac{b^*_{ARG,t}}{P_t^{1-\eta}}$.

Assume that each country has an (inverse) isoelastic supply curve given by

$$p_{ct} = q_{ct}^{\omega} \exp(\xi_{ct}) \tag{20}$$

Where ω is the (inverse) export supply elasticity of the good and and ξ_{ct} is a technology shock.

I exploit the panel structure of the data to eliminate any time and good-specific unobservables that may bias the estimation of the demand elasticity. I take first differences across time to eliminate good-specific unobservables, denoting this with Δ. Then I also difference with respect to a common country k to eliminate time-specific unobservables, denoting this with the superscript k. Taking logs and applying the said differences:

$$\Delta^k \ln s_{ct} \equiv \Delta \ln s_{ct} - \Delta \ln s_{kt} = -(\eta - 1)\Delta^k \ln_{p_{kt}} + \varepsilon^k_{ct} \tag{21}$$

$$\Delta^k \ln p_{ct} \equiv \Delta \ln p_{ct} - \Delta \ln p_{kt} = \left(\frac{\omega}{1+\omega}\right) \Delta^k \ln s_{ct} + \delta^k_{ct} \tag{22}$$

Where $\varepsilon^k_{ct} = \Delta^k \ln b_{ct}$ and $\delta^k_{ct} = \frac{\eta_{ct}}{1+\omega}$ are unobservable demand and supply shocks.

I multiply both equations to arrive at the estimable equation

$$Y_{ct} = \theta_1 X_{1ct} + \theta_2 X_{2ct} + u_{ct} \tag{23}$$

Where the variables are constructed as

[7] EU 25 beef production is on the order of 8 million tons, Argentine imports before the ban were 75 thousand tons, approximately 1 percent.

$$Y_{ct} \equiv \left(\Delta^k \ln p_{ct}\right)^2 \tag{24}$$

$$X_{1ct} \equiv \left(\Delta^k \ln s_{ct}\right)^2 \tag{25}$$

$$X_{2ct} \equiv \left(\Delta^k \ln s_{ct}\right)\left(\Delta^k \ln p_{ct}\right) \tag{26}$$

$$u_{ct} \equiv \frac{\varepsilon_{ct}^k \delta_{ct}^k}{1-\rho} \tag{27}$$

The parameters, in turn, are given by:

$$\theta_1 \equiv \frac{\rho}{(\eta-1)^2(1-\rho)} \tag{28}$$

$$\theta_2 \equiv \frac{2\rho-1}{(\eta-1)(1-\rho)} \tag{29}$$

$$\rho \equiv \frac{\omega(\eta-1)}{1+\omega\eta} \in \left[0, \frac{\eta-1}{\eta}\right) \tag{30}$$

The parameter ρ has an economic interpretation; it corresponds to the correlation between vertical shifts in the demand curve and the change in the equilibrium price. As such, it is between 0 and 1.

If $\theta_1 > 0$[8] we can solve the system of equations to obtain

$$\rho = \begin{cases} \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{1}{4+\frac{\theta_2^2}{\theta_1}}} & \text{if } \theta_2 > 0 \\ \frac{1}{2} - \sqrt{\frac{1}{4} - \frac{1}{4+\frac{\theta_2^2}{\theta_1}}} & \text{if } \theta_2 < 0 \end{cases} \tag{31}$$

$$\eta = 1 + \frac{2\rho-1}{1-\rho}\frac{1}{\theta_2} > 1 \tag{32}$$

[Feenstra, 1994] estimates (23) by taking averages across time and using weighted least squares (WLS) with the number of time periods as the weights. He shows that this is mathematically equivalent to estimating the equation via two-step least squares (2SLS) using country dummies as instruments. Instrumental variables estimators are consistent but not unbiased. Consistency in panel data requires not only large N, in our case the number of countries, but large T, the number of years. Since trade data is usually a few decades long at most, using U.S. data at the HS8 level [Soderbery,

[8] If the estimation method results in $\theta_1 < 0$, the formulas fail to provide estimates for both η and ρ that in the ranges $\eta > 1$ and $\rho \in [0, 1)$, they may even be imaginary. [Broda and Weinstein, 2006] provides a GMM routine that constrains θ_1 to be positive. [Soderbery, 2015] improves upon this method. I do not elaborate here since, as we shall see shortly, it is not the case for our data.

2015] shows that [Feenstra, 1994] tends to overestimate elasticities, on average by over 35%. Given the large amount of instruments and low T, [Soderbery, 2015] suggests estimating with the Limited Information Maximum Likelihood (LIML) developed by [Anderson and Rubin, 1949] [9]. For our preferred estimate, I follow [Soderbery, 2015] but include [Feenstra, 1994] in Table 8 in the appendix; I also find that the latter provides a larger estimate.

For the estimation, I aggregate HS codes 0201 (chilled beef) and 0202 (frozen beef) for the years 1988-2023 for the EU 25 countries[10]. Given the high level of aggregation of our good and the large size of the importing country, I have a large number of countries in the sample, 115, which adds robustness to the estimation. I drop Argentina from the sample for the ban period, as well as the "unspecified" country. To choose the k country, it is best to have a country that is present in all years in the panel to avoid having to drop data points when differencing; I have 6 such countries. The second criterion is trade volume, I therefore choose the country with the highest average import share, which, with a value of 0.27, is Brazil.

I present the results of the estimation of (23) in Table 3. I add a constant to the specification to control for possible measurement error. I find that the coefficient is statistically not different from zero, which implies that measurement error is not significant. The estimate for θ_1 is statistically above zero, which implies that our assumption of $\rho \in [0,1], \eta > 1$ is not violated by the data and I do not need to follow constrained estimation techniques as in [Broda and Weinstein, 2006] or [Soderbery, 2015].

Given the estimates of θ_1 and θ_2 I obtain an elasticity of 2.825. This estimate is very close to the value 2.710 found by [Kim et al., 2021] for Japan, using traditional IV instruments for price[11]. Note that in (32) $\eta > 1$ by construction, which implies most likely an asymmetric distribution. I avoid employing Central Limit Theorem arguments and instead, obtain then standard errors and confidence intervals by simulating 10,000 draws of (θ_1, θ_2) given our estimates of the mean and covariance matrix, and compute η for each draw. The 95% confidence intervals place η in the range of approximately 2 to 4.

Home's Elasticity of Substitution across Cattle Varieties σ

I estimate σ using time series variation of relative prices and quantities, instrumenting prices with the ban itself.

[9] For another example of the use of LIML in applied International Trade work, see [Atkin, 2013], who chooses it in an estimation setting with a large number of instruments.

[10] Including the United Kingdom, that was a EU member at that time.

[11] Interestingly, using the standard [Feenstra, 1994] methodology they obtain a larger estimate of 3.373, supporting the argument of using LIML.

Table 3: Estimation Results: Foreign Demand Elasticity η

Parameter	θ_0	θ_1	θ_2	η
Estimate	0.072	0.117	-0.371	2.825
S.E	(0.088)	(0.017)	(0.178)	(0.475)
95% C.I.	[-0.101, 0.245]	[0.082, 0.151]	[-0.719, -0.024]	[2.169, 3.974]
Countries		115		
Obs		1,158		

The table presents the results of the estimation of the foreign's demand elasticity η using the LIML estimator proposed in [Soderbery, 2015]. $\theta_0, \theta_1 \theta_2$ are the result of the LIML estimation of equation (23). I include a constant θ_0 in the estimation to capture any measurement error that may bias our estimates. θ_0 is not significantly different from zero, implying measurement error is not large in our sample. θ_1 is statistically significant above zero, which means that the method will deliver an elasticity of substitution within the structural assumption of $\eta > 1$ and I do not need to employ any corrections like in [Broda and Weinstein, 2006]. Finally, our elasticity is 2.825, which is very close to [Kim et al., 2021] value of 2.710 estimating a similar elasticity for Japan, using traditional IV instruments for price. As (32) shows, η is above 1 by construction and its distribution is most likely asymmetric. To capture this I simulate 10,000 draws of θ based on our estimates of its first and second moments, and compute η for each draw to obtain standard errors and a 95% confidence interval. The estimate is relatively precise ranging from approximately 2 to 4.

Taking logs of the CES demand function, I arrive at the estimable equation:

$$\ln \frac{C_{xt}}{C_{yt}} = -\sigma \ln \frac{P_{xt}}{P_{yt}} + \sigma \ln \frac{a_{xt}}{a_{yt}} \tag{33}$$

Since relative quantities and prices are observable, the relative taste shocks appear in the error term. I present the results of the estimation in Table 4.

Table 4: Estimation Results: Home's Elasticity of Substitution across Varieties σ

	DV: log relative quantities old/young			
(log) relative price	4.850**	-7.851**	-4.474	-11.147
	(2.323)	(3.189)	(12.867)	(76.790)
Instrument	OLS	log exports	RER	relative rain
Obs	19	9	10	19
F first stage	N/A	41.11	1.53	0.055

The table presents the results of the estimation of the home's demand elasticity of substitution across cattle varieties σ using the equation (33). In the first column, I present the OLS specification for the whole period (ban and no ban). In the second column, our preferred specification, during the ban periods use exports as an instrument for relative price. The first stage is significant, with an F statistic of over 40. Demand appears to be very elastic, with an elasticity of almost 8. I also share other instruments, that albeit with weaker first stages lead us to reaffirm our assumption that demand is very elastic. In column three the real exchange rate for the years of no ban, and in column four the relative rain for all periods. Standard errors in parentheses. Statistically significant at *10% **5% ***1%.

In the first column, I present the results of the estimation with OLS. I obtain an incorrect sign, as expected due to standard endogeneity issues.

In the years when the ban was present, we can assume exports to be an exogenous variable; it is unlikely that the Argentine government managed the ban in response to relative demand shocks. However, with exports being concentrated on one variety, they are likely to affect relative prices. The F-statistic of 41 shows that this assumption seems to be the case, and the elasticity is estimated to be high, in the order of 8.

This makes intuitive sense, since we are analyzing cattle of the same sex with only one year difference in age. The data presented so far has also been hinting at high substitutability; we had seen that prices are very similar to each other in levels and they tend to co-move. The correlation between them in the data is very high, 0.98; I show them graphically in Figure 17 in the Appendix. Moreover, similar amounts are consumed of each variety.

I show in the next two columns the estimation results using other instruments. Low sample size poses a challenge to the power of the estimate, but there is a pattern of elasticities being above 4 which makes them, for economic purposes, equivalent. I use in the third column the real exchange rate for the years when there is no ban. The logic being that a weak currency would make foreign demand stronger. I also use relative rain, constructed as the average of rain across each county, weighted by the share of that county stock of old or young relative to the total stock nationwide.

Given the specificity of the demand specification, there are not many studies that have studied this elasticity. Closest to us, [Aadland, 2004] estimates demand for heifers and cows in the United States as two AR(1) processes; the contemporaneous correlation of the process capturing demand substitutability. The autocorrelation they find is high, 0.77, which is consistent with our findings.

Supply Elasticity θ I take the value from [Dominguez-Iino, 2021], who estimates a model based on [Costinot et al., 2016] as well for the same country in a similar time period (2002-2018).

Real Interest Rate r I chose a lower value than the usual 10% in the literature to allow for more flexibility in the cattle margins. A lower value than that in developed countries is warranted given that in the period Argentina faced substantial amounts of financial repression, pushing real interest rates comfortably in the negative territory. As an example, for certificates of deposit of 60 days or more the realized return in the period was -7% annualized.

4.2 Inversion

In this section, I discuss the method to obtain taste and productivity shocks given the parameters and the data.

I start with the inversion of productivity. The task amounts to finding productivities to solve the simultaneous system of equations (10) - (11), that I rewrite here for the reader's convenience:

$$
\begin{aligned}
K_{x,i,t+1} &= \frac{\left(\frac{E_t P_{x,t+1}}{1+r} - P_{y,t}\right)^{\theta-1} (Z_{xit})^{\theta}}{\phi_{it}^{\frac{\theta-1}{\theta}}} \\
Q_{a,i,t} &= \frac{(P_{at})^{\theta-1} (Z_{ait})^{\theta}}{\phi_{it}^{\frac{\theta-1}{\theta}}} \\
\phi_{it} &= \left[\left(\frac{E_t P_{x,t+1}}{1+r} - P_{y,t}\right) Z_{xit}\right]^{\theta} + (P_{at} Z_{ait})^{\theta}
\end{aligned}
$$

Given our assumption that firms believe that productivity will remain at its average in the future, we must also have $(\bar{Z}_{xi}, \bar{Z}_{ai}) = \frac{1}{T}\sum_t (Z_{xit}, Z_{ait}) \forall i$. Note that at this stage parameters η, θ, σ, r are known, variables $K_{x,i,t+1}$, Q_{ait}, P_{yt}, P_{at} are data, and I will use the model to compute $E_t P_{x,t+1}$.

The method for obtaining Z_{ait}, Z_{xit} is as follows:

1. Guess average productivities $(\bar{Z}_{xi}, \bar{Z}_{ai})$
2. For each period $t = 1, \ldots T-1$:
   (a) Compute $E_t P_{x,t+1}$ as the saddle path price given future aggregate capital $\sum_i K_{x,i,t+1}$.
   (b) Solve (10) and (11) to obtain (Z_{ait}, Z_{xit})
3. Compare the guess $(\bar{Z}_{xi}, \bar{Z}_{ai})$ with the newly obtained $\frac{1}{T}\sum_t (Z_{xit}, Z_{ait}) \forall i$. If close, stop. If not, update and go back to 1.

Inversion of demand is straightforward.

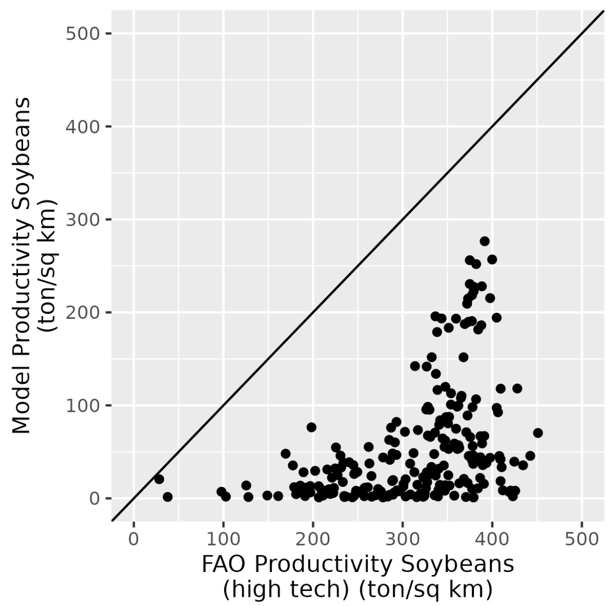
For Home, given that monotonic transformations of utility preserve preferences, we can set $a_{yt} = 1$. We take ratios of demand equations (3) (4) to obtain

$$a_{xt} = \left(\frac{C_{xt}}{C_{yt}}\right)^{\frac{1}{\sigma}} \frac{P_{xt}}{P_{yt}} \tag{34}$$

For Foreign, for the years without the ban, we obtain the taste shocks by inverting equation (6):

$$a^*_{xt} = C^*_{xt} P^{\eta}_{xt} \tag{35}$$

Figure 7: Model Validation: Soybean Productivity



The image shows the correlation between the land productivity inferred by the model after inversion, and an external measure of maximum theoretical productivity created by the FAO.

4.3 Validation

I present the results of the inversion of agricultural and cattle productivities across time and space.

On the spatial dimension, the model's productivity correlates with FAO GAEZ productivities. I show the plot of the model's soybean productivities versus FAO GAEZ soybean productivities with the best technology in Figure 7.

Given that we are comparing real-world productivity with theoretically maximum productivities, we expect our model to deliver lower productivity on average. The difference is explained by lower potential or realized productivity. Counties may have lower potential productivity due to limited access to the cutting-edge technology or lack of incentives to incorporate it (caused in turn by remoteness and taxation[12]) Even with optimal potential output, counties may see lower realized productivities due to adverse weather events, such as the 2008-9 drought.

This is what we observe in the graph, the distribution of realized productivities is shifted down compared to the theoretical one. We also see a clear correlation, with land that has higher productivity for the FAO also having higher productivity in our model.

For a more precise analysis, we present the results of the regressions in Table 5. We

[12]In the time period, soybean exports suffered a 35% ad-valorem tax.

Table 5: Model Validation: Soybean Productivity

DV: Average Model Productivity		
Ind. Variable	FAO high	FAO low
Marginal Effect	0.182***	0.967***
S.E.	(0.017)	(0.070)
R^2	0.209	0.321
Obs	405	

The table presents the results of regressing our measure of productivity averaged across time on external measures by the FAO GAEZ. We present results with both the FAO's high and low productivity specifications. In both cases, the results are positive and statistically significant, with the correlation being strongest with the low productivity specification. Standard errors in parentheses. Statistically significant at *10% **5% ***1%

see that for both of FAO's definitions of productivity, high and low, there is a positive and statistically significant marginal effect, with the correlation being strongest with FAO's measure of low productivity.

The model also shows a feature of the comparative advantage principle present in land allocation: it is not that there is land that is best for agriculture and land that is best for cattle raising. Agriculture requires the best land, since crops are plants influenced by humans to maximize calorie production, at the expense of other features, most notably resiliency. Cattle obviously profit from fertile lands, but less so than plants since they consume plants that are less sensitive to weather and fertility. Therefore, comparative advantage dictates that the best land be allocated for agriculture, and the second-best land for cattle.

This is shown in the inversion results in a few ways. First, there is a positive correlation in land productivity for different uses, as seen in Figure 8. Second, when we look at average productivity, we see that the land that is on average most productive selects into agriculture, see Figure 9.

I plot the maps of productivity and output in the appendix.

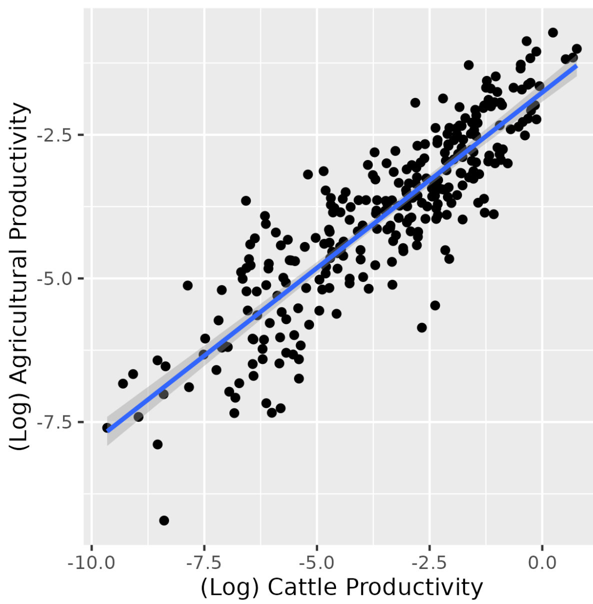
I also present the results of the estimation across time in Figure 10. I collapse all the county variation by taking averages. I observe a co-movement in productivity, both series reaching their lowest point in 2009, the year of the drought.

Finally, I show the time variation of the expected price, and plot it together with the prices of young and old in the data in Figure 11. We observe that expected prices generated by the model follow realized prices closely.

5 Counterfactuals

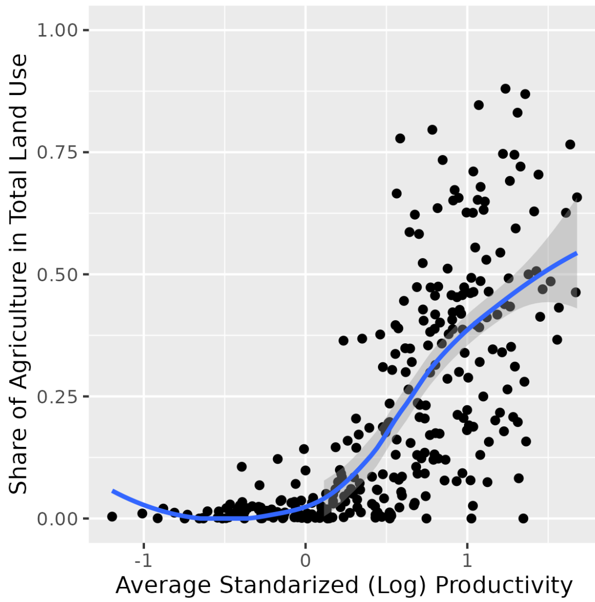
We present two counterfactuals.

Figure 8: Agricultural vs. Cattle Productivities



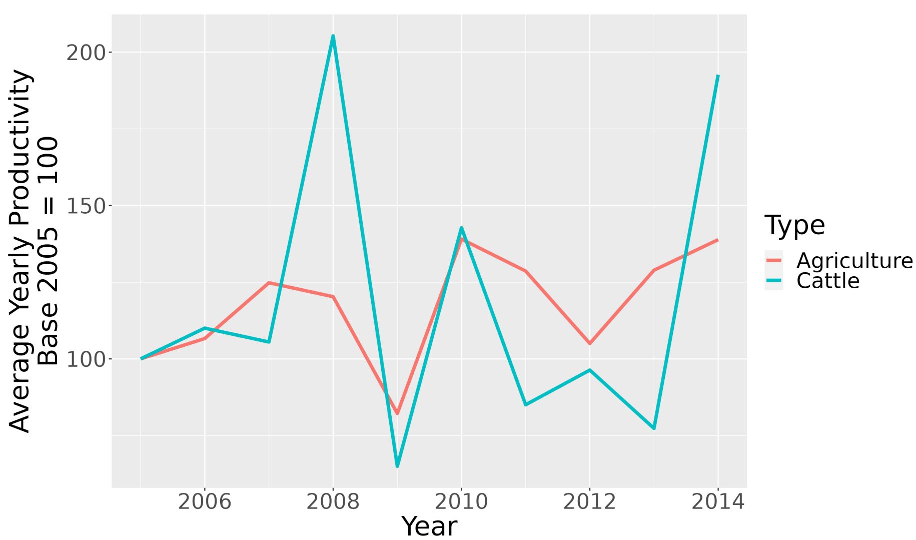
The figure shows the positive correlation between (log) cattle productivity and (log) agricultural productivity as inferred by the model. Each observation is county averaged across time. Observations with zero agricultural shares were dropped. The straight blue line represents the linear fit from OLS. The marginal effect is 1.25, positive and highly statistically significant, with a t-statistic of 30 and an R squared of 0.77. This shows how land allocation in Argentina is mainly driven by comparative advantage; there is no land that is good for agriculture and other that is good for cattle, what a negative correlation would imply. Instead, relative productivity determines what use the land will have.

Figure 9: Agricultural Shares vs. Average (Log) Productivities



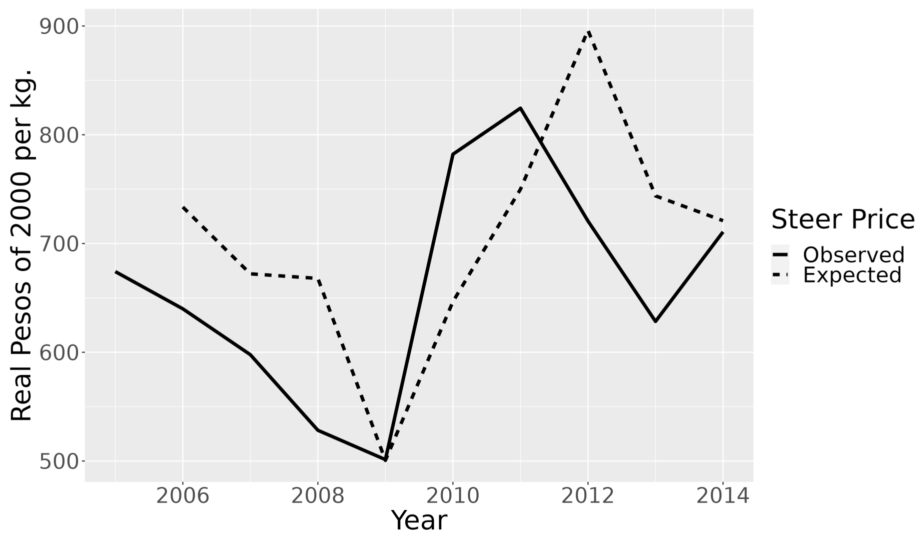
The figure shows the positive correlation between average log standardized land productivity and the share of land that is used by agriculture for the year 2005. Average standardized log productivity is computed by taking country-wide mean and standard deviation of log productivity for each land use (agriculture and cattle). We then standardize: subtracting each use, county observation for the corresponding mean, and dividing by the corresponding standard deviation. Then, the two standardized values for each county are averaged. This gives a measure of how productive land in the county is on average, avoiding scale inconsistencies. In blueof how, on average, we see the loess fit of the data. The figure shows how, on average, more productive land is devoted to agriculture. This is consistent with crops being more fragile, suffering more from low-quality land, while cattle are more flexible.

Figure 10: Time Variation of Productivity



The figure shows the time series of average productivity for the two line uses: agriculture and cattle. Productivity for both cattle and agriculture plunges in the year 2009, the year of the drought.

Figure 11: Evolution of Expected prices, Compared to Observed Prices



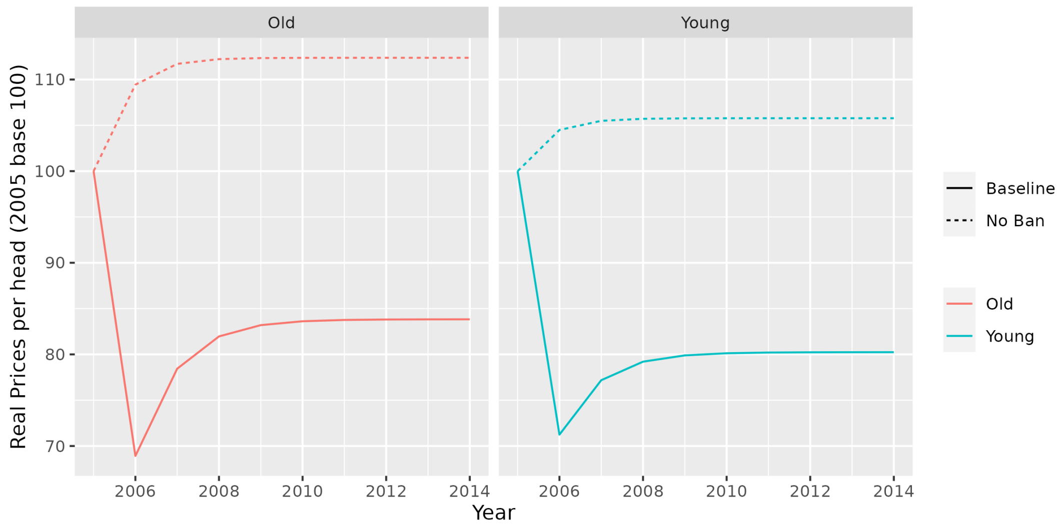
The figure shows the time series of the price of old (the export variety) in a solid line and the price the model thinks farmers expected that year, a year before $E_{t-1}P_{xt}$ in a dashed line. Initially we see agents believe prices are going to be higher than they actually were, as given our assumptions they underestimate the strictness of the export restrictions. They correctly foresee that prices will increase after the drought in 2009.

In this time period there were external factors that affected the strength of the policy, namely the drought. Since this event and its extent was unpredictable, a simple counterfactual removing the ban given the state of the economy could be misleading to the relevance of the study moving forward: what should we expect from policy like this in the future. This is analogous to why taking a risky bet and having the realization of the bet be positive is not an indictment that the choice was correct. We then take a purist approach of leaving every time-varying variables fixed, and present a comparison of this world without ban and one with a simple ban with the final strength of the ban from year 1 until the end. This also serves to elucidate the mechanisms behind the export restrictions. We call this an ex-ante analysis, because it is what a policy maker that was well informed but did not have perfect foresight could have expected to happen.

The second counterfactual answers is the question of what would have happened if instead of the sequence of restrictions we had had a fully unrestricted economy. For this analysis we keep the realizations of productivity and demand as we inferred them in the data. We call this the ex-post analysis, and we use it to conclude what the actual effect of the ban was.

For both of our analysis we will be computing welfare. For consumers, given that we have utility functions, we compute compensating variations. For producers, given our assumption of perfect competition, they will always have zero profits, since they

Figure 12: Counterfactual Evolution of Prices of Cattle, Ex-ante analysis



The figure shows the time series of the prices of young and old, for our ex-ante counterfactual, which means keeping all time varying exogenous variables fixed and imposing a simple constant ban. The dotted line shows the situation with no ban, and the solid line with ban. Under the no-ban situation, prices would have increased anyway, meaning that the steady-state level of prices was higher. With the ban, prices would have fallen initially, since exporters must liquidate their stock but young and old are close substitutes. With time, exporters reduce supply so prices recover, but less for young since their demand is dampened by the reduced investment.

are competitive firms bidding for an input in fixed supply. Therefore, we will define welfare instead as value added. Call W_s the welfare of sector s:

$$W_{yt} = P_{yt} K_{yt}$$
$$W_{xt} = \left[P_{xt} - P_{y,t-1}(1+r)\right] K_{xt}$$
$$W_{at} = P_{at} Q_{at}$$

5.1 Ex-ante

We present the counterfactual effect of the ban, but keeping the rest of the variables fixed in time. By doing so we are most importantly assuming there was no drought, but also no demand shocks or variations in cattle spending. As explained above, the purpose is to show the effect of the ban in the cleanest way possible, elucidating what we could expect of such policies in general and not for the particular realizations of demand and productivity that happened in Argentina in the period.

We start by prices in Figure 12. The dotted line shows the situation with no ban, and the solid line with ban. We see first that given the level of capital, the steady state level of prices was higher, so that prices would have continued increasing[13]. In the solid line we see the effect of a 75% permanent ban. We see on impact prices of the exported variety falling, but also prices of the domestic variety. What is happening is that exporters had built up a capital stock to liquidate fully, but they find foreign demand to be closed. Since the old must be consumed anyway, they are forced to sell their full stock domestically, leading to a 30% year-over-year change and 40% vs counterfactual. Since goods are substitutes, this reduces demand for the domestic variety, pushing prices of the young as well.

However, as time passes, we observe prices recovering partially in a few years. The mechanism behind is the adjustment of investment that the ranchers make knowing their export market to be restricted from now on. They invest less, lowering their quantity supplied and, given demand, increasing prices. But investing less means they buy less young, which dampens the price increase of young, and is the main mechanism through which the exporters are able to pass the effect of the ban to domestic producers.

We move on to show the effect on exports and stocks of old in Figure 13. We first notice the magnitude of the export ban in the experiment: approximately 75% vs the 2005 level. The graph shows that even under the no-ban situation, stocks would have fallen as the steady-state level of capital was lower than the actual level. As such, exports would have fallen in equilibrium. In the counterfactual, the stock falls even more, but the difference between counterfactuals is not as large as the export restriction, merely 20%.

Since consumption is simply inversely related to prices, we present the results in the Appendix in Figure 22.

Finally, we show what all of this means for welfare in Figure 14. We show for each year, the difference in welfare between the world with no ban, and the world with a ban. We see that on impact, exporters are affected but only on impact. They care both about the price of old, but also of the young. As the price of the young falls, their margins recover, and their transfer is minimal. For the domestic producers, since they are the origin of the good, they cannot pass the demand shock to anyone else[14].

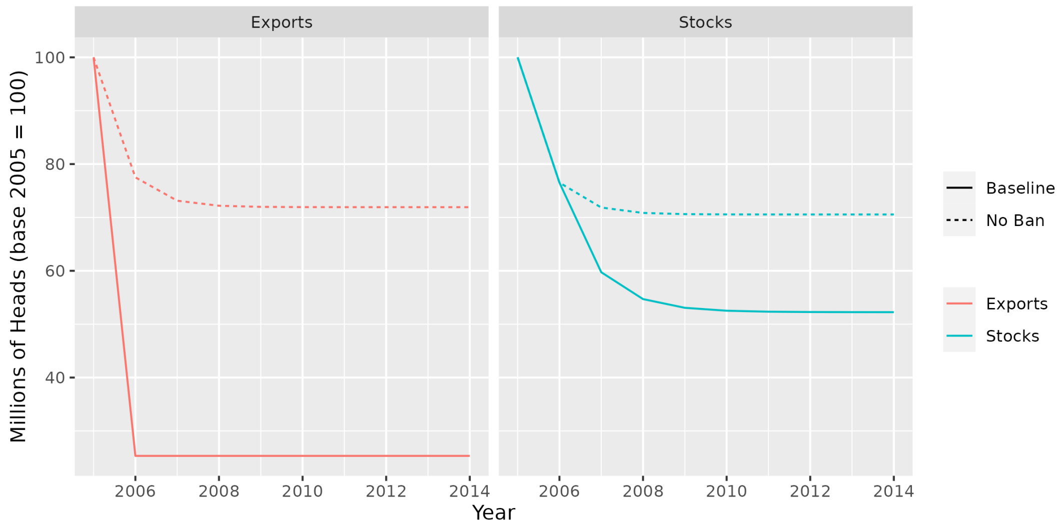
5.2 Ex-post

We now move to our ex-post analysis, we use the realizations of demand and supply shocks in the data, and we compare that world with and without ban; the world with ban being simply the data.

[13] This may be an argument why the government was forced to act.

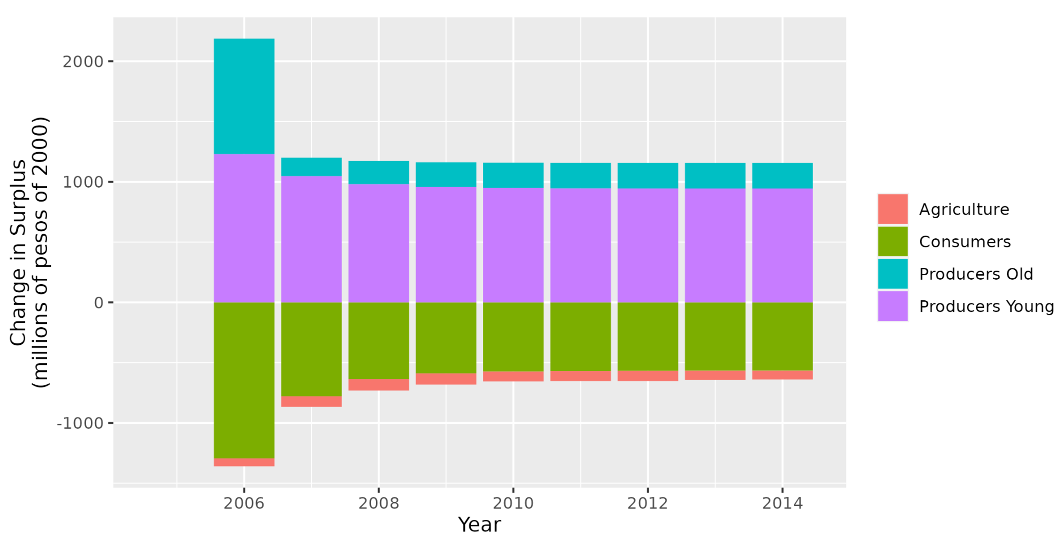
[14] In reality, with more types producers of young may pass the shock onto producers of calves, and in turn the producers of cows that give birth to calves. The most accurate interpretation of the result is to what is the producer of young in the model to be the amalgamation of the whole upstream cattle chain.

Figure 13: Counterfactual Evolution of Old Stock and Exports, Ex-ante analysis



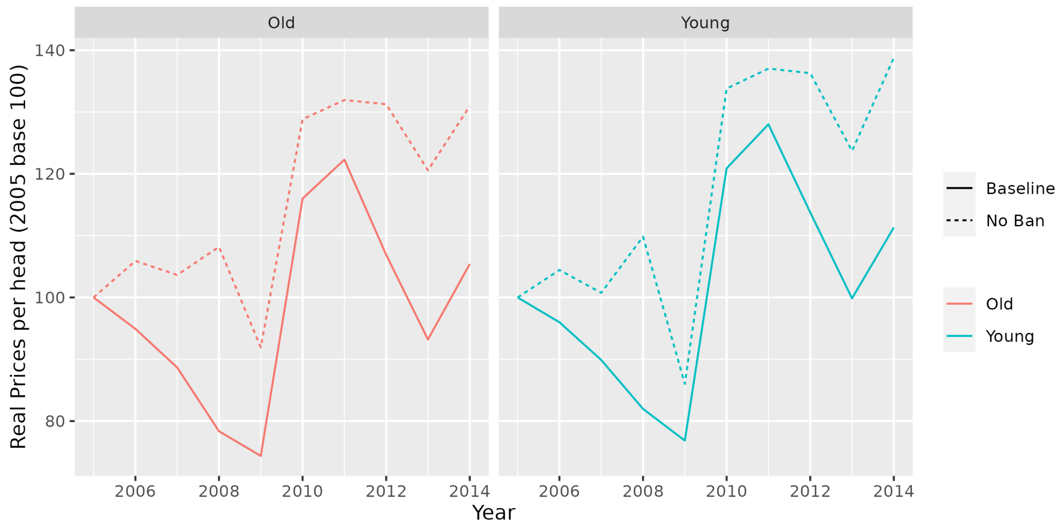
The figure shows the time series of the stocks of exports and the old stocks, for the counterfactual, which means keeping all time varying exogenous variables fixed and imposing a simple constant ban. The dotted line shows the situation with no ban, and the solid line with ban. Under the no-ban situation, stocks would have fallen as the steady-state level of capital was lower than the actual level. As such, exports would have fallen in equilibrium. With the ban, exports fall much more and abruptly, the magnitude of the ban chosen was the level of exports at the end of the period, 25% of 2005 exports. The stock also falls, the difference being between counterfactuals being 20%.

Figure 14: Welfare Effect Decomposition



The figure shows the decomposition of the welfare effects of the ban for each year, for the ex-ante counterfactual, which means keeping all time varying exogenous variables fixed and imposing a simple constant ban. This is to be read, if there was no ban, who would win (positive numbers) and who would lose (negative numbers). We see an initial strong impact on exporters, but that effect dwindles with time as they are able to adjust their investment decision, improving their prices and lower the prices of their suppliers, all things equal. Consumers see initial low prices but later those prices increase, reducing their gains.

Figure 15: Counterfactual Evolution of Prices of Cattle, Ex Post Analysis



The figure shows the time series of the prices of young and old, for our ex-post counterfactual, which means keeping all demand and supply shocks. The dotted line shows the situation with no ban, and the solid line with ban. Given that under the no-ban case prices are constant in the first few years, the model points to the ban for being the main cause of falling prices. Later on, the model believes that the drought would have caused the prices to fall initially and increase later also without ban.

We start by presenting the evolution of prices in Figure 15. We remember from Figure 5 that we saw an initial fall in prices as the ban was imposed, a collapse with the drought and an increase as the scarcity of capital lead to high prices, to induce capital accumulation.

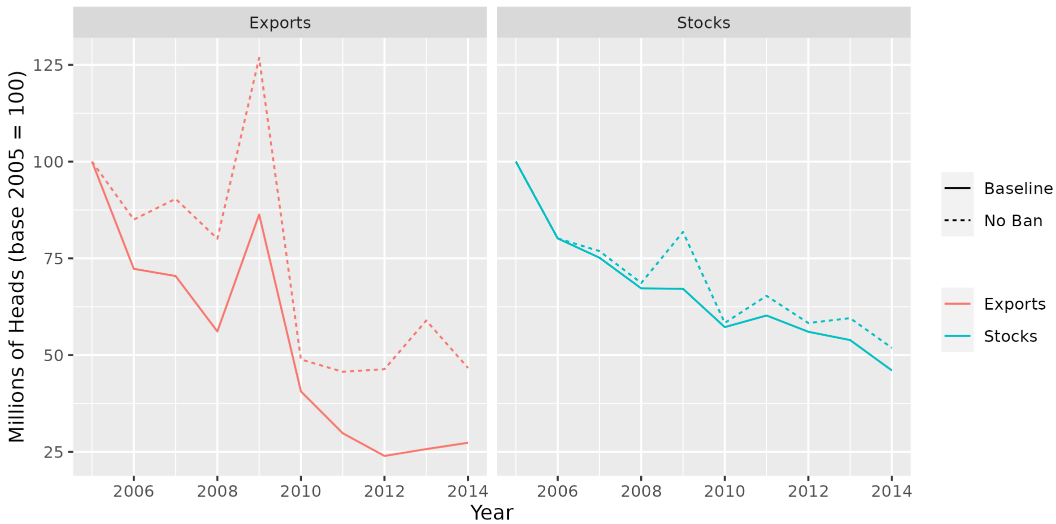
The analysis states that the initial fall we see of prices is due entirely to the export restrictions, as without the ban prices would have been stable. When the drought hits, prices would have fallen, but by less, and later would have still increased. We see that the difference between prices with and without ban is minimal immediately after the drought; since there is no supply there are no cattle left over to export, so the foreign market is almost as good as closed.

Looking at the evolution of prices across sectors we see that they are very similar; given that what matters for the exporting sector is not the absolute level of prices but the difference, we can already foresee that the exporting sector is able to pass most of the shock to the domestic producers.

We show next the effect of the ban on old cattle in Figure 16. We show both the evolution of exports (a flow variable) and number of old cattle each year (a stock variable).

Unsurprisingly, exports being a flow variable face larger changes than the slower-moving stock variable. Both stocks and exports would have been larger without the ban. The total amount of exports lost amounts to 4.9 Bn USD. For reference, the

Figure 16: Effect of the Ban on the Supply Side



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The figure shows the time series of the prices of young and old, for our ex-post counterfactual, which means keeping all demand and supply shocks. The dotted line shows the situation with no ban, and the solid line with ban. Unsurprisingly we see higher exports without the ban. Stocks, however, seem to see little change. This points to supply causes such as the drought and growing soybean productivity as the main drivers of cattle stock contraction in the period.

foreign exchange reserves of the Argentine Central Bank were 25 Bn USD at the end of 2015, so the loss of exports represents more than 25% of Central Bank reserves.

Stocks do not seem to have been affect that much, as the model still predicts a decline even without restrictions. This is unsurprising given our previous ex-ante analysis we saw only an effect of 20% on stocks given export restrictions of 75%. In this scenario we have two major forces diminishing the effect of the ban: first is the drought and soybean productivity.

The drought had the effect of forcing a liquidation of the cattle stock. Without cattle stock, there is no comparative advantage and there no exports even without policy restrictions.

The second factor goes back to the third fact shown in Table 1: we observed in a data a that cattle contraction was related to soybean expansion. In the inversion results there was an increase in soybean productivity, linking them together it means that the contraction of stock was also caused by increased agricultural productivity. So even undoing the ban would not restore the stock to its original level.

We finally move on to provide of a decomposition of the welfare effects of the ban.

We show and the aggregate result in Table 6, leaving the graph with the per-year calculation the Appendix in Figure 24. The intention of the ban was to transfer welfare from exporters to consumers. We see that the model shows there are a lot more factors at play.

Table 6: Aggregate Welfare Effects

Sector	Welfare Effect
Agriculture	-198
Consumers	-3267
Producers Old	1552
Producers Young	4802
DWL	2889

The table shows the welfare effects for each sectors, aggregated for the whole period, in millions of real pesos of 2000, equivalent to US dollars. This is to be read as, if the ban had not taken place, who would have won (positive effect) and who would have lost (negative effect). We see that the biggest winner of a lifting of the ban are not the producers of old varieties, the intended targets of the policy, but the producers of young varieties, the domestic producers. The difference is substantial, the domestic producers would three times as much as exporters. The biggest losers if the ban would have been lifted are consumers, but the winners could easily compensate the losers since the dead weight loss of the policy is in the order of 2.9 Bn, almost 50% of the total income captured from cattle producers.

First, both domestic and export-oriented producers would have been better off without the ban. Domestic producers are actually footing the larger port of the redistributive bill. This is what we expected above given the little change of the difference between prices, which composes the margin of the exporting sector. Domestic producers lose 4.1 Bn pesos of 2000[15] whereas export-oriented ones only 1.5Bn, or 75-25% respectively.

Second, both agricultural and consumers would be worse off. Consumers would have had 3.2Bn less in real income had the ban not taken place. Agricultural producers only 200M, which shows the little effective substitutability the model sees across soybeans and cattle, and relates to the small effect the ban has on cattle stocks altogether.

Finally, dead weight loss is in the order of 3Bn, which is 45% of all welfare captured from domestic and export-oriented cattle ranchers.

We see that roughly three fourths of the surplus to be redistributed comes from an unintended loser, and almost half of welfare is lost. The analysis shows this policy to be a very coarse tool to redistribute income.

6 Conclusion

Food exporting countries react to food price increases with export bans. I study the effect of that policy in a dynamic setting: the restrictions on cattle exports in Argentina 2005-2015.

[15]In the year 2000, the Argentine peso was pegged to the US dollar one-to-one, so all these measures can be thought of as equivalent to US Dollars (ignoring purchasing power parity corrections).

Constructing a panel of cattle stocks per category and soybean output and land shares, I find that exports are composed mostly of one variety of animal: the oldest variety of male cattle, steers. The stock of this variety starts falling as the ban is imposed. At the same time, there was a major soybean expansion that may be the consequence or another factor in cattle stock contraction. Cattle prices seems to be volatile in time falling and rising with a drought but constant in space.

I build a dynamic structural model merging the problem of cattle raising in [Rosen et al., 1994] with the land-share literature of [Costinot et al., 2016]. Farmers must choose whether to buy young to turn into old and sell them tomorrow, or grow soybeans to sell immediately at the market price. Estimation of elasticities provides high substitutability across varieties and standard trade elasticity of 2.8. Inverted productivity is correlated with external measures of productivity.

The quantitative analysis reveals that the ban is most effective in the short run. As exporters are able to adjust their investment decision, they pass the burden onto domestic producers and diminish the gains to consumers. While the ban had a strong effect on prices, being the sole cause for the fall in prices in the first three years, the effects on cattle stocks was limited. Other factors, such as the drought and the increase in soybean productivity, explain most of the fall in stocks.

In numbers, the ban signified a transfer of 6.3 Bn pesos away from producers, 75% of which came from domestic producers. Of those 6.3 Bn, only 3.2Bn went to consumers, and only 0.2Bn to soybean producers. That means that almost half of the surplus was lost. As such, we find the ban to have perverse dynamics, working as intended only in the short-run, which may explain the short-lived nature of these policies. We also find the ban being an inefficient redistributive tool, extracting surplus from unintended sources and losing most of it on the way.

7 Appendix 1: Tables

Table 7: No Spatial Variation

	DV: (log)Price per Live Kg Old			
distance port	0.003			
	(0.014)			
export share		-0.139		
		(0.108)		
export share EU			0.058	
			(0.042)	
population density				-0.011
				(0.005)
Obs	2,592,243	367,950	2,638,713	2,588,903
R squared	0.897	0.361	0.882	0.887
cluster	county	county	county	county
breed FE	YES	YES	YES	YES
category FE	YES	YES	YES	YES
time FE	YES	YES	YES	YES

The table shows the regression of (log) price of live old cattle on different covariates, controlling for breed, category and time fixed effects, from the universe of cattle transactions 2018-2022, equation (1). We do not use county fixed effects, because our covariates change at the county level. We see that counties closer to export ports do not have on average statistically significant higher prices. We construct a measure of county exports by merging state-level exports of beef with transaction data on slaughter, and we get a theoretically incorrect sign, non significant. We regress against whether the transaction has an EU export license, we get a positive but statistically insignificant result. Finally, we correlate with the population density of the county, and we get again an incorrect sign, not statistically significant. This makes us conclude that prices are homogenous across space. Standard errors clustered at the county-level in parentheses. Statistically signficant at *10% **5% ***1%.

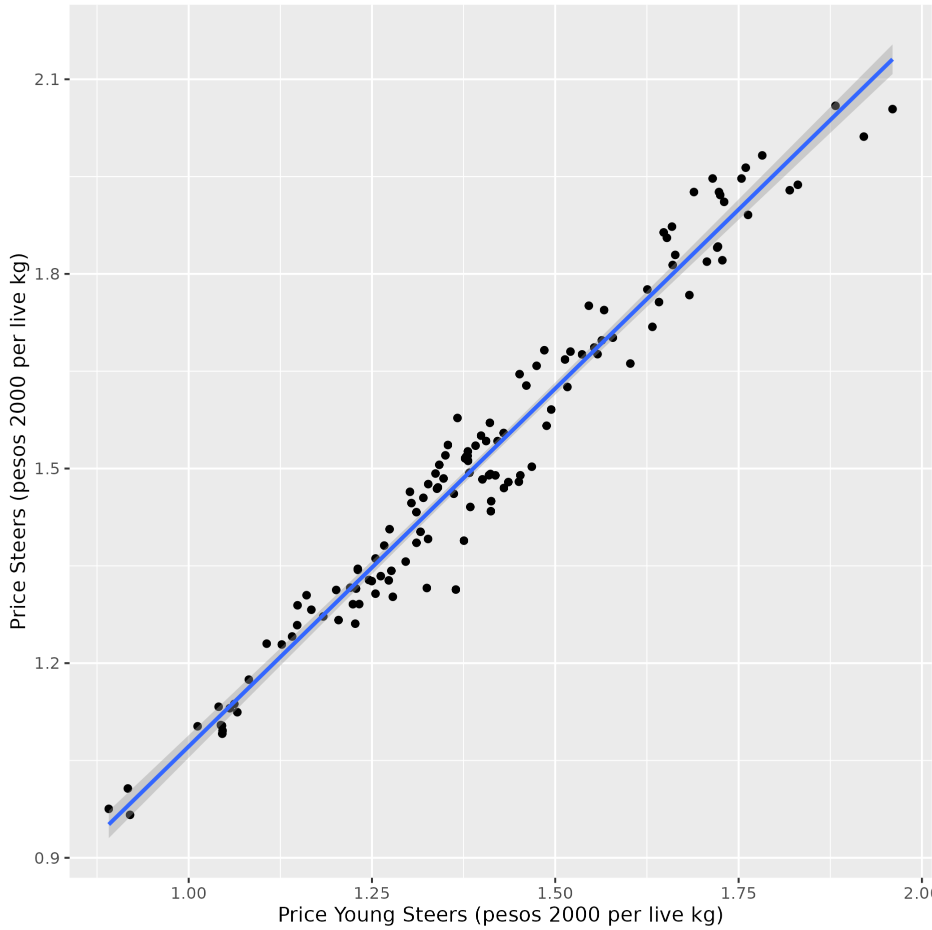
Table 8: Estimation Results: Foreign Demand Elasticity η

Parameter	θ_0	θ_1	θ_2	η
Estimate	0.251	0.070	-0.085	4.326
S.E	(0.085)	(0.015)	(0.086)	(0.699)
95% C.I.	[-0.101, 0.245]	[0.082, 0.151]	[-0.719, -0.024]	[3.296, 5.949]
Countries		115		
Obs		1,158		

The table presents the results of the estimation of the foreign's demand elasticity using the standard WLS method in [Feenstra, 1994] instead of the LIML proposed by [Soderbery, 2015]. $\theta_0, \theta_1 \theta_2$ are the result of the WLS estimation of equation (23) taking averages across time and using the number of years per country as weights. We include a constant θ_0 in the estimation to capture any measurement error that may bias our estimates. θ_1 is statistically significant above zero, which means that the method will deliver an elasticity of substitution within the structural assumption of $\eta > 1$ and we do not need to employ any corrections like in [Broda and Weinstein, 2006]. Finally, our elasticity is 4.326 is higher that what we obtain in LIML, as we would expect given the [Soderbery, 2015] argument. [Kim et al., 2021] also find higher values for the beef trade elasticity when using the standard WLS in Feenstra vs a standard IV approach of instrumenting price (3.373 vs 2.710). As (32) shows, η is above 1 by construction and its distribution is necessarily assymetric. To capture this we simulate 10,000 draws of θ based on our estimates of its first and second moments, and compute η for each draw to obtain standard errors and a 95% confidence interval. The estimate is ranges from approximately 3 to 6.

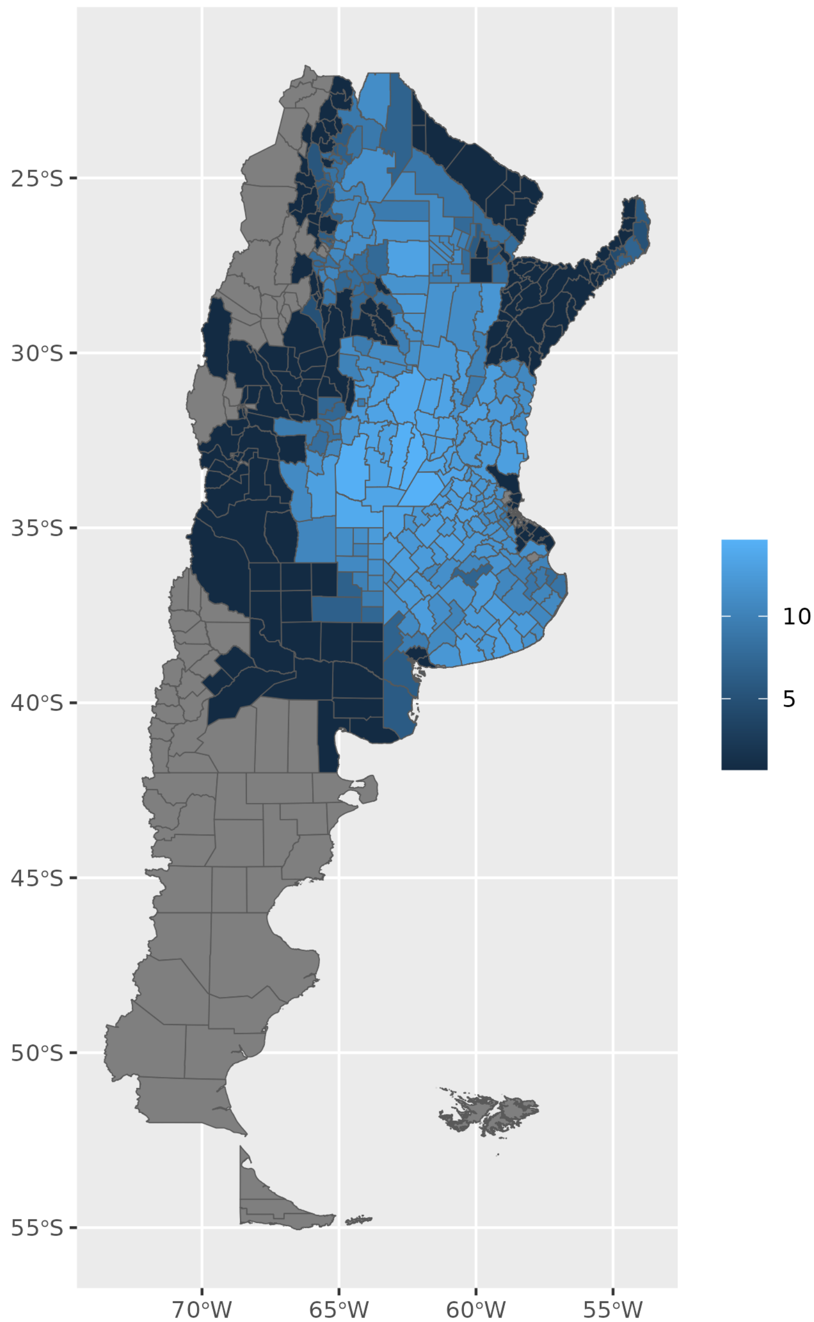
8 Appendix 2: Figures

Figure 17: Correlation between Real Monthly Average Prices in Buenos Aires Central Market



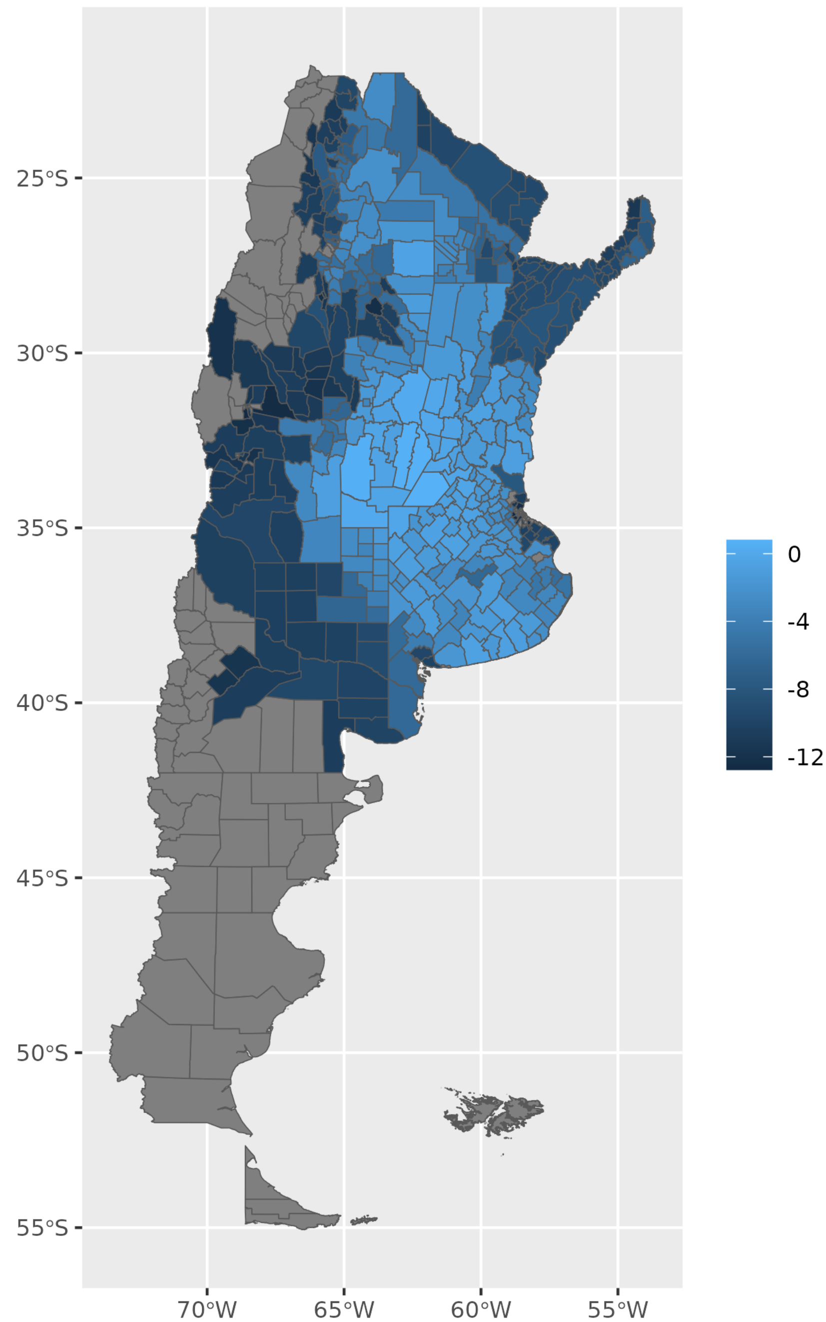
The figure shows the strong correlation between prices of young and old. The unit is pesos of January 2000 per kilogram of live cattle. Each dot represents a monthly average of these prices in the main cattle market of Argentina, the M.A.G. (Mercado AgroGanadero, Agro-Cattle Market), formerly known as Liniers, from January 2005 to December 2015 inclusive. The correlation is 0.98. The linear fit of prices of steers on young steers as a constant coefficient of 0.08, a linear coefficient of 0.87 and an R squared of 0.96.

Figure 18: (Log) Soybean Output, year 2005



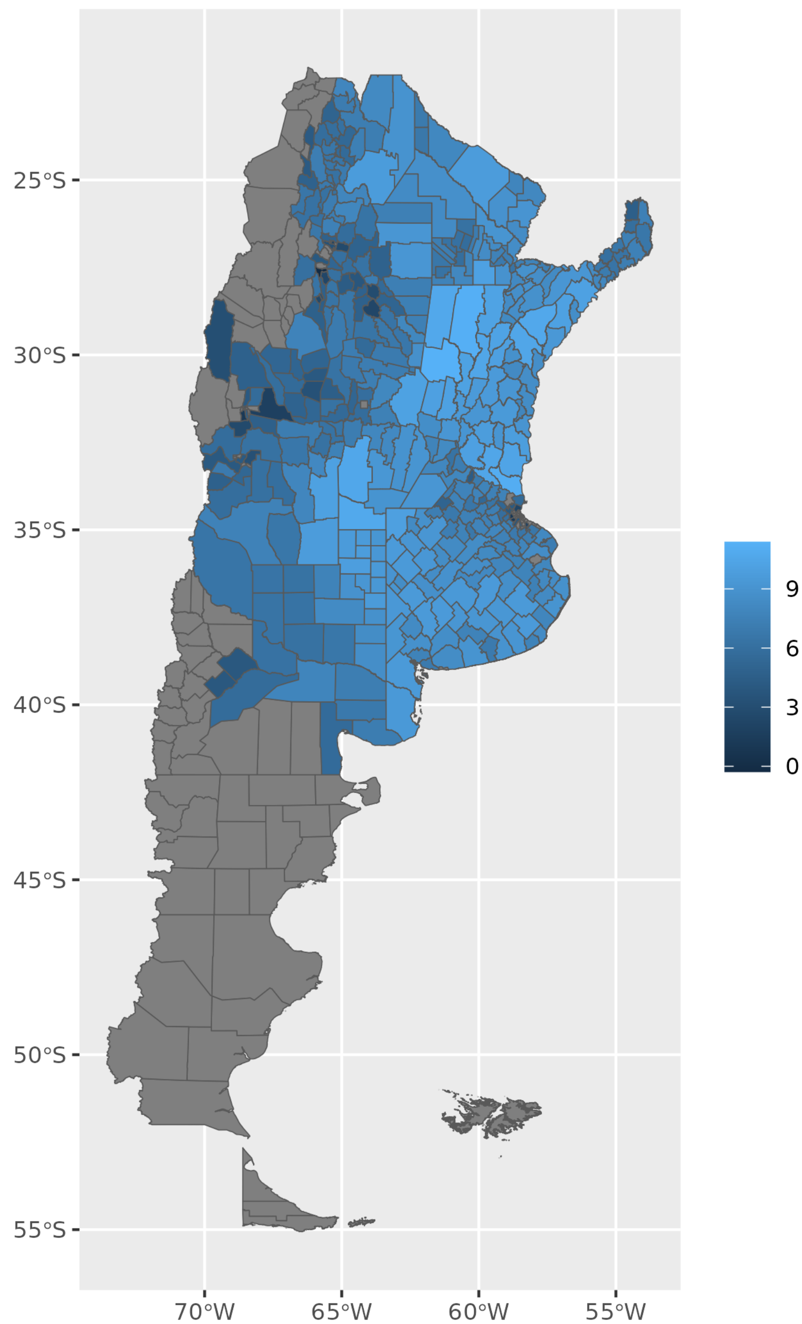
The figure shows the geographic distribution of (log) soybean production. We see a map of Argentina, at the county level. The lighter the blue color, the higher the (log) soybean output in that county. There is a clear nucleus of fertile land in the center of the country, which corresponds to the city of Rosario, which extends north and south, falling sharply to the west, with more deserted and mountainous areas, andt the south, the Patagonian tundra. For the counties in gray we have no data.

Figure 19: Model Inversion of Agricultural Productivity, year 2005



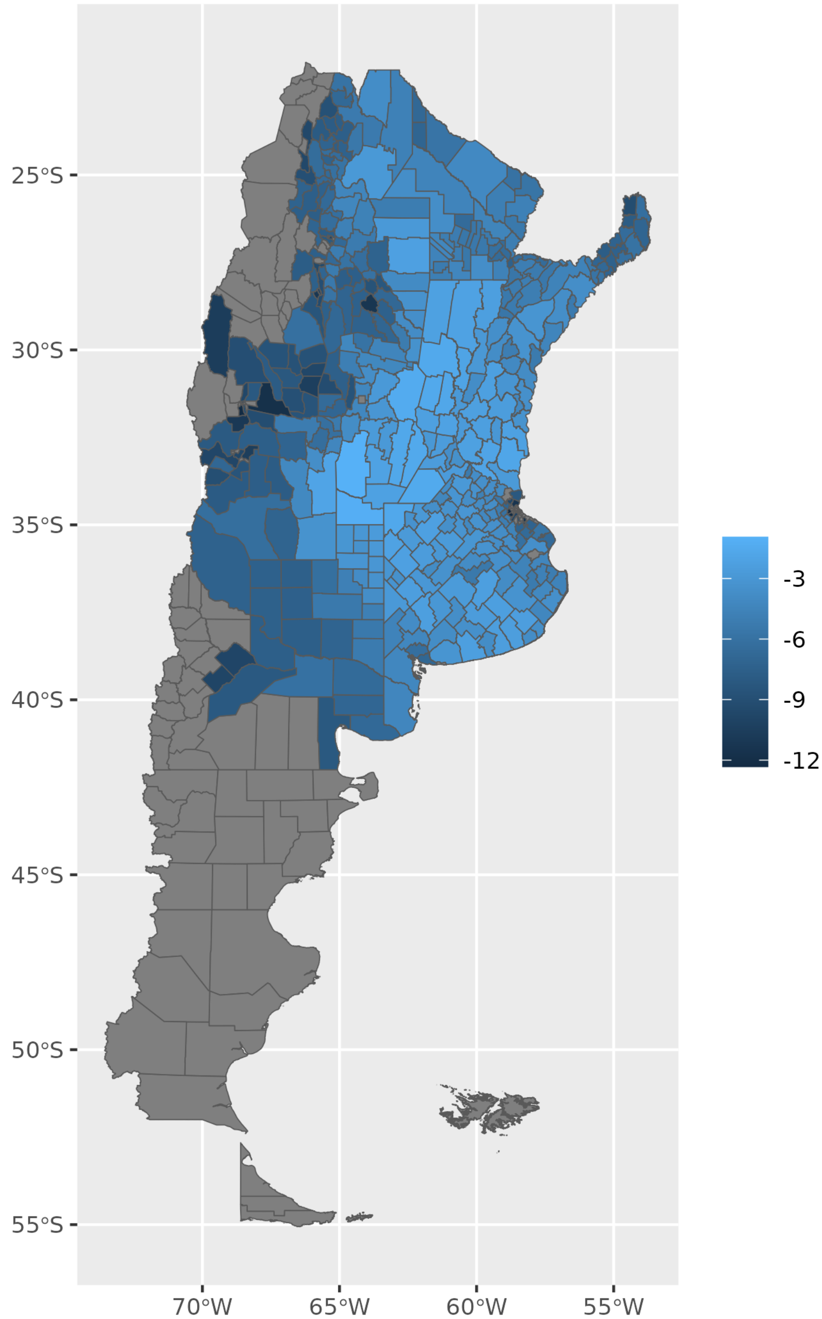
The figure shows the results of the agricultural productivity inversion of the model. The lighter the blue color, the higher the (log) agricultural productivity of the county. In gray, the counties for which there is no data. While agricultural productivity is not only derived from agricultural shares, the inverted productivities point to the land in the nucleus being more productive, and productivity falling as we get away from the center.

Figure 20: (Log) Steer Stocks, year 20



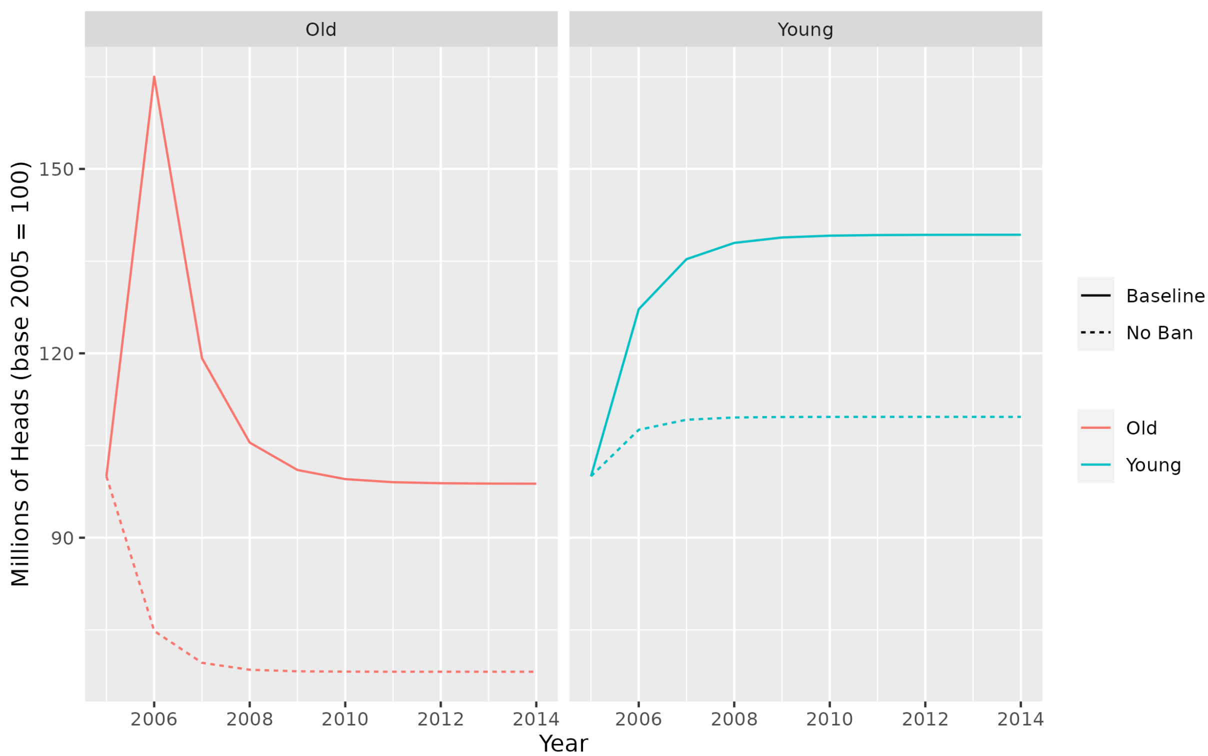
The figure shows the geographic distribution of old in 2006. The lighter the blue color, the higher the (log) stock of steers in the county. In gray, the counties for which there is no data. We see cattle stocks surrounding the fertile agricultural nucleus shown in the figure of agricultural shares. We also notice that cattle raising is less concentrated geographically than agriculture.

Figure 21: Model Inversion of Cattle Productivity, year 2005



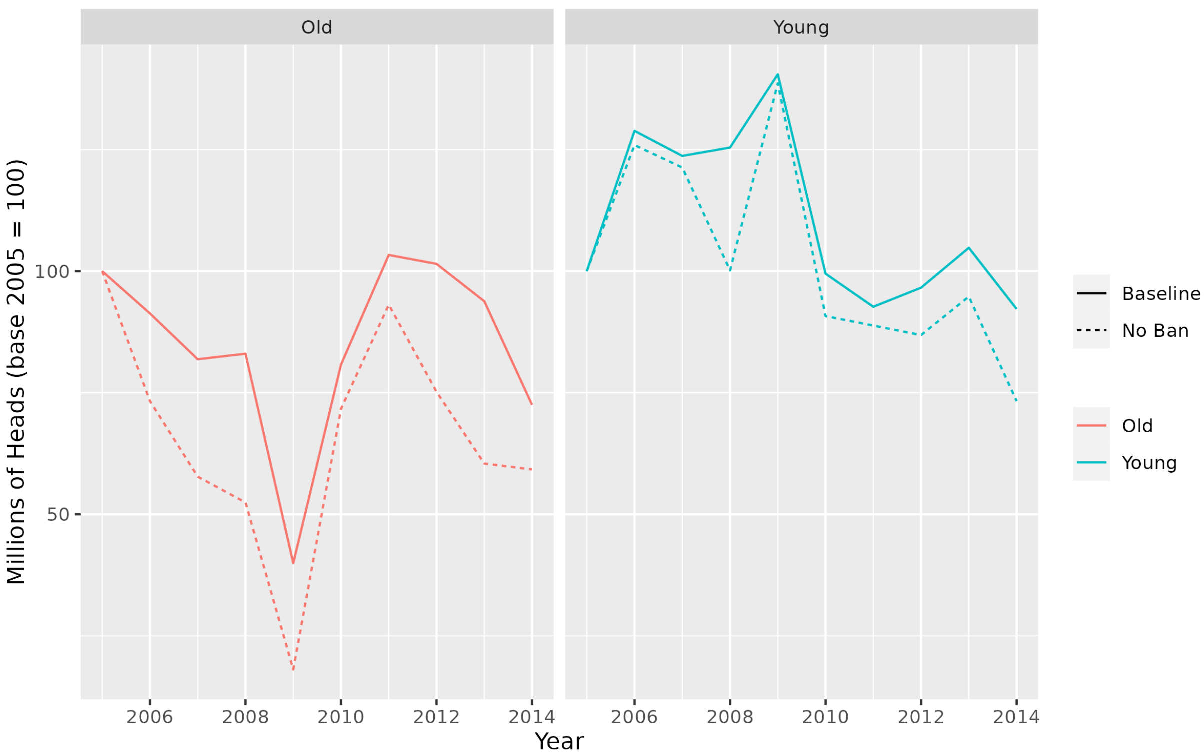
The figure shows the results of the cattle productivity inversion of the model. The lighter the blue color, the higher the (log) cattle productivity of the county. In gray, the counties for which there is no data. While cattle productivity is not only derived from cattle stocks, it follows a similar pattern. Interestingly, the model recognizes as the fertile center as also apt for cattle raising, despite it being allocated mostly to agriculture.

Figure 22: Counterfactual Evolution of Consumption, Ex-ante Analysis



The figure shows the time series of consumption of old and young, for the ex-ante counterfactual. The dotted line shows the situation with no ban, and the solid line with ban. Under the no-ban situation, consumption of old would have fallen as the steady-state level of capital was lower than the actual level. Consumption of young, on the other hand, would have increased lightly. On impact, consumption of old skyrockets as the stock that was raised for export must be consumed domestically. Consumption of young also increases as the demand of young as investment to be turned into old collapses given the reduction in expected exports. Both consumptions are above the counterfactual, by approximately 30%.

Figure 23: Counterfactual Evolution of Consumption, Ex-post Analysis



The figure shows the time series of consumption of old and young, for the ex-post counterfactual, that is, keeping all demand and supply shocks. The dotted line shows the situation with no ban, and the solid line with ban. We observe every year lower consumption of both old and young with no ban, as we had seen higher prices.

Figure 24: Welfare Effect Decomposition

The figure shows the decomposition of the welfare effects of the ban for each year. This shows how much larger/smaller would have welfare been for each sector (in millions of real pesos) if the ban had not taken place. For the ones in positive numbers, we see that clearly without the ban, both domestic and export-oriented producers would have been better off. Interestingly, it is domestic producers that are footing the largest portion of the bill. On the other side of the redistributive scheme, it is not only consumers but also agricultural producers that would have been worse off.

References

[Aadland, 2004] Aadland, D. (2004). Cattle cycles, heterogeneous expectations and the age distribution of capital. *Journal of Economic Dynamics and Control*, 28(10):1977–2002.

[Adão et al., 2022] Adão, R., Carrillo, P., Costinot, A., Donaldson, D., and Pomeranz, D. (2022). Imports, exports, and earnings inequality: Measures of exposure and estimates of incidence. *The Quarterly Journal of Economics*, 137(3):1553–1614.

[Alvarez, 2017] Alvarez, F. (2017). Capital accumulation and international trade. *Journal of Monetary Economics*, 91:1–18.

[Anderson et al., 2015] Anderson, J. E., Larch, M., and Yotov, Y. V. (2015). Growth and trade with frictions: A structural estimation framework.

[Anderson and Rubin, 1949] Anderson, T. W. and Rubin, H. (1949). Estimation of the parameters of a single equation in a complete system of stochastic equations. *The Annals of mathematical statistics*, 20(1):46–63.

[Armington, 1969] Armington, P. S. (1969). A theory of demand for products distinguished by place of production (une théorie de la demande de produits différenciés d'après leur origine)(una teoría de la demanda de productos distinguiéndolos según el lugar de producción). *Staff Papers-International Monetary Fund*, pages 159–178.

[Atkin, 2013] Atkin, D. (2013). Trade, tastes, and nutrition in india. *American economic review*, 103(5):1629–63.

[Borusyak and Jaravel, 2021] Borusyak, K. and Jaravel, X. (2021). The distributional effects of trade: Theory and evidence from the united states.

[Bounds, 2022] Bounds, A. (2022). Wto takes aim at export controls in effort to stem rising food prices. *Financial Times*.

[Broda and Weinstein, 2006] Broda, C. and Weinstein, D. E. (2006). Globalization and the gains from variety. *The Quarterly journal of economics*, 121(2):541–585.

[Costinot et al., 2016] Costinot, A., Donaldson, D., and Smith, C. (2016). Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. *Journal of Political Economy*, 124(1):205–248.

[Cravino and Sotelo, 2019] Cravino, J. and Sotelo, S. (2019). Trade-induced structural change and the skill premium. *American Economic Journal: Macroeconomics*, 11(3):289–326.

[Do et al., 2014] Do, Q.-T., Levchenko, A. A., and Ravallion, M. (2014). Trade insulation as social protection. pages 345–366.

[Dominguez-Iino, 2021] Dominguez-Iino, T. (2021). Efficiency and redistribution in environmental policy: An equilibrium analysis of agricultural supply chains.

[Eaton and Kortum, 2002] Eaton, J. and Kortum, S. (2002). Technology, geography and trade. *Econometrica*.

[Espitia et al., 2022] Espitia, A., Rocha, N., and Ruta, M. (2022). How export restrictions are impacting global food prices. *World Bank Blog*.

[Fajgelbaum and Khandelwal, 2016] Fajgelbaum, P. D. and Khandelwal, A. K. (2016). Measuring the unequal gains from trade. *The Quarterly Journal of Economics*, 131(3):1113–1180.

[Farrokhi et al., 2023] Farrokhi, F., Kang, E., Pellegrina, H. S., Dhabi, N. A., and Sotelo, S. (2023). Deforestation: A global and dynamic perspective.

[Favaro, 1990] Favaro, E. (1990). *A dynamic model for the Uruguayan livestock sector*. The University of Chicago.

[Feenstra, 1994] Feenstra, R. C. (1994). New product varieties and the measurement of international prices. *The American Economic Review*, pages 157–177.

[Galle et al., 2023] Galle, S., Rodríguez-Clare, A., and Yi, M. (2023). Slicing the pie: Quantifying the aggregate and distributional effects of trade. *The Review of Economic Studies*, 90(1):331–375.

[Giordani et al., 2016] Giordani, P. E., Rocha, N., and Ruta, M. (2016). Food prices and the multiplier effect of trade policy. *Journal of International economics*, 101:102–122.

[Jarvis, 1974] Jarvis, L. S. (1974). Cattle as capital goods and ranchers as portfolio managers: an application to the argentine cattle sector. *Journal of Political Economy*, 82(3):489–520.

[Kim et al., 2021] Kim, J., Nakano, S., and Nishimura, K. (2021). Armington elasticity estimation with or without instruments.

[Leamer, 1981] Leamer, E. E. (1981). Is it a demand curve, or is it a supply curve? partial identification through inequality constraints. *The Review of Economics and Statistics*, pages 319–327.

[Malpass, 2022] Malpass, D. (2022). A new global food crisis is building. *Barron's*.

[Martin and Anderson, 2012] Martin, W. and Anderson, K. (2012). Export restrictions and price insulation during commodity price booms. *American Journal of Agricultural Economics*, 94(2):422–427.

[Martin and Ivanic, 2016] Martin, W. and Ivanic, M. (2016). Food price changes, price insulation, and their impacts on global and domestic poverty. *Food price volatility and its implications for food security and policy*, pages 101–113.

[Nicita et al., 2014] Nicita, A., Olarreaga, M., and Porto, G. (2014). Pro-poor trade policy in sub-saharan africa. *Journal of International Economics*, 92(2):252–265.

[Porto, 2006] Porto, G. G. (2006). Using survey data to assess the distributional effects of trade policy. *Journal of International Economics*, 70(1):140–160.

[Ravikumar et al., 2019] Ravikumar, B., Santacreu, A. M., and Sposi, M. (2019). Capital accumulation and dynamic gains from trade. *Journal of International Economics*, 119:93–110.

[Rosen, 1987] Rosen, S. (1987). Dynamic animal economics. *American Journal of Agricultural Economics*, 69(3):547–557.

[Rosen et al., 1994] Rosen, S., Murphy, K. M., and Scheinkman, J. A. (1994). Cattle cycles. *Journal of Political Economy*, 102(3):468–492.

[Rother et al., 2022] Rother, M. B., Sosa, M. S., Kim, M. D., Kohler, L., Kohler, M. L. P., Pierre, M. G., Kato, N., Debbich, M., Castrovillari, C., Sharifzoda, K., et al. (2022). *Tackling the Global Food Crisis: Impact, Policy Response, and the Role of the IMF*. International Monetary Fund.

[Scott, 2014] Scott, P. (2014). Dynamic discrete choice estimation of agricultural land use.

[Soderbery, 2015] Soderbery, A. (2015). Estimating import supply and demand elasticities: Analysis and implications. *Journal of International Economics*, 96(1):1–17.

[Sotelo, 2020] Sotelo, S. (2020). Domestic trade frictions and agriculture. *Journal of Political Economy*, 128(7):2690–2738.

[Topalova, 2010] Topalova, P. (2010). Factor immobility and regional impacts of trade liberalization: Evidence on poverty from india. *American Economic Journal: Applied Economics*, 2(4):1–41.

[Vance and Geoghegan, 2002] Vance, C. and Geoghegan, J. (2002). Temporal and spatial modelling of tropical deforestation: a survival analysis linking satellite and household survey data. *Agricultural economics*, 27(3):317–332.