The Effects of Farm Subsidies on Farm Exports in the United States

Lan Anh Tong[a], Cong S. Pham[b], and Mehmet A. Ulubaşoğlu[b,*]

[a] Foreign Trade University, Hanoi, Vietnam
[b] Deakin University, Melbourne, Australia

Forthcoming in the *American Journal of Agricultural Economics*

December 2018

Abstract

We estimate the elasticity of U.S. farm exports to U.S. farm subsidies using a gravity model of state-level farm exports to 100 major trading destinations, for the period 1999 to 2011. Our identification strategy exploits the within-state variation that is free of endogeneity bias in the levels and trends of farms subsidies and farm exports. We find that a 1% decrease in farm subsidies would reduce U.S. farm exports by 0.40% per annum. This equivalently means that the complete abolishment of the farm subsidy program would reduce U.S. farm exports by approximately US$ 15.3 billion per year. Importantly, we document robust evidence that amber box subsidy programs, such as counter-cyclical payments and marketing loan gains, have the strongest effect on farm exports, while green box subsidy payments, such as direct payments, have negligible effects. Finally, subsidy payments affect exports only in agricultural commodities, not in livestock. Our subsidy elasticity estimates are statistically significant, stable, and economically meaningful, and are vitally needed by U.S. and global policymakers in the face of critical domestic and international developments.

Key words: Farm subsidies, U.S. farm bills, gravity equation, U.S. farm exports

JEL codes: F14

Running Head: Farm Subsidies and Farm Exports

---

* Corresponding author: Ulubasoglu. 70 Elgar Road, Burwood, VIC 3125, Australia. Tel: +61 3 9244 6592. Email: mehmet.ulubasoglu@deakin.edu.au

Acknowledgements: We would like to thank Editor James Vercammen and three anonymous referees for their insightful comments on an earlier version of this paper. We also thank the seminar participants at the Viet Nam Center of Research in Economics, Management and Environment, Foreign Trade University, and Deakin University for their useful feedback on a preliminary version of our article. The usual disclaimer applies.

The Effects of Farm Subsidies on Farm Exports in the United States

Abstract

We estimate the elasticity of U.S. farm exports to U.S. farm subsidies using a gravity model of state-level farm exports to 100 major trading destinations, for the period 1999 to 2011. Our identification strategy exploits the within-state variation that is free of endogeneity bias in the levels and trends of farms subsidies and farm exports. We find that a 1% decrease in farm subsidies would reduce U.S. farm exports by 0.40% per annum. This equivalently means that the complete abolishment of the farm subsidy program would reduce U.S. farm exports by approximately US$ 15.3 billion per year. Importantly, we document robust evidence that amber box subsidy programs, such as counter-cyclical payments and marketing loan gains, have the strongest effect on farm exports, while green box subsidy payments, such as direct payments, have negligible effects. Finally, subsidy payments affect exports only in agricultural commodities, not in livestock. Our subsidy elasticity estimates are statistically significant, stable, and economically meaningful, and are vitally needed by U.S. and global policymakers in the face of critical domestic and international developments.

Key words: Farm subsidies, U.S. farm bills, gravity equation, U.S. farm exports

JEL codes: F14

The United States is by far the largest agricultural exporter in the world, and the third-largest agricultural producer after China and India. To assist agriculture, U.S. administrations operate complex and encompassing support programs embedded within farm bills. The current farm bill, the *Agricultural Act of 2014*, is a large $489 billion legislation that covers the provisions of food, energy, and conservation. Agricultural and livestock subsidies, together called farm subsidies, constitute a significant component of this major Act, benefiting more than one million recipients every year.

Farm bills are political documents. Not only do they concern the welfare of millions of rural voters, but they also represent the economic standpoints of the Democratic or Republican executives. While the Democratic administrations generally back price-support programs or agricultural subsidies that supplement farmers' income, Republican lawmakers traditionally vote in favor of limiting such subsidies and other regulations. Farm bills are key items in presidential campaigns, about which candidates are challenged by a number of advocacy groups. In addition, U.S. farm bill negotiations are closely followed by the international community because a large country such as the United States can significantly influence world prices.

As Donald J. Trump settles into the U.S. presidency, the course of U.S. agricultural policy is at the center of several crossroads. There are initial signs that Trump will follow the traditional Republican trajectory of reducing agricultural support. However, high levels of uncertainty exist due the facts that U.S. rural communities voted considerably in favor of Trump in the 2016 elections, and that Trump's presidential campaign lacked details regarding agricultural support. Another ambiguity relates to the global sphere. Despite the recent breakthrough in the decades-long multilateral talks by the World Trade Organization (WTO) to reduce agricultural production support worldwide, substantial differences exist between developing countries and the United

States and the European Union (EU) on phasing out agricultural subsidy programs, leaving uncertain the global prospects for free trade. Trump's negative stance on multilateral agreements poses yet another challenge in this setting.

How much would U.S. farm exports change if the U.S. administration cuts farm subsidies? Which subsidy programs have the highest and, for that matter, the lowest trade effects? Despite the large sums of U.S. taxpayer monies allocated to farm subsidies to date, limited evidence currently exists about the influence of subsidies on U.S. farm exports. Thus, the central objective of this article is to estimate the elasticity of U.S. farm exports to U.S. farm subsidies using a gravity model of state-level farm exports to 100 major trading partners of the United States, for the period 1999 to 2011. Our dataset covers farm subsidies embedded within three major farm bills (*Federal Agriculture Improvement and Reform [FAIR] Act 1996*, *Farm Security and Rural Investment [FSRI] Act 2002*, and *Food, Conservation, and Energy [FCE] Act 2008*) that allocated a total subsidy amount of US$285 billion to U.S. farm producers.[1] Quantifying the trade responsiveness of U.S. farm subsidies at this critical juncture is vitally needed for U.S. and global policymakers alike.

Exploiting variation at the United States' state level is appropriate to obtain empirical estimates of the responsiveness of farm exports to farm subsidies, as farm bills allocate farm subsidies to each state. However, the key methodological challenge is endogeneity. The allocation of farm subsidies to states is not random and might reflect several observable and unobservable state characteristics that could be correlated with state-level farm export levels and trends. Thus, to ensure that observed changes in farm exports are meaningfully attributed to subsidies, we rely on the longitudinal nature of our dataset, and control for an array of characteristics that would account for several observed and unobserved heterogeneities of states.

First, because states with large farm exports are also recipients of larger farm subsidies, we control for state fixed effects. This leaves us with within-state variation over time. Second, weather conditions that influence production and, consequently, subsidy payments under crop insurance, are not specific to states, but to regions, and are likely to vary from one year to the next. In addition, there could be spillovers across regions in the export effects of farm subsidies. We address this problem by controlling for region-by-year fixed effects. These two measures address the endogeneity bias in the levels of subsidies. Third, to address the possible selection bias on trends, we control for state-specific time trends. This isolates the cases in which more subsidies are allocated to certain states in expectation of increased exports owing to such a program. An additional factor that alleviates the possibility of selection bias on trends is that farm bills are legislated every five years, meaning that the farm bills set in stone the total amount to be allocated for the subsequent five years.

Taken together, controlling for permanent state differences, region-by-year fixed effects, and state-specific time trends, our estimation approach uses the differences in the year, state, and intensity of subsidy payments to estimate the elasticity of farm exports. Central to this identification strategy is the assumption that, once state fixed effects, region-by-year fixed effects, and state-specific time trends are all accounted for, the remaining variation in subsidy payments is plausibly exogenous to state-level exports. These variations may come from changes in new farm bills, emergency legislations, random distribution of risk preferences, and stochastic prices that arise every year. Controlling for state-fixed effects, region-by-year fixed effects and state-specific time trends could also address, if not fully resolve, the measurement error problem in the dependent variable (i.e., state-level farm exports) because inland states ship some of their exports through coastal states, leading to understated exports for inland states and overstated exports for coastal states in the International Trade Administration (ITA) data.

Empirical studies find positive impact of subsidies on indicators of production, including an increase in land use and input use (Chavas and Holt 1990; Antón and Le Mouël 2004; Key, Lubowski, and Roberts 2005; Bhaskar and Beghin 2010); an increase in land rental rate and tenants' revenue (Roberts, Kirwan, Hopkins 2003; Kirwan 2009); and an increase in on-farm work or a decrease in off-farm work or leisure activities (Mishra and Goodwin 1997; El-Osta et al. 2004; Ahearn et al. 2006; Key and Roberts 2009).[2] However, the extant empirical literature on the influence of domestic subsidies on exports, imports, and trade is rather scant. Notably, Hertel and Keeney (2006) and Diao, Somwaru and Roe (2001) compared the effect of farm subsidies on global trade and welfare with the effect of tariffs. Hoekman, Ng and Olarreaga et al. (2004) and Dimaranan, Hertel and Roman (2004) shed light on the effect of agricultural support reform in developed countries. Koo and Kennedy (2006) compared the effect on global price, exports, and welfare of border support typically undertaken by the EU, and the effect of domestic support undertaken by the United States. Dewbre, Anton and Thompson (2001) and Dewbre and Short (2002) evaluated the effects of market price support, output payments, area payments, and variable input payments used by Organization for Economic Co-operation and Development (OECD) countries on trade, production, and income. They found that input support is the most trade distorting, followed by market price support and output payments. The least trade distorting is area payments, while historical payments are assumed to have no effect on trade. Thus, despite some global scholarly attention devoted to the role of domestic subsidies, the effect of U.S. farm subsidies on U.S. farm exports is a major gap in the literature that remains to be bridged.

In a nutshell, we depart from the extant literature in two major respects. First, this is the first study to estimate the trade effects of U.S. farm subsidies for the recent period of 1999 to 2011, corresponding to three major U.S. farm bills. Second, we examine whether or not different categories of subsidy payments—such as those belonging to the amber box and green box—affect U.S. states' exports in ways consistent with their perceived distortionary effects.

Contextual Background

U.S. Farm Bills and Farm Subsidy Categorization

An Overview of U.S. Farm Bills 1996, 2002, and 2008

The support of the U.S. federal government for farm producers is institutionalized in farm bills that are updated about every five years. The *FAIR Act of 1996*, known as the "production flexibility contract," marks a significant change in the course of farm support in U.S. history. As per this Act, producers could freely plant crops, except fruits and vegetables, to be eligible for support. In addition, subsidy payments were divorced from current production because the support calculation was based on historical production, known as base acreage and yield. However, the poor market conditions from 1998 to 2000 triggered an ad hoc market loss assistance payment. This program became an official payment in the next farm bill—the *FSRI Act of 2002*—under the name of counter-cyclical payments (CCP). In addition, soybeans and other oilseeds were added as "covered commodities." Moreover, farmers were allowed to change their reference period for base acreage and yield, as per this Act. Critics have argued that the opportunity to update base acreage may trigger current production if farmers expect a similar updated base acreage and yield in the future. The *FCE Act of 2008* continued the previous farm bill provisions, with small adjustments in the subsidy rate for eligible crops. In addition, the Act introduced the average crop revenue election (ACRE), which is triggered when revenue falls below a threshold. Farmers could choose to enroll in either ACRE or CCP, but not both.

U.S. Categorization of Farm Subsidies

U.S. farm subsidies are categorized into four programs: commodity, crop insurance, disaster payment, and conservation reserve. The commodity program is the largest and most important category, accounting for two-thirds of total farm subsidies. This program includes direct payments (DP), CCP,[3] marketing assistance loans (MLs) for crops, and payments for dairy and sugar. Commodities eligible for DP and CCP are called "covered commodities" and include wheat, corn, grain sorghum, barley, oats, upland cotton, rice, and pulse crops. Meanwhile, "loan commodities" include covered commodities, plus extra-long staple cotton, wool, mohair, honey, dried peas, lentils, and small chickpeas, and refer to commodities for which MLs apply. To be eligible for commodity payments, farmers must "actively engage in farming," meaning they must share the risks of producing crops. In addition, farmers must comply with certain environmental and land conservation measures, as well as planting flexibility rules.

The DP is granted to covered commodities (except pulse crops), plus peanuts, with a fixed rate based on historical entitlement. The CCP is delivered to covered commodities based on acreage, which is similar to the DP, however, it is triggered when harvest-time market price (or revenue, if referring to ACAE) falls below a predetermined price in the statute. Meanwhile, MLs provides farmers with interim financing and, if market prices drop below the loan prices set in the statute, additional income supports are granted as loan deficiency payments (LDPs). Market loans are nonrecourse loans that allow farmers to borrow cash using their harvested crops as collateral when market prices of crops are low. Alternatively, if farmers sell their commodities at a price lower than the setting loan price in the statute, they will receive support for the gap between the loan prices and market prices. Unlike DP and CCP, which are "decoupled" from production, MLs are linked to both market price and current production.

Crop insurance programs help reduce losses caused by natural disasters and weather-related diseases. For insurable crops, farmers can choose to insure the yield level alone or the revenue level, and pay a premium for the chosen level. The U.S. government has spent increasingly greater amounts on these programs with the hope that they can replace ad hoc disaster payments. These annual payments amounted to US$500 million in the 1980s, doubled after a decade, and, since 2000, have cost approximately US$3.3 billion per annum. The majority of this fund is paid to farmers to support their payments for insurance coverage; in 2004, approximately 370 crops and 80% of planted acreage had insurance coverage.

Supplementing the crop insurance, disaster payments provide support to relieve losses of crops or livestock that are not eligible for crop insurance. If a crop experiences a loss of at least 50% compared with historical production, 55% of the market price payment for this crop will be granted. Although sharing a common purpose with crop insurance to help farmers with financial recovery, disaster payments are granted after losses occur.

Finally, conservation reserve programs (CRPs) are delivered to encourage farmers to retire erodible lands. To receive payments, farmers must remove low-quality land from production and plant species that help improve land quality and health.

The WTO Categorization of Farm Subsidies: Amber, Blue, and Green Box Categories

The WTO classifies agricultural production subsidies into the amber, blue, and green boxes. Amber box supports are related to price support or production promotion, and hence distort trade. An amber box payment becomes a blue box payment if it is accompanied by restrictions on production that can offset production stimulation to a reasonable degree. A green box payment provides minimal trade and production distortion. In U.S. farm assistance, disaster payments and payments under CRPs are classified into green boxes. Crop insurance programs are assigned to amber boxes, as they reduce yield and price risks, and these effects are known to farmers when they make their planting decisions. The commodity programs MLs and CCP are categorized as amber box payments, as they are related to market prices and/or current production. DP is related to neither market condition nor current production, and is currently assigned to the green box.

Doha Round Trade Talks

U.S. farm subsidies cannot be considered independent of the international context—particularly the ongoing Doha Round of trade talks run by the WTO. The reduction of domestic production subsidies and elimination of export subsidies in agriculture have been at the very center of the Doha negotiations since 2001. Although developing and developed members of the WTO recently agreed to remove export subsidies from agricultural exports in 2018, the reduction or elimination of farm production subsidies soon remains an impossible mission.[4]

The gloomy prospect for Doha trade talks of reducing domestic agricultural production support is the result of several factors. First, developed countries have frequently implemented export subsidies and domestic subsidies in excessively large amounts over decades. For example, 49 OECD and emerging countries transferred an annual average of US$601 billion to agricultural producers during 2012–2014; see OECD (2015). Because stakes are extremely high, powerful interest groups have formed to advocate maintaining domestic production farm support in ongoing trade talks (Da Conceição-Heldt 2011). Second, the lack of progress in the Doha Round illustrates the poor understanding of the constraints faced by governments in determining their trade policy (Gawande and Hoekman 2009) and the consequences of these policies (Sumner

2005). On one hand, the uncertain consequences of removing domestic production farm support will make it harder for negotiators and policymakers to engage in effective trade negotiations. On the other hand, powerful political forces resisting to reform always maintain that the negative consequences of reforms for domestic farmers outweigh their potential gains by domestic consumers. Negotiators need a clear evidence that the agreed upon trade reforms do not represent unfair disadvantages for domestic farmers.

Data Description and Summary Statistics

Data Description and Sources

We use data on farm exports of 45 U.S. states to the 100 largest trading partners of the United States, which account for 98% of U.S. total trade of all merchandise (sum of imports and exports). The sample spans the period 1999–2011. Alaska, North Dakota, South Dakota, Wyoming, Hawaii, and the District of Columbia are excluded from the sample because their trade flows are negligible. These regions together comprise less than 2% of total trade value.

Annual data of bilateral export values for aggregate farm products, as well as the data on agricultural and livestock exports, were collected from the U.S. Commodity Flows Surveys (CFS) of the ITA. The state-level bilateral exports/imports data by sector are appealing for the gravity model and have been adopted by several studies (e.g., Hillberry 2002, and Hillberry and Hummels 2008). These studies find that the gravity model fit the bilateral ITA data well. Farm exports in the CFS data include agricultural exports and livestock exports. Agricultural exports encompass crop exports, while livestock exports include livestock exports plus milk exports.[5]

However, the CFS dataset has an important shortcoming that it tracks products at the customs frontier they cross. Although in the majority of cases the customs frontier is the state where the products are produced, in some cases the customs frontier is not the same state where production takes place. This leads to the overstatement of exports for coastal states and understatement of exports for inland states in the ITA data. The alternative data source, United States Department of Agriculture (USDA), includes estimated exports based on cash receipts at the farm gate, hence suffers less from the point-of-origin problem, but it only includes the states' exports to the whole word but not their bilateral exports. Nonetheless, the USDA data enable us to understand the size of the measurement error problem in the ITA data. Appendix Table A1 in online appendix shows that average leakage of inland states over the sample period is 18%, while average excess for coastal states is 135%.[6] We discuss whether and how this co-mingling in the exports data could affect the subsidy elasticity estimates in the *Empirical Framework* section.

Moving on to subsidies, data on annual state-level domestic subsidies, both as disaggregate categorizations of agricultural and livestock products and at the aggregate level, were obtained from the Farm Subsidy Database of the Environmental Working Group. We include dairy subsidies into livestock subsidies. Data on the subsidy payments include DP, CCP, and commodity, disaster, and crop insurance.[7]

Gross domestic product (GDP) for each state was derived from the United States Department of Commerce. The bilateral distance between a state and a trading partner is the flight distance between the two corresponding capital cities, calculated by the authors using the website Worldatlas. Data on U.S. states' binary indicators of having a shared land border or coastline were collected from online sources, such as Reference.

A Snapshot of U.S. Farm Subsidies and Farm Exports

Figure 1 shows that each year during the period 1996–2012, 1.2–1.6 million farmers received farm subsidies across the entire United States. The total number of recipients over the whole period is more than 25 million. The number of recipients trended somewhat downward over time, consistent with the decreased subsidy payments in the *FCE Act of 2002*.

Subsidy payments differ substantially across U.S. states. Figure 2 depicts the *average* subsidy payments for each state during the period 1999–2011, portraying substantial cross-sectional variation. It also illustrates that almost half of the states (21) receive less than US$170 million annually, and eight of 45 states receive in the range of US$170–300 million per year. Fewer states receive higher levels of payments, with only three states receiving more than annual average of US$1.2 billion.[8] Moving onto farm exports, average annual exports from a given state to an importing country in the sample are $8,480,780. Exports from a typical state to its ten largest trading partners[9] account for up to 70% of its exports worldwide, while exports to Mexico and Canada make up 23% of the total export value.

Importantly, the within-state variation of subsidy receipts is large. Figure 3 paints the picture for six selected states ranked differently in the subsidy tally: Minnesota and Texas as high receivers, Alabama and Idaho standing in the middle, and Rhode Island and New Hampshire as low receivers. Subsidy payments vary sizably over time for a state and the pattern of variation is also markedly different among states. For example, Rhode Island received a tiny subsidy in years 2011 and 2001, but the payment was around 13 times higher in 2008 and 2005. By contrast, Texas consistently receives a large amount of support over time, with the maximum value in 1999 being only twice as large as the minimum value in 2010.

Figure 3 also shows that farm subsidies generally exhibit declining trends. Recall that programs that hinge on market prices—such as marketing loan gains, LDPs, and commodity certificates—are instigated when market price at the time of harvest falls below a predetermined price and the payment closes the gap. Our sample period witnessed drastically declined prices of subsidized crops at the harvest times in the period 1999–2002. Hence, these years saw high amounts of subsidy payments. The subsequent years exhibit fluctuating payments with a declining trend. Thus, despite the quite stable subsidy policy through the farm bills of 1996, 2002, and 2008, actual payments were highest during 1999–2002, inducing a declining trend over time.

Figure 3 also displays that, in contrast to subsidy payments, farm exports follow a clear upward trend. Increasing export trends are typically caused by expanding global demand and reduced trade barriers. Trends of both farm subsidies and farm exports are state specific.

For the summary statistics of the main covariates used in this article, see table 1.

Empirical Framework

The Gravity Model

We use the gravity equation as the standard workhorse to explain the value of bilateral trade. A structural gravity model a la Anderson and van Wincoop (2003) has the following form:

(1) $$EX_{ij} = \frac{GDP_i GDP_j}{GDP_w}\left(\frac{T_{ij}}{M_i M_j}\right)^{1-\sigma}$$

where i, j and w denote the exporter, the importer and the world and M_i and M_j represent the multilateral resistance terms or the exporter's and the importer's ease of market access, respectively (Yotov et al., forthcoming). The bilateral trade cost between exporter i and importer j, T_{ij}, is accounted for by factors standard geographic variables and trade policy variables. Policy variables can includes tariffs or subsidies.

Transforming gravity model (1) into a log-linearized econometric specification using panel data of U.S. farm exports we obtain:

(2) $$Log(EX_{ijt}) = \alpha_0 + \alpha_1 Log(GDP_{it}) + \alpha_2 Log(GDP_{jt}) + \alpha_3 Log(GDP_{wt}) + \alpha_4 Log(T_{ijt}) + \alpha_5 Log(M_{it}) + \alpha_6 Log(M_{jt}) + \varepsilon_{2ijt}$$

where EX_{ijt} is now the value of farm exports from U.S. state *i* to importer country *j* in year *t*. GDP_i and GDP_j are the states' GDP and the importer's GDP in year *t*, respectively, while T_{ijt} represent the bilateral trade cost between them. For our purpose of estimating the export effects of U.S. farm subsidies on U.S. farm exports we first rely on the following baseline gravity model:

$$(3)\quad Log(EX_{ijt}) = a_{jt} + b_i + \alpha_1 Log(Subsidy_{it}) + \alpha_2 Log(GDP_{it}) + \alpha_3 Border_{ij} + \alpha_4 Coastline_i + \alpha_5 Log(Distance_{ij}) + \varepsilon_{3ijt}$$

where the bilateral trade cost, T_{ijt}, is modeled as a function of the following variables: $Subsidy_{it}$ is the subsidy amount granted to state *i* in year *t*; $Border_{ij}$ is a dummy variable equal to 1 if state *i* and importer *j* share a land border and 0 otherwise; and $Coastline_i$ is a dummy variable equal to 1 for states with a coastline and 0 otherwise. $Distance_{ij}$ is the bilateral distance between the capital city of a state and its trading partner.[10]

In gravity-based econometric models, a_{jt} controls for importer-year-specific effects, which accounts for GDP_{wt}, GDP_{jt}, and all importer-specific trade-promoting or -restricting components of T_{ijt}. If U.S. farm subsidies are correlated with the subsidies of the importer countries (be it production or export subsidies), then not controlling for importer countries' subsidies in the model would bias the elasticity estimates of U.S. farm subsidies. However, the quality and credibility of data on subsidy of other countries are questionable because of a number of missing observations and inaccurate notifications (Nuetah, Zuo and Xian 2011). Further, importer-year dummies account for "multilateral resistance" from the importer side as well. Meanwhile b_i dummies partly take care of "multilateral resistance" from state side. Failing to control for this will bias the gravity coefficients (Anderson and van Wincoop 2003). In our empirical analysis, we provide a robustness check by removing importer-year fixed effects and adopting GDP_{jt} as well as running regressions for sub-samples of importer country groups of different development levels.

Crucially, we enrich equation (3) by including the lagged subsidies, because ignoring possible dynamic effects of subsidies would lead to biased estimates of its total effect. If agricultural subsidies affect agricultural production by increasing farm productivity, then we could observe an effect of subsidies in year *t* on farm exports in the following year(s). In addition, programs that are trigged based on market price at harvest time, including CCP, MLs and LDPs, are unknown to producers in the current year. As such, farmers may use the payment of previous years to make production decisions in this year (Goodwin and Mishra 2006). In this case, subsidies would affect exports with a lag, and the effect may be large as those are important programs whose payments hinge on both production and price. As it turns out, the first lag of subsidy is significantly estimated in our empirical models. The specification incorporating state fixed effect and lag of subsidies is:

$$(4)\quad Log(EX_{ijt}) = a_{jt} + b_i + \alpha_1 Log(Subsidy_{it}) + \beta Log(Subsidy_{i(t-1)}) + \alpha_2 Log(GDP_{it}) + \alpha_3 Border_{ij} + \alpha_4 Log(Distance_{ij}) + \varepsilon_{4ijt}$$

Finally, we cluster the standard errors for state–importer pairs.

Endogeneity and Identification

In the absence of an exogenous shock to U.S. farm subsidies, subsidy payments might reflect several observable and unobservable state characteristics that might be correlated with state-level farm export levels and trends. There are two identification concerns regarding subsidy levels. First, subsidy programs such as DP and to some extent CCP are paid on historical entitlements or planting acreage and yields, which are state specific and change little annually. Thus, the relative ranking of states in the subsidy tally is stagnant over time, with large states being the larger recipients of the subsidy payments, and vice versa. This type of cross-sectional non-random sorting problem leads to a positive time-invariant correlation between subsidies and exports. We address this time-invariant bias to a large extent by using state fixed effects (b_i) in the gravity model. Since we have Cov$((Log\ (Subsidy_{it}),\ b_i) > 0$ and Cov$((Log\ (Subsidy_{it-1}),\ b_i) > 0$, we expect the elasticity of subsidies (i.e., α_1 and β) reduce in magnitude when state fixed effect is controlled for.[11]

The second identification concern with subsidy levels is the way subsidies are allocated to states under crop insurance and disaster programs. As explained in the *Contextual Background* section, these programs are characterized by a common feature that subsidy payments on average negatively correlate with the production and exports of U.S. states that belong to regions with similar natural and weather conditions. For example, under crop insurance and disaster programs, farmers who suffered losses owing to weather or natural disaster and consequently experienced decline in production in a given year are eligible to receive subsidies.[12] It is evident that such factors that influence the production of farmers and subsidy payments are not specific to states, but to regions, and are likely to vary annually. The resulting omitted variables problem leads to a negative correlation between subsidies and farm exports. To address this, we include the region-by-year dummies (c_{rt}) in our gravity equation.[13] If such problem indeed exists, we must have Cov$((Log\ (Subsidy_{it}),\ c_{rt}) < 0$ and Cov$((Log\ (Subsidy_{it-1}),\ c_{rt}) < 0$, and thus the effect of subsidy payments on exports (i.e., α_1) would increase when region-by-year fixed effects are controlled for.

An alternative identification problem is selection on trends, whereby differences between states in the temporal evolution of subsidies and exports could trigger bias. Recall from Figure 3 that subsidy payments exhibit a downward trend, while exports follow a clear upward trend. The opposing trends in subsidies and exports would lead to Cov(($Log\ (Subsidy_{it}),\ \tau_i$) < 0 and Cov(($Log\ (Subsidy_{it-1}),\ \tau_i$) < 0 meaning that failing to control for state-specific trends might mistakenly attribute a lower effect to subsidies. As the linear trend assumption is hardly satisfied over long periods and given the non-linear patterns noticeable in subsidies and farm exports in Figure 3, we also use the quadratic, cubic, and fourth-degree polynomials of these trends.

An additional advantage of controlling for state-specific time trends is to relax the parallel trends assumption, as it could be violated in a sample period of more than 10 years. Controlling for such trends levels off the trajectories of the subsidy-receiving and non-subsidy-receiving states—or high-receiving and low-receiving states. For a meaningful interpretation of elasticities, states subject to lower subsidies should ideally constitute counterfactuals that trend similarly to states that receive subsidies.

All these considerations lead us to our preferred gravity model:

$$(5)\qquad Log(EX_{ijt}) = a_{jt} + b_i + c_{rt} + \tau_{it} + \tau_{it}^2 + \tau_{it}^3 + \tau_{it}^4 + \alpha_1 Log(Subsidy_{it}) + \beta Log(Subsidy_{i(t-1)}) + \alpha_2 Log(GDP_{it}) + \alpha_3 Border_{ij} + \alpha_4 Log(Distance_{ij}) + \varepsilon_{5ijt}$$

Accounting for permanent state differences, region-by-year effects, and higher polynomials of state-specific time trends in equation (5) is likely to isolate a myriad of unobservable characteristics in subsidy payments (see Cesur et al 2017 and 2018 for a similar argument). While this approach may not entirely rule out all the endogenous variation in subsidies, the remaining variation is likely to be free of bias in subsidy levels and trends with respect to state-level farm exports. This restrictive specification is expected to permit plausibly exogenous empirical leverage, at least initially, to estimate the elasticity of state-level farm exports to farm subsidies.

An important question is what could be behind the remaining (i.e., exogenous) variation in farm subsidies. There are a few possible factors. First, new farm bills introduce new amounts of total subsidies for the subsequent five years. Second, emergency legislations in 1998 and 1999 provided largely unanticipated subsidy changes (Kirwan 2009). Third, stochastic price changes every year trigger different amounts of CCP and MLs payments. As stipulated in the *A Snapshot of U.S. Farm Subsidies and Farm Export*s section, higher commodity prices during our sample period reduced the CCP, and hence farm commodity spending. Fourth, risk distribution of farmers may differ randomly over time, which could lead to different levels of crop insurance uptake. While the first two variations are discrete changes, the latter two cause continuous fluctuations. Figure 3 instructively demonstrates the year-on-year fluctuations in individual and total subsidy outlays. Taken together, after taking into account permanent state characteristics, region-by-year effects, and state-specific time trends, our exogenous variation is likely to be driven by factors that translate the nation-level changes in farm bills, emergency legislation, commodity prices, and program coverage to each state, as well as random differences in farmers' risk behavior.

Next, we undertake two tests to determine whether our identification is indeed successful. First, we run a regression of *Log (Subsidy)* on all the explanatory variables in equation (5). The results presented in Online Appendix table A3 show that equation (5) can isolate a wide range of biases mentioned above. Column (1) shows that subsidy levels are endogenous to several state covariates, such as GDP, distance, coastline, and land border. Subsequent columns increasingly impose restrictions on this model by adding b_{jt}, c_{rt}, τ_{it}, and higher-degree polynomials of the latter. The last column includes the fullest array of explanatory variables in equation (5). As expected, this specification renders all state covariates insignificant to explain the subsidy payments. Consequently, we seem to be able to have the U.S. states comparable on average to one another on factors, other than subsidies, that affect farm exports.

Second, we test for the "feedback effect" in which, conditional on state fixed effects, region-by-year fixed effects, and state-specific time trends, farm exports reverse-cause farm subsidies. Note that trade shocks or trade performance may provide feedback for future subsidy changes, whereby farmers might expand their current production in the hope of receiving more future payments, see Sumner (2005). The requirement of no "feedback effect" is referred to as a "strict exogeneity" condition for fixed-effects estimation to be consistent (see Wooldridge 2002, and Baier and Bergstrand 2007). The test includes the lead value of the suspected endogenous variable in the fixed-effects model. If the remaining within-state variation in farm subsidies is strictly exogenous to farm exports, we would expect future subsidies to not be related to contemporaneous exports. Several regression results reported in Online Appendix table A4 yield no evidence supportive of the "feedback effect" in our benchmark models, probably because several measures present in the model are doing a good job eliminating these biases.

The final estimation issue is the measurement error in farm exports. Recall that the inland states ship some of their exports through coastal states, leading to overstated exports for coastal states and understated exports for interior states in the ITA data.[14] As the gravity model includes the dependent variable in natural logarithm, this measurement error is assumed to be a fraction of states' exports (i.e., $EX_{it}*v_{it}$, where v is the measurement error, such that $log(EX_{it}*v_{it})=log(EX_{it})$ +

$log(v_{it})$). It is not immediately clear whether and how subsidies are correlated with the percentage leakage in inland states' exports and excess in coastal states' exports and what the direction of the potential bias is in our key elasticity estimate. Nonetheless, the time-invariant component of this measurement error would be captured by state-fixed effects (i.e., on average inland states report lower exports and coastal states report higher exports). Region-by-year fixed effects and state-specific time trends could capture some, if not all, of its time-varying component. For example, if subsidies favor bulk crops, such as corn, rice and cotton, over time, they will divert resources away from fruit and vegetables (which are more likely to be shipped by air), increasing the percentage leakage in exports. Region-by-year fixed effects can help here because states in the same region generally share common crops (i.e., regions are categorized based on farm resources), and thus, their response resource changes in subsidies is likely to be similar. State-specific time trends can kill any trend due to economic recession, declining trends in prices, increasing trends in subsidies, as well as the trends in the consequent leakages. We consider some robustness exercises in the *Sensivity Analysis* to check the implications of this problem on our key results.[15]

Results and Analysis

Elasticity of U.S. Farm Exports to U.S. Farm Subsidies

Table 2 presents the results from a range of models. Columns (1) and (2) display the estimates from equations (1) and (2), respectively. Column (3) adds region-by-year dummies, and column (4) includes linear state-specific time trends. Columns (5) to (7) relax the linear trend assumption by cumulating quadratic, cubic, and fourth-degree polynomials of the state-specific time trends. Column (8) and (9) add, respectively, the first and second lags of subsidies in the model.

Column (1) shows that all the coefficient estimates have the expected sign from a gravity model and are statistically significant at the 1% level. Specifically, bilateral distance reduces exports, while the GDP of U.S. states and the binary indicators of shared land borders and having a coastline are associated with higher exports. The richer specifications from columns (2) to (7) also perform well, with the only seemingly counterintuitive result being that GDP is insignificant. The latter could be because columns (2) to (9) include state fixed effects. Since the GDP of U.S. states does not vary much over time, it strongly correlates with state fixed effects.[16]

Turning to subsidy elasticities, the results in columns (1) to (9) in table 2 show that farm subsidy payments exert a positive and statistically significant influence on the level of farm exports. In the absence of any controls for selection, the elasticity estimate in column (1) is 0.617. Controlling for state fixed effects, and subsequently the endogenous variation in subsidy payments caused by time-invariant state characteristics, we find the elasticity estimate to be much lower, standing at 0.144 (column 2). This decrease is expected because, without addressing the said endogeneity, one is likely to overestimate the effect of subsidies on exports. Controlling for region-by-year effects in column (3) does not have any effect on the elasticity estimate. By contrast, controlling for selection on trends has a greater influence on the elasticity estimate. When state-specific time trend is accounted for in linear form (column 4), the estimate increases to 0.208. This increase is anticipated owing to the negative correlation between the subsidy and export trends. The effect fluctuates moderately between 0.16 and 0.20 with the inclusion of the higher-degree polynomial of the state-specific time trend. The full model in column (7) delivers an elasticity estimate of 0.18. Lastly, column (8) shows that the first lag of subsidies is also significant, with the elasticity estimate in both year t and $t-1$ being 0.20, suggesting that the total effect on total exports is 0.40. This result is not surprising, as the lag effect of subsidies reflects the effect of programs that hinge on market price at the harvest time such as CCP, MLs, and LDP. Because column (9) indicates that the second lag of subsidies is insignificant, column (8) represents our benchmark empirical model for numerical implications.

Taken together, the estimate from our preferred specification shows that a one-percentage point decrease in farm subsidies would reduce U.S. farm exports by 0.40%. Equivalently, if the U.S. farm subsidy program was to be completely abolished, its farm product exports to the world markets would decrease by 40% or US$15.28 billion each year.[17] While this could suggest that other countries—especially the low-income countries that heavily depend on agriculture—might have better opportunities to access the world market, U.S. jobs may be placed at risk. Recall that farm subsidies benefitted more than 25 million recipients across the U.S. during 1996–2012.

To put our estimated export elasticity of subsidies in perspective, let us compare them with production elasticity estimates. Key, Lubowski, and Roberts (2005) find that complete abolishment of the subsidy program would reduce crop area by 38–59%, while Gardner, Hardie, and Parks' (2010) results suggest that a 100% reduction in acreage payments would lead to a 48% reduction in crop area. These studies use, respectively, farm-level and county-level panel data from the U.S. Agricultural Censuses of 1987, 1992, 1997, and 2002. Given that our approach is based on a state-level gravity model that includes dynamic subsidies and over the period 1999–2011, the results are not strictly comparable. Nonetheless, this comparison suggests that our export elasticity estimate of 40% is reasonable.

Farm Subsidies and Farm Exports: Agricultural Commodities vs Livestock

More than 98% of U.S. farm subsidy payments are made to agricultural commodities (including all eligible crops), and only a tiny proportion is granted to livestock. Agricultural subsidies encompass the program payments of DP, CPP, and MLs whereas livestock subsidies include only disaster payments. To determine whether the subsidy effect is stronger for the agricultural subsidies, we take advantage of the decomposition in the data and estimate the effect of agricultural and livestock subsidies on agricultural and livestock exports. Panels A and B in table 3 report the results, respectively, for agricultural and livestock exports using our benchmark model that includes both contemporaneous and the first lag of subsidies.

In Panel A, columns (1) to (7) report the variations of gravity model as in table 2. The estimated magnitude and pattern of elasticities of agricultural exports to agricultural subsidies is analogous. In column (8), which also includes the lagged agricultural subsidies, the elasticity estimate is 0.20 for year *t* and 0.26 for *t-1*, with the total effect being 0.46. Column (9) additionally includes livestock subsidies in the model, yielding total elasticity for agricultural subsidies to be 0.42. Meanwhile, the livestock subsidy effect is estimated to be insignificant for year *t* and -0.02 for year *t-1*, which is significant at 10% level. The negative sign indicates possible crowding out of agricultural exports by livestock subsidies, but this effect seems to be small and statistically weak.

Panel B in table 3 reports no statistically significant relationship between livestock subsidies and livestock exports, for both years *t* and *t-1* (columns 1 to 9). This result is understandable as livestock is not a focus of support programs. Subsidies for livestock encompass programs that compensate parts of losses caused by diseases and are unanticipated to producers, thus are expected not to cause distortion to production and exports. In column (9), where agricultural subsidies are additionally controlled for, agricultural subsidies are estimated to have a positive effect on livestock exports in year *t*, an effect that is significant at 10% level. The estimated elasticity coefficient is 0.22, suggesting that agricultural subsidies could have positive spillovers on livestock exports. The positive effect of agricultural subsidies on livestock exports could occur when subsidized crops used to feed livestock become cheaper, making the livestock production become more competitive in the international market.

Identifying the Export Effects of Different Subsidy Programs by U.S. Categorization

We next explore the effects of commodity, disaster, and crop insurance payments on farm exports. Recall that commodity payments are the largest category of subsidies, and encompass programs that ensure a minimum market price, such as CCP and LDPs, or that provide interim financing, such as a marketing loan gain. The export-promoting effect of this program is expected to be the strongest. The remaining two subsidy categories—crop insurance, and disaster payment comprise less than 30% of all payments.

Table 4 presents the results using our preferred gravity model. As we do not know, *a priori*, the dynamic nature of the relationship using different subsidy categorizations, we present the results with and without lagged subsidies included. Columns (1) and (2) reveal that the commodity program is the major contributor to total farm exports. The elasticity estimate in column (2) stands at 0.19 for year *t* and 0.15 for year *t-1*, both significant at the 1% level, with the total subsidy effect being 0.34. By contrast, the elasticities of disaster payments are insignificantly estimated, see columns (1) and (2). The crop insurance subsidies, interestingly, exert a negative effect on total farm exports, with the lagged effect being significant at 1% level. The estimated elasticity, -0.15, may point to the moral hazard problem. When their crops are insured, farmers may have less incentive to prevent diseases or risk from occurring, and may use less risk-reducing input, such as fertilizer and pesticides (see Roberts, Key and O'Donoghue, 2006).

Identifying the Export Effects of Farm Subsidies by WTO Categorization

In accordance with the WTO rules and terminology, the United States assigns price and/or current production-related programs, including CCP and MLs, to the amber box. The support for disaster-relief payments and DP is categorized into the green box. It is expected that amber box payments would be the most trade distorting, while green box payments would have less, if any, effect. The availability of detailed information on program payment categorization enables us to verify the effect of separate subsidy classifications on U.S. farm exports.

Columns (3) and (4) in table 4 present the results. The estimated elasticity of subsidies in the amber box category is positive and statistically significant, with the coefficient estimates being 0.12 for both years *t* and *t-1* (column 4), suggesting that a one-percentage point decrease in amber box payments would reduce U.S. farm exports by 0.24%. The influence of the amber box subsidies is smaller than that of the total subsidies (0.24 < 0.40). This is likely because the amber box category covers a narrower range of commodities than the overall subsidies. Meanwhile, the green box effect is, as anticipated, relatively lower; the elasticity in year *t* is 0.06, which is statistically insignificant, and 0.07 in year *t-1*, which is significant at 10% level.

The Subsidy Effects of the DP Program on Farm Exports

DP were signed into law in the *FAIR Act of 1996* and removed with the 2014 farm bill. The DP is a key component of “decoupled” support programs, which are policies reformed to minimize interference on agricultural production and trade.[18] Nonetheless, the “minimal” influence of these programs on production and trade is subject to considerable controversy. For example, according to Hennessy (1998), under the condition of uncertainty, if producers are risk averse with decreasing absolute risk-aversion preferences, an increase in wealth would reduce absolute risk aversion. In addition, government payments help reduce income variability, referred to as the “insurance effect.” As a consequence of the wealth and insurance effects, “decoupled” payments might encourage farmers to grow in a crop area that is otherwise too risky. In addition, if farmers face credit constraints, DP can affect their investment plans by promoting liquidity easement (Goodwin and Mishra 2005, 2006).

Chau and de Gorter (2005) argued that DP can help cover fixed costs; thus, producers who would otherwise be forced to shut down can stay in business. Although there are numerous empirical studies on "decoupled" payments, they mainly focus on their production effect (Young and Westcott 2000; Burfisher, Robinson and Thierfelder 2000; Adams et al. 2001; Antón and Le Mouël 2004; El-Osta, Mishra and Ahearn 2004; Makki, Johnson and Somwaru 2005; Goodwin and Mishra 2005, 2006; Ahearn, El-Osta and Dewbre 2006; Serra et al. 2005, 2011; Mcintosh 2007; Key and Roberts 2009; Bhaskar and Beghin 2010; Femenia, Gohin and Carpentier 2010; O'Donoghue and Whitaker 2010). To our best knowledge, no study has hitherto illuminated the effect of "decoupled" payments on *trade*. In studies that distinguish the effects of different subsidy programs on trade, "decoupled" payments are either absent or their effect is assumed to be zero (Dewbre, Antón and Thompson 2001; Diao, Somwaru and Roe 2001).

We present the results in table 4 in two scenarios. In the first scenario, we include DP alongside the remaining subsidy payments (total subsidies minus DP). The results of this scenario, presented in columns (5) and (6) of table 4, indicate that DP has no effect on exports. This lends support to the credibility of "decoupling," which implies no export-promotion effect. The remaining part of the subsidies is significant at the 1% level, with combined contemporaneous and lagged effect being of about 0.29.

In an alternative scenario, we decompose total subsidies into three categories: DP, disaster payments, and amber box payments. Columns (7) and (8) show that DP is again insignificant in affecting total farm exports. By contrast, amber box payments have a positive and statistically significant effect on exports, with a total subsidy effect of 0.25. Disaster payments have a relatively negligible effect on exports (0.03), even though the estimate is significant at 10% (column 8). In sum, the regression results on the effects of the DP program on exports align with those on the production effect of decoupled payments; that is, the influence of DP is negligible. Our results are in agreement with the current categorization of DP in the green box. [19]

The Effects of Farm Subsidies on Farm Exports over Farm Bills 1996, 2002, and 2008

As a general tendency, subsidization undertaken by developed countries has shifted toward programs that limit their distortion on production and trade to satisfy the WTO regulations. The *FAIR Act of 1996* significantly reformed the U.S. subsidization policy by divorcing the payment rate from current production and commodity prices. Ad hoc payments in the following years and the subsequent 2002 farm bill legislated payments that again depended on market conditions. The 2008 farm bill continued with few amendments from the previous farm bill, making the subsidization policy more or less stable during this decade. However, with subsidy rates kept almost the same over time and with the general increase in market prices, program payments triggered by low market prices—such as marketing loans, LDPs, and commodity certificates—have been deactivated in recent years, thereby reducing total subsidy payments.

To investigate the export effect of subsidies over time, we allow the subsidy coefficient to vary over the farm bills by interacting contemporaneous and lagged subsidies in equation (3) with farm bill periods (i.e., 1999-2001 for farm bill 1996, 2002-2007 for farm bill 2002, and 2008-2011 for farm bill 2008). We consider total farm subsidies, agricultural subsidies, and livestock subsidies in relation to total farm exports, agricultural commodity exports, and livestock exports, respectively. The results presented in table 5 show that the effects of total subsidies on total farm exports are positive, steadily increasing, and significant across all three farm bills. The total effects combining the contemporaneous and lagged subsidies are 0.39, 0.47, and 0.56 for the farm bills of 1996, 2002, and 2008, respectively (columns 1 and 2). The agricultural subsidy effect on agricultural exports is likewise positive and relatively stable, with respective total elasticities of 0.45, 0.59, and 0.62 (columns 3 and 4). Livestock subsidies are insignificant in explaining livestock exports over different farm bills (columns 5 and 6).

Sensitivity Analysis

We now conduct some robustness checks for the subsidy payments-farm exports relationship.

Agricultural subsidies differ (in magnitude and targets) across trading partners of the United States, most prominently across their levels of development. To understand the role of importer-country development level in our results, we group importer countries as low-income, low- and lower-middle income, upper-middle income, and high-income trading partners of U.S. states. Results in columns (1) to (4) in table 6 show that U.S. subsidies increase farm exports significantly to upper-middle income and high-income trading partners, with the combined elasticity estimates, respectively, being 0.64 and 0.35. The effect is insignificant for low- and lower-middle-income trading partners. One potential explanation is that U.S. farm subsidies do not have any bearing on exports to less developed countries because the latter have small markets. Results also suggest that U.S. farm subsidies affect the upper-middle income importers most strongly, while high-income importers, despite being affected, may have measures that counter-balance U.S. farm support programs. Note that we cannot quantify the GDP effect of importers on U.S. farm exports with importer-by-year fixed effects in the model. To address this, we utilise importers' GDP directly in our full sample (and remove the importer-by-year fixed effects) in column (5), and estimate a positive and significant effect of importers' GDP on U.S. farm exports. This regression still yields a positive and significant effect of total subsidies on total farm exports.

An important issue is the possible discrepancy in the ITA data regarding the point of agricultural production and customs. We already control for state-fixed effects, region-by-year fixed effects and state-specific time trends to capture the various components of this measurement error. One way of checking how successful our preferred gravity equation is with addressing the measurement error in state farm exports is to estimate the model for inland and coastal state sub-samples. If the two sub-samples provide elasticity estimates whose 'weighted average' is not dramatically different than the estimate produced by the full sample, then we could take some comfort with our approach. Column (6) in table 6 reports that the subsidy effect is significant and large for inland states, with a combined elasticity of 0.44 in years *t* and *t-1*. Turning to coastal states, column (7) shows that the combined elasticity for these states is 0.24, with relatively weak, if not negligible, statistical power (with t-statistics hovering around 1.3). Because the two-thirds of subsidy payments are received by inland states, we feel that our key subsidy effect in the full sample, 0.40 is a reasonable 'weighted average' of 0.44 and 0.24. However, in the absence of a direct remedy, we cannot entirely rule out some bias in our full sample estimate, and this remains an important shortcoming of our analysis.[20]

Our identification strategy is based on a large set of fixed effects, and is shown to be producing stable elasticity estimates. We next check the sensitivity of our treatment effect to an alternative method by estimating instrumental variable regressions using exogenous variation in natural disasters. We exploit the detailed data on natural disasters in U.S. states in the National Oceanic and Atmospheric Administration database.[21] We use four different natural-disaster-related variables to capture different aspects of disaster severity in a state: the number of disasters; the proportion of affected counties in total number of counties; the share of direct and indirect injuries in state population; and the share of direct and indirect deaths in state population, all for a given year in a given state.[22] These measures could capture the frequency, intensity, and spatial and demographic effects of disasters within a state over time. Table 7 reports the instrumental variable (IV) results using our preferred gravity equation with both contemporaneous and lagged subsidies (instrumented with contemporaneous and lagged natural disasters, respectively)[23]. Columns (1) to (4), utilizing each natural disaster measure separately, yield insignificant subsidy effects in year *t*. However, the subsidy effect is significant (weakly significant) for year *t-1* when we use the share of direct and indirect deaths (injuries) in the state population as IV, see columns (3) and (4). Our preferred IV estimation, reported in column (5), utilize all the four natural disaster measures. This estimation yields a lagged subsidy elasticity of 0.67, which is significant at 1% level. Note that using natural disasters as IV yields a local average treatment effect (LATE), which is the response of the subsidy-exports relationship to natural disasters, while our key elasticity estimate 0.40 is the average of all exogenous changes in subsidies. The estimated total LATE, 0.67, is not far from 0.40. This model shows that our key estimate, 0.40, is not very sensitive to an alternative estimation that teases out only one of the sources of those exogenous changes. Nonetheless, the contemporaneous subsidy effect is insignificant in a year with natural disasters, but the following year witnesses a significant effect of 0.67. This could be because the natural disaster hampers production, whose export impact shows up with a delay. Finally, column (6) shows that removing region-by-year fixed effects from the model does not make a meaningful change to the results.[24]

Another concern is whether there are spillover effects between states. If subsidy and production decisions by one state affect the exports of another state, the mean equation will suffer from omitted variable bias. We address this concern by using bordering states' subsidies as an additional explanatory variable (over and above the subsidies of state *i*) in our preferred gravity equation. Our hypothesis is that if subsidy spillovers from neighbors to state *i* are present, then neighbors' subsidies would explain state *i*'s exports significantly. In addition, a significant neighbors effect would alter the estimated coefficient of the subsidies of state *i*. We measure the bordering states' subsidies as unweighted average of all land-bordered neighbors' subsidies, as well as their weighted averages, where the weights are neighbors' sizes measured by population, GDP, and surface area.[25] Online Appendix table A6 shows that, controlling for state fixed effects, region-by-year fixed effects, and importer-by-year fixed effects, all the neighbors' average subsidy variables (unweighted and weighted) are estimated to be insignificant. The coefficients of the subsidies of state *i* also remained mostly unchanged.

An additional question is whether certain states affect the estimates. For example, on average, Texas, Illinois, and Iowa receive more than US$1 billion per annum in agricultural subsidies during the period 1999-2011. In order to determine whether the estimated effect of subsidies on agricultural exports is mainly due to Texas, Illinois, and Iowa, we report estimates of equation (3) excluding these three states from the sample. Consistent with our earlier estimates, Online Appendix table A7 reports a positive and significant subsidy elasticity of 0.19% for year *t*. However, the subsidy effect in year *t-1* becomes much smaller standing at 1%, implying that the lag subsidy effect is mostly driven by the afore-mentioned three states.[26]

Another estimation issue is the zero observations in the dependent variable, a perennial issue in the study of trade flows. Unsurprisingly, the suggested estimation methods to account for zero values in farm exports, such as Tobit and Poisson, have not yielded converging econometric estimation in our case, probably because non-linear models may not reach a global maximum in the presence of several types of fixed effects in the model. Thus, we use only positive trade values in our models, a practice that parallels several other studies, such as Rose and Wincoop (2001), Disdier et al (2008), and Djankov et al (2010).[27]

A final consideration is that using only positive export flows in the regressions captures patterns in the intensive margin of trade whereby farm subsidies enable more exports to existing destinations. Thus, we also analyze the extensive margin of exports, that is, whether farm subsidies reduce the fixed cost of export products that otherwise would not go onto the world markets (using positive and zero export flows). Probit estimations in Online Appendix table A8, using a binary dependent variable that takes 1 for positive trade flows and 0 for zero trade flows, show that farm subsidies boost exports in the extensive margin too because they increase the state farm and agricultural exports to new destinations. Moreover, rich importers drive this effect, offering a mechanism for our earlier result that farm subsidies increase U.S. farm exports mostly to high-income importers (see table 6).

Conclusions

The United States is well known to have a long history of intensively subsidizing its farm producers. Farm subsidies represent a core economic policy question for U.S. administrations—Democrats typically expand the agricultural support programs, while Republicans tend to limit them. Despite the $285 billion taxpayer monies poured by the United States Congress into the agricultural support programs under the farm bills of 1996, 2002, and 2006, benefiting more than 25 million farm recipients, U.S. public policymakers lack evidence on the effect of farm subsidies on key outcomes, such as farm exports. Similarly, international negotiators have no access to reliable empirical evidence on the trade effects of farm subsidies, despite the latter being a hot debate in the multilateral trade talks of Doha Round since 2011.

Using a gravity model of state-level farm exports to the 100 largest trading partners of the United States in the period 1999–2011, we estimate the responsiveness of U.S. farm exports to U.S. farm subsidies. This is the first study to provide the export elasticity of U.S. farm subsidies in the literature. In addition, we document the relative importance of elasticities for a different range of subsidy payment programs, highlighting which subsidy programs boost farm exports the most, and which are the most trade distorting. We present significant, positive, and stable elasticity estimates that accord with economic intuition and can facilitate informed decision making for U.S. and global policymakers alike.

The subsidy programs in the United States provide a major advantage for studying the trade effects of farm subsidies because U.S. subsidy payments vary substantially not only across states, but also yearly. This feature of U.S. subsidy programs allows us to address the potential endogeneity owing to selection on the levels and trends of U.S. farm subsidies and farm exports. Specifically, in our preferred gravity model, we eliminate the potentially endogenous variation in subsidy payments by accounting for permanent state differences, region-by-year effects, and state-specific linear time trends. Our identification assumption is that once time-invariant state characteristics, regional differences that vary over time, and trends in subsidy payments are isolated, the remaining within-state variation in subsidy payments is likely to be reasonably exogenous to state-level farm exports, and would permit estimating meaningful trade elasticities of U.S. farm subsidies. Numerous tests, such as the feedback effect, confirm the plausibility of our subsidy elasticity estimates. The anticipated differences in the elasticity estimates across different gravity specifications also lend clear support to our finding.

Our findings document that a one-percentage-point decrease in subsidy payments would reduce U.S. exports by 0.40%. This correspondingly means that the complete abolishment of the domestic farm support program would result in a reduction of U.S. annual farm exports by about $15.3 billion. Importantly, in line with the WTO categorization, we document that amber box subsidy payments (subsidy programs that relate to current production decisions and interfere with market conditions) have the most trade-distorting effects, while the effects of green box subsidy payments, such as DP, are negligible. Similarly, the estimates of disaster programs are statistically insignificant. We also find that the subsidy effects are driven by agricultural commodities, rather than livestock program payments. Finally, we also examine the subsidy elasticities over time. The findings indicate that the elasticities of subsidy payments under the *FSRI Act of 2002*, *FAIR Act of 1996*, and *FCE Act of 2008* are relatively stable over time.

References

Adams, G., P. Westhoff, B. Willott and R. Young, II. 2001. 'Do Decoupled Payments Affect U.S. Crop Area? Preliminary Evidence from 1997-2000'. *American Journal of Agricultural Economics* 83 (5): 1190–5.

Ahearn, M., H. El-Osta and J. Dewbre. 2006. 'The Impact of Coupled and Decoupled Government Subsidies on Off-farm Labor Participation of U.S. Farm Operators'. *American Journal of Agricultural Economics* 88 (2): 393–408.

Anderson, J. 1979. "A Theoretical Foundation for the Gravity Equation", *American Economic Review*, 69(1): 106-116.

Anderson, J. and E. van Wincoop. 2003. 'Gravity with Gravitas: A Solution to the Border Puzzle'. *American Economic Review*, 93 (1): 170–92.

Antón, J. and C. Le Mouël. 2004. 'Do Counter-Cyclical Payments in the 2002 U. S. Farm Act Create Incentives to Produce'. *Agricultural Economics* 31: 277–84.

Baier, S. L. and J. H. Bergstrand. 2007. 'Do Free Trade Agreements Actually Increase Members' International Trade?' *Journal of International Economics* 71: 72–95.

Baldwin, R, and J. Harrigan. 2011. "Zeros, Quality, and Space: Trade Theory and Trade Evidence." *American Economic Journal: Microeconomics 3*(2): 60-88.

Bergstrand, J. 1985. "The Gravity Equation in International Trade: Some Microeconomics Foundations and Empirical Evidence". *Review of Economics and Statistics*, 67: 474-481.

Bhaskar, A. and J. Beghin. 2010. 'Decoupled Farm Payments and the Role of Base Acreage and Yield Updating Under Uncertainty'. *American Journal of Agricultural Economics* 92, 3.

Burfisher, M., S. Robinson and K. Thierfelder. 2000. 'North American Farm Programs and the WTO'. *American Journal of Agricultural Economics* 82 (3): 768–77.

Cesur, R., E. Tekin, and A. Ulker. 2017. "Air Pollution and Infant Mortality: Evidence from the Expansion of Natural Gas Infrastructure." *The Economic Journal 127*(600):330-362.

Cesur, R., E. Tekin, and A. Ulker. 2018. "Can natural gas save lives? Evidence from the deployment of a fuel delivery system in a developing country." *Journal of Health Economics 59*:91-108.

Chau, N. and H. de Gorter. 2005. 'Disentangling the Consequences of Direct Payment Schemes in Agriculture on Fixed Costs, Exit Decisions, and Output'. *American Journal of Agricultural Economics* 87 (5): 1174–81.

Chavas, J.P., and M.T. Holt. 1990. 'Acreage Decisions Under Risk: The Case of Corn and Soybeans.' *American Journal of Agricultural Economics* 72 (3): 529-53.

Da Conceição-Heldt, E. 2011. *Negotiating Trade Liberalization at the WTO: Domestic Politics and Bargaining Dynamics*. Basingstoke: Palgrave Macmillan.

Dewbre, J. and C. Short. 2002. 'Alternative Policy Instruments for Agriculture Support: Consequences for Trade, Farm Income, and Competitiveness'. *Canadian Journal of Agricultural Economics* 50: 443–64.

Dewbre, J., J. Antón and W. Thompson. 2001. 'The Transfer Efficiency and Trade Effects of Direct Payments'. *American Journal of Agricultural Economics* 83 (5): 1204–14.

Diao, X., A. Somwaru, and Terry Roe. 2001. "A Global Analysis of Agricultural Reform in WTO Member Countries," Background for Agricultural Policy Reform in the WTO: The Road Ahead. USDA, Economic Research Service, ERS-E01-001.

Dimaranan, B., T. Hertel and K. Roman. 2004. 'OECD Domestic Support and Developing Countries'. In *The WTO, Developing Countries and the Doha Development Agenda: Prospects and Challenges for Trade-Led Growth*, edited by B. Guha-Khasnobis, 63-91. UK: Palgrave Macmillan.

Disdier, A.-C., L. Fontagné, and M. Mimouni. 2008. "The Impact of Regulations on Agricultural Trade: Evidence from SPS and TBT Agreements." *American Journal of Agricultural Economics 90* (2): 336–350.

Djankov, S., C. Freund, and C.S. Pham. 2010. "Trading On Time." *Review of Economic and Statistics 92*(1): 166–173.

El-Osta, H. S., A. K. Mishra and M. C. Ahearn. 2004. 'Labor Supply by Farm Operators Under "Decoupled" Farm Program Payments'. *Review of Economics of the Household* 2 (4): 367–85.

Femenia, F., A. Gohin and D. Carpentier. 2010. 'The Decoupling of Farm Programs: Revisiting the Wealth Effect'. *American Journal of Agricultural Economics* 92 (3): 836–48.

Gardner B., I. Hardie, and P. Parks. 2010. "United States Farm Commodity Programs and Land Use." *American Journal of Agricultural Economics* 92(3): 803–820

Gawande, K. and B. Hoekman. 2009. ‘Why Governments Tax or Subsidize Trade: Evidence from Agriculture’. Agricultural Distortions Working Paper No. 85. Washington, DC: World Bank.

Goodwin, B. K. and A. K. Mishra. 2005. ‘Another Look at Decoupling: Additional Evidence on the Production Effects of Direct Payments’. *American Journal of Agricultural Economics* 87 (5): 1200–10.

Goodwin, B. K. and A. K. Mishra. 2006. ‘Are “Decoupled” Farm Program Payments Really Decoupled? An Empirical Evaluation’. *American Journal of Agricultural Economics* 88 (1): 73–89.

Hennessy, D. 1998. ‘The Production Effects of Agricultural Income Support Policies Under Uncertainty’. *American Journal of Agricultural Economics* 80 (1):46–57.

Hertel, T. W. and R. Keeney. 2006. ‘What’s at Stake: The Relative Importance of Import Barriers, Export Subsidies and Domestic Support’. In *Agricultural Trade Reform and the Doha Development Agenda*, edited by K. Anderson and W. Martin, 37-62. London: Palgrave Macmillan and Washington DC: World Bank.

Hillberry, R. 2002. “Aggregation Bias, Compositional Change and the Border Effect”. *Canadian Journal of Economics*, 35(3): 517-530.

Hillberry, R. and Hummels, D. 2008. “Trade Responses to Geographic Frictions: A Decomposition Using Micro-Data.” *European Economic Review*, 52(3): 527-550.

Hoekman B., F. Ng and M. Olarreaga. 2004. ‘Agricultural Tariffs versus Subsidies: What’s More Important for Developing Countries?’ *World Bank Economic Review* 18 (2): 155–174.

Key, N. and R. Roberts. 2009. ‘Nonpecuniary Benefits to Farming: Implications for Supply Response to Decoupled Payments’. *American Journal of Agricultural Economics* 91 (1): 1–18.

Key, N., R. Lubowski, and M. Roberts. 2005. “Farm-level Production Effects from Participation in Government Commodity Programs: Did the 1996 Federal Agricultural Improvement and Reform Act Make a Difference?” *American Journal of Agricultural Economics 87*(5): 1211–1219.

Kirwan, B. 2009. `The Incidence of U.S. Agricultural Subsidies on Farmland Rental Rates.’ *Journal of Political Economy* 117 (1): 138–164.

Koo, W. W., and P. L. Kennedy. 2006. "The Impact of Agricultural Subsidies on Global Welfare." *American Journal of Agricultural Economics*, *88*(5): 1219–1226.

Koo, W. W. Karemera, D., and Taylor, R. 1999. "A Gravity Model Analysis of Meat Trade Policies". *Agricultural Economics*, 10: 81-88.

Lovely, M. and Pham Cong S. "China's Exports and their Effects on the Intensive Margin and the Extensive Margin of its Competitors: The Case of Exports in Electronics". Mimeo.

Makki, S., D. Johnson and A. Somwaru. 2005. 'Farm-Level Effects of Counter-Cyclical Payments'. Paper presented at the annual meeting of the American Agricultural Economics Association, Providence, RI.

Mcintosh, C., J. Shogren and E. Dohlman. 2007. 'Supply Response to Counter-Cyclical Payments and Base Acre Updating Under Uncertainty: An Experimental Study'. *American Journal of Agricultural Economics* 89 (4): 1046–57.

Mishra, A., and B. Goodwin. 1997. 'Farm Income Variability and the Supply Of Off-Farm Labor'. *American Journal of Agricultural Economics* 79: 880-887.

National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/stormevents/ftp.jsp

Nuetah, J. A., T. Zuo and X. Xian. 2011. 'Agricultural Export Subsidies and Domestic Support Reform Under the WTO System: What Does It Mean for Welfare in West Africa?' *The World Economy* 34 (12): 2044–62.

O'Donoghue, E. J. and J. B. Whitaker. 2010. 'Do Direct Payments Distort Producers' Decisions? An Examination of the Farm Security and Rural Investment Act of 2002'. *Applied Economic Perspectives and Policy* 32 (1): 170–93.

OECD. 2015. 'Agricultural Policy Monitoring and Evaluation 2015: Highlights'. Accessed 15 March 2017. http://www.oecd.org/tad/agricultural-policies/monitoring-evaluation-2015-highlights-july-2015.pdf.

Roberts, M. J., N. Key and E. O'Donoghue. 2006. 'Estimating the Extent of Moral Hazard in Crop Insurance Using Administrative Data'. *Review of Agricultural Economics* 28 (3): 381–90.

Roberts, M., B. Kirwan, and J. Hopkins. 2003. "Incidence of Government Program Payments on Land Rents: The Challenges of Identification." *American Journal of Agricultural Economics* 85 (3):762-769.

Rose and Wincoop. 2001. “National Money as a Barrier to International Trade: The Real Case for Currency Union.” *The American Economic Review 91* (2): 386-390.

Serra, T., B. K. Goodwin and A. M. Featherstone. 2011. ‘Risk Behavior in the Presence of Government Programs’. *Journal of Econometrics* 162 (1):18-24.

Serra, T., D. Zilberman, B. Goodwin and A. Featherstone. 2005. ‘Decoupling Farm Policies: How Does This Affect Production?’ Paper presented at the annual meeting of the American Agricultural Economics Association, Providence, RI, July 24-27.

Sumner, D. A. 2005. ‘Production and Trade Effects of Farm Subsidies: A Discussion’. *American Journal of Agricultural Economics* 87 (5): 1229–30.

Yotov, V. Y, Piermartini, R., Monteiro, J-A. and Larch, M. *An Advanced Guide to Trade Policy Analysis : the Structural Gravity Model*. Geneva: United Nations and World Trade Organization.

Young, C. and P. Westcott. 2000. ‘How Decoupled is U. S. Agricultural Support for Major Crops?’ *American Journal of Agricultural Economics* 82 (3): 762–7.

Wooldridge, J. 2002. *Econometric Analysis of Cross Section and Panel Data,* Cambridge, Mass: MIT Press.

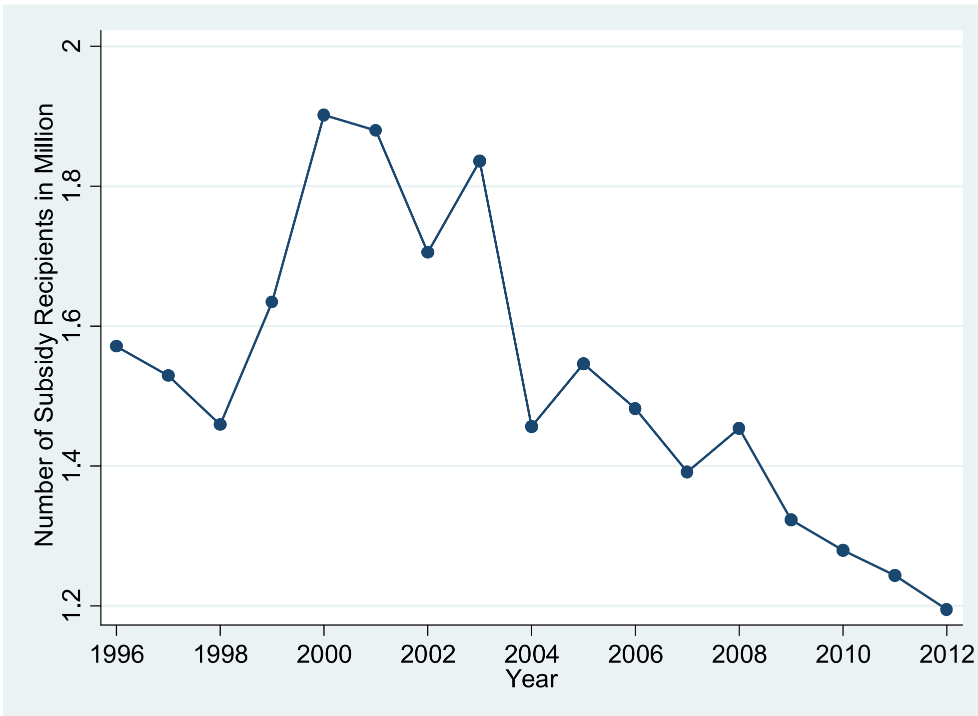

Figure 1 Total number of farm subsidy recipients across the United States, 1996–2012

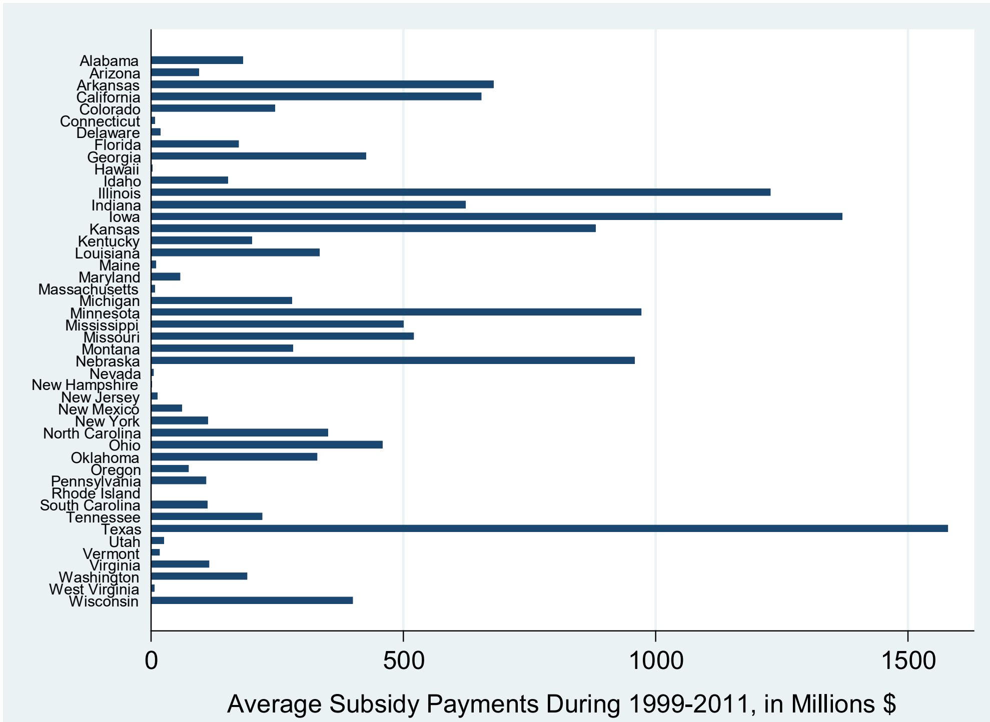

Figure 2 Average annual subsidy payments for each state (1999–2011)

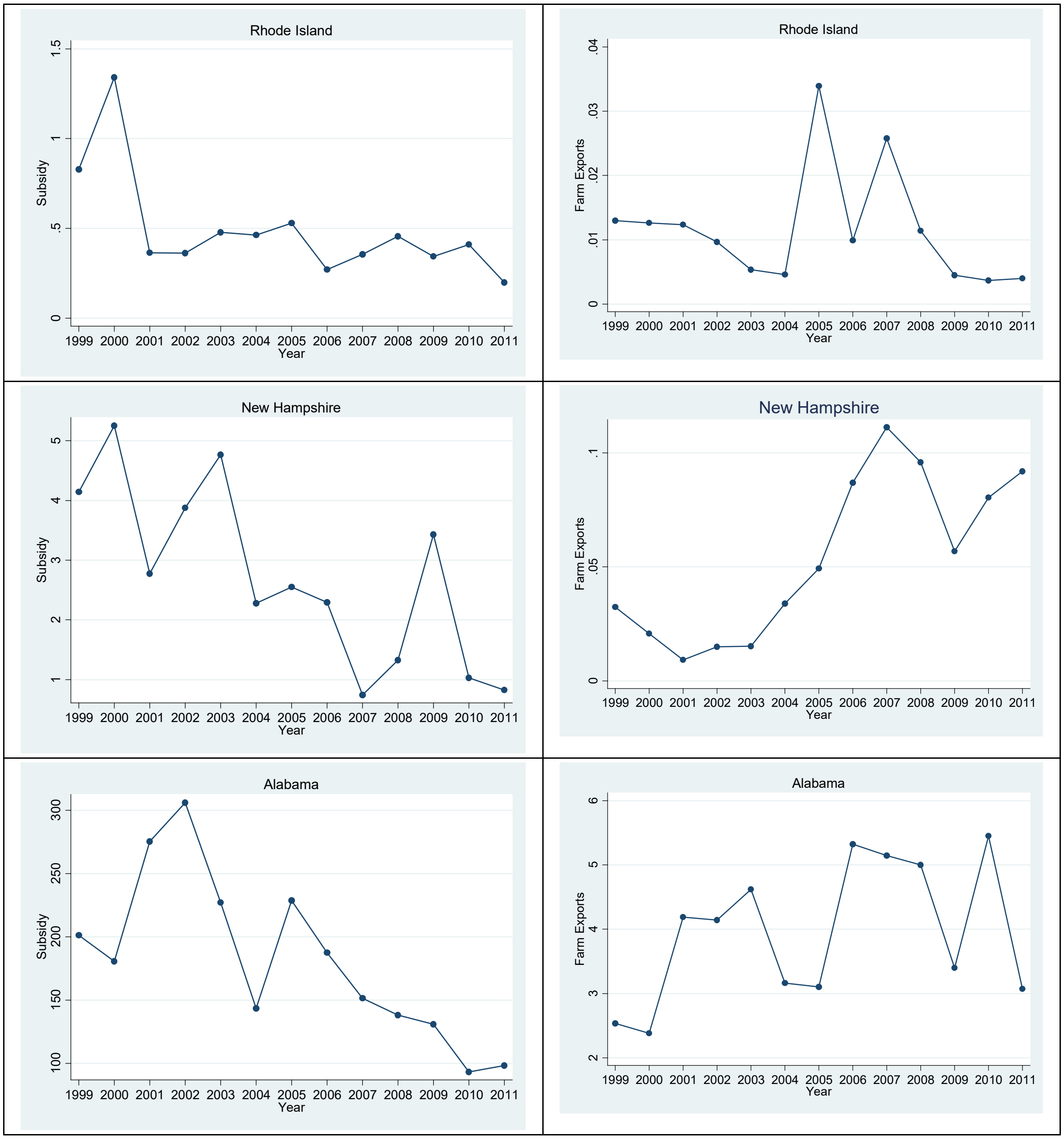

Figure 3: The evolution of farm subsidies and farm exports over time for selected states

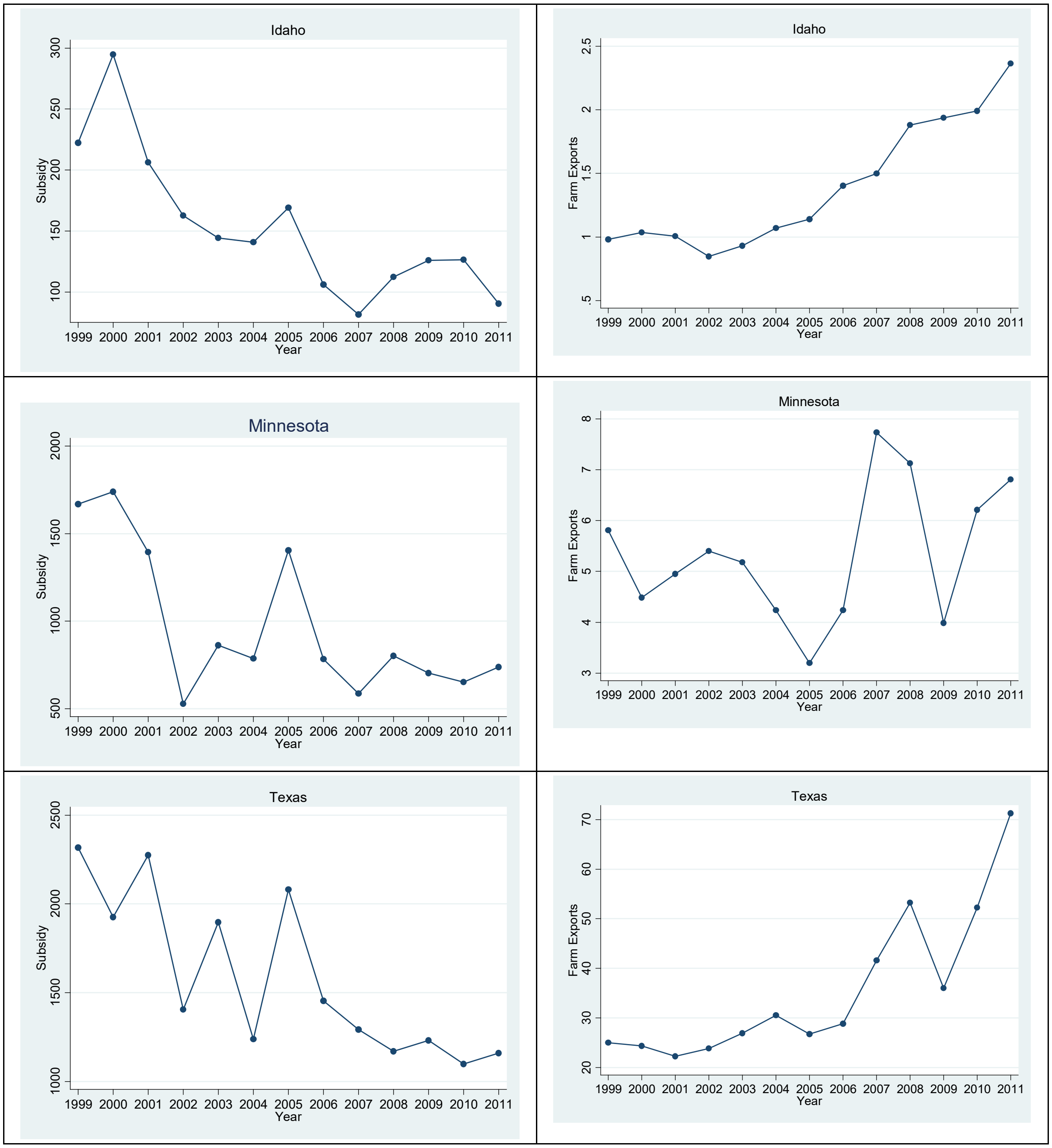

Figure 3: The evolution of farm subsidies and farm exports over time for selected states, cont'd.

Table 1: Summary Statistics

	Obs	Mean	Sd	Min	Max
Log (Farm Exports$_{ijt}$)	29165	6.184	2.735	.798	15.397
Log (Agricultural Exports$_{ijt}$)	26186	6.177	2.804	.798	15.397
Log (Livestock Exports$_{ijt}$)	13321	4.760	2.113	.798	12.281
Farm Exports$_{ijt}$	58500	8483.191	79143.73	0	4863888
Agricultural Exports$_{ijt}$	58500	8201.029	78308.67	0	4862289
Livestock Exports$_{ijt}$	58500	282.162	2970.455	0	215520.1
Log (Distance$_{ij}$)	58500	8.475	.525	5.498	9.271
Border$_{ij}$	58500	.00333	.0576	0	1
Log (GDP$_{it}$)	585	12.036	.961	9.847	14.383
Coastline$_i$	585	.467	.499	0	1
Log (Total Subsidy$_{it}$)	585	11.625	1.906	5.295	14.738
Log(Agricultural Subsidy$_{it}$)	585	11.521	1.987	4.761	14.73743
Log(Livestock Subsidy$_{it}$)	560	7.802	2.240	-.977	12.431
Log (Commodity Payments$_{it}$)	585	11.073	2.164	3.073	14.691
Log (Disaster Payments$_{it}$)	584	8.980	1.977	2.317	13.406
Log (Crop Insurance Payments$_{it}$)	585	9.787	2.002	3.738	13.374
Log (Amber Box Payments$_{it}$)	585	11.007	1.997	4.075	14.486
Log (Green Box Payments$_{it}$)	585	10.709	1.928	4.346	13.953
Log (Direct Payments$_{it}$)	582	10.205	2.279	2.388	13.443
Log (Total Subsidy$_{it}$-Direct Payments$_{it}$)	585	11.272	1.844	5.221	14.495
GDP$_{it}$	585	266060.6	296821.9	18908	1763450
Total Subsidy$_{it}$	585	334513.8	435279.3	199.353	2514588
Agricultural Subsidy$_{it}$	585	322755.7	429959.1	116.865	2514118
Livestock Subsidy$_{it}$	585	11758.12	25274.65	0	250323.9
Commodity Payments$_{it}$	585	243352.8	363508.5	21.615	2398840
Disaster Payments$_{it}$	585	30739.21	58592.93	0	663906.8
Crop Insurance Payments$_{it}$	585	60397.58	89176.4	42.019	643139.8
Amber Box Payments$_{it}$	585	202642.4	298279.9	58.839	1955876
Green Box Payments$_{it}$	585	131847.2	161871	77.136	1147631
Direct Payments$_{it}$	585	101108	127615.5	0	688860.1
Total Subsidy$_{it}$-Direct Payments$_{it}$	585	233405.8	326997.4	185.1984	1973576

Note: Farm exports, agricultural exports, and livestock exports are reported in thousand US dollars. GDP is measured in million US dollars. Total subsidies and subsidy programs (Commodity Payments, Disaster Payments, Crop Insurance Payments, Amber Box Payments, Green Box Payments, Direct Payments) are reported in thousand U.S. dollars. Distance is in miles. Farm exports, agricultural exports, livestock exports, distance, and border are bilateral variables between a U.S. State and its trading partner, so there are 58,500 observations in total (45 states*13 years*100 importers). Log of Farm Exports, Log of Agricultural Exports, and Log of Livestock Exports, are defined for positive exports only. GDP, total subsidy, and specific subsidy program payments are at the state level, so the number of observations is 585 (45 states*13 years).

Table 2: The Effect of U.S. Farm Subsidies on U.S. Farm Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent Variable: Log (Total Farm Exports)								
Log (Total Subsidy$_{it}$)	0.617***	0.144***	0.144**	0.208***	0.159***	0.204***	0.181***	0.200***	0.208***
	(25.19)	(3.12)	(2.54)	(3.57)	(2.78)	(3.54)	(2.96)	(3.25)	(3.34)
Log (Total Subsidy$_{i(t-1)}$)								0.198***	0.215***
								(4.36)	(4.04)
Log (Total Subsidy$_{i(t-2)}$)									0.0235
									(0.55)
Log (Distance$_{ij}$)	-0.396***	-1.227***	-1.227***	-1.221***	-1.220***	-1.216***	-1.219***	-1.217***	-1.218***
	(2.95)	(10.19)	(10.24)	(10.11)	(10.07)	(10.02)	(10.03)	(10.02)	(10.02)
Log (GDP$_{it}$)	0.288***	-0.320	-0.500	-0.449	-0.00542	-0.873	-0.497	-0.570	-0.525
	(6.61)	(0.90)	(1.14)	(0.63)	(0.01)	(0.92)	(0.47)	(0.54)	(0.49)
Border$_{ij}$	1.843***	1.396***	1.390***	1.388***	1.386***	1.390***	1.386***	1.385***	1.385***
	(5.57)	(3.97)	(3.95)	(4.00)	(4.00)	(4.05)	(4.05)	(4.04)	(4.04)
Coastline$_i$	1.514***								
	(17.62)								
N	29165	29165	29165	29165	29165	29165	29165	29165	29165
adj R^2	0.386	0.495	0.497	0.502	0.504	0.505	0.505	0.506	0.506
Gravity Equation Includes									
a_{jt}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b_i	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ_{it}	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	No	No	No	No	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	No	No	No	No	No	Yes	Yes	Yes	Yes
τ^4_{it}	No	No	No	No	No	No	Yes	Yes	Yes

Note: t-statistics computed based on the robust standard error allowing for the clustering of the state-importer pair are in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 3: **The Effect of Agricultural Subsidies and Livestock Subsidies on Agricultural and Livestock Exports**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Dependent Variable: Log (Agricultural $Exports_{it}$)					
Log (Agricultural $Subsidies_{it}$)	0.644***	0.105**	0.109	0.212***	0.146**	0.233***	0.161**	0.204**	0.171**
	(24.19)	(2.03)	(1.61)	(3.21)	(2.08)	(3.19)	(2.07)	(2.57)	(2.02)
Log (Agricultural $Subsidies_{i(t-1)}$)								0.262***	0.250***
								(4.53)	(4.04)
Log (Livestock $Subsidies_{it}$)									-0.0156
									(1.02)
Log (Livestock $Subsidies_{i(t-1)}$)									-0.0227*
									(1.74)
N	26186	26186	26186	26186	26186	26186	26186	26186	25445
adj. R^2	0.366	0.499	0.502	0.507	0.508	0.508	0.509	0.509	0.511
				Dependent Variable: Log (Livestock $Exports_{it}$)					
Log (Livestock $Subsidies_{it}$)	0.0943***	-0.0411***	-0.0110	-0.00610	0.0121	0.0115	0.0115	0.0161	0.0231
	(6.66)	(4.13)	(0.79)	(0.46)	(0.87)	(0.80)	(0.75)	(0.92)	(1.29)
Log (Livestock $Subsidies_{i(t-1)}$)								0.0168	0.0193
								(1.06)	(1.22)
Log (Agricultural $Subsidies_{it}$)									0.218*
									(1.94)
Log (Agricultural $Subsidies_{i(t-1)}$)									0.0188
									(0.23)
N	12891	12891	12891	12891	12891	12891	12891	12891	12891
adj. R^2	0.198	0.344	0.349	0.359	0.363	0.364	0.364	0.364	0.364
Gravity Equation Includes									
a_{jt}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b_i	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ_{it}	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	No	No	No	No	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	No	No	No	No	No	Yes	Yes	Yes	Yes
τ^4_{it}	No	No	No	No	No	No	Yes	Yes	Yes

Note: Robust standard errors are exporter-importer clustered. *t*-statistics are in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 4: The Effects of US Farm Subsidies on U.S. Farm Exports: By Subsidy Programs and WTO Category

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Log (Total Farm Exports)							
Log (Commodity Payments$_{it}$)	0.171***	0.188***						
	(3.35)	(3.60)						
Log (Commodity Payments$_{i(t-1)}$)		0.151***						
		(3.62)						
Log (Disaster Payments$_{it}$)	0.00312	0.0177					0.00679	0.0247*
	(0.23)	(1.25)					(0.49)	(1.74)
Log (Disaster Payments$_{i(t-1)}$)		0.000128						0.000104
		(0.27)						(0.21)
Log (Crop Insurance Payments$_{it}$)	-0.0566	-0.0722						
	(0.49)	(0.63)						
Log (Crop Insurance Payments$_{i(t-1)}$)		-0.146***						
		(3.48)						
Log (Amber BoxPayments$_{it}$)			0.136***	0.122***			0.121***	0.113**
			(3.16)	(2.83)			(2.77)	(2.55)
Log (Amber Box Payments$_{i(t-1)}$)				0.121***				0.141***
				(3.34)				(3.16)
Log (Green Box Payments$_{it}$)			0.0179	0.0563				
			(0.44)	(1.31)				
Log (Green Box Payments$_{i(t-1)}$)				0.0740*				
				(1.93)				
Log (Direct Payments (DP)$_{it}$)					0.130	0.0547	0.126	0.0507
					(0.72)	(0.28)	(0.70)	(0.26)
Log (Direct Payments (DP)$_{i(t-1)}$)						0.0482		0.0342
						(0.72)		(0.48)
Log (Total Subsidies$_{it}$-DP$_{it}$)					0.127***	0.142***		
					(2.81)	(3.07)		
Log (Total Subsidies$_{i(t-1)}$-DP$_{i(t-1)}$)						0.145***		
						(3.25)		
N	29154	29154	29165	29165	29121	29121	29110	29110
adj. R^2	0.505	0.506	0.505	0.506	0.504	0.505	0.504	0.505
Gravity Equation Includes								
a_{jt}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b_i	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^4_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: t-statistics computed based on the robust standard error allowing for the clustering of the state-importer pair are in parentheses.
* p<0.10, ** p<0.05, *** p<0.010

Table 5: The Effects of Farm Subsidies on Farm Exports: Different Farm Bills

Dependent Variables	(1) Log (Farm Exports)	(2) Log (Farm Exports)	(3) Log (Agricultural Exports)	(4) Log (Agricultural Exports)	(5) Log (Livestock Exports)	(6) Log (Livestock Exports)
Farm Bill 1996						
Log (Total Subsidies$_{it}$)	0.186***	0.170**				
	(2.76)	(2.46)				
Log (Total Subsidies$_{i(t-1)}$)		0.223***				
		(4.23)				
Log (Agricultural Subsidies$_{it}$)			0.158*	0.181**		
			(1.80)	(1.98)		
Log (Agricultural Subsidies$_{i(t-1)}$)				0.265***		
				(4.06)		
Log (Livestock Subsidies$_{it}$)					0.0322	0.0363
					(1.37)	(1.34)
Log (Livestock Subsidies$_{i(t-1)}$)						0.0165
						(0.81)
Farm Bill 2002						
Log (Total Subsidies$_{it}$)	0.181***	0.233***				
	(2.85)	(3.49)				
Log (Total Subsidies$_{i(t-1)}$)		0.239***				
		(4.20)				
Log (Agricultural Subsidies$_{it}$)			0.182**	0.270***		
			(2.30)	(3.16)		
Log (Agricultural Subsidies$_{i(t-1)}$)				0.318***		
				(4.58)		
Log (Livestock Subsidies$_{it}$)					-0.00131	0.00312
					(0.06)	(0.13)
Log (Livestock Subsidies$_{i(t-1)}$)						0.0168
						(0.87)
Farm Bill 2008						
Log (Total Subsidies$_{it}$)	0.163**	0.265***				
	(2.35)	(3.58)				
Log (Total Subsidies$_{i(t-1)}$)		0.290***				
		(4.41)				
Log (Agricultural Subsidies$_{it}$)			0.125	0.253***		
			(1.45)	(2.72)		
Log (Agricultural Subsidies$_{i(t-1)}$)				0.368***		
				(4.62)		
Log (Livestock Subsidies$_{it}$)					-0.0252	-0.0224
					(0.65)	(0.57)

Log (Livestock Subsidies$_{i(t-1)}$)						0.0465
						(0.94)
N	29165	29165	26186	26186	12891	12891
Gravity Equation Includes						
a_{jt}	Yes	Yes	Yes	Yes	Yes	Yes
b_i	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	Yes	Yes	Yes	Yes	Yes	Yes
τ_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^4_{it}	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors are clustered for state-importer pairs. *t*-statistics are in parentheses. * p<0.10, ** p<0.05, *** p<0.010. To save space we suppress the coefficient estimates of the gravity control variables.

Table 6: Sensitivity to Different Sub-Samples and Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Low Income Trading Partners Sample	Low and Lower-Middle Income Trading Partners Sample	Upper-Middle Income Trading Partners Sample	High-Income Trading Partners Sample	Controlling for GDP of Importers (Full Sample)	Inland U.S. States Sample	Coastal U.S. States Sample
	Dependent Variable: Log (Total Farm Exports)						
Log (Total $Subsidy_{it}$)	1.155	0.182	0.354***	0.165**	0.148***	0.242**	0.122
	(0.89)	(0.97)	(2.71)	(2.23)	(3.00)	(2.52)	(1.26)
Log (Total $Subsidy_{i(t-1)}$)	-0.425	0.129	0.281***	0.180***	0.0772**	0.196***	0.118
	(0.29)	(0.93)	(2.87)	(3.27)	(2.08)	(3.20)	(1.34)
Log ($Distance_{ij}$)	-1.520	-0.861***	-1.257***	-1.188***	-0.869***	-0.731***	-1.475***
	(1.47)	(3.41)	(4.94)	(7.06)	(13.09)	(4.38)	(8.78)
Log (GDP_US $States_{it}$)	-10.75	-2.299	-1.195	0.366	-0.659	-0.577	0.739
	(0.69)	(0.86)	(0.56)	(0.27)	(0.70)	(0.35)	(0.45)
Log (GDP_$Importer_{it}$)					0.633***		
					(26.77)		
$Border_{ij}$	n.a.	n.a.	1.211**	1.378***	2.694***	1.837***	1.047*
			(2.50)	(2.97)	(8.71)	(4.96)	(1.66)
N	371	5526	6948	16691	29165	14574	14591
adj R^2	0.453	0.452	0.554	0.553	0.401	0.447	0.535
Gravity Equation Includes							
a_{jt}	Yes	Yes	Yes	Yes	No	Yes	Yes
b_i	Yes	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
τ^4_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors are clustered for state-importer pairs. *t*-statistics are in parentheses. * p<0.10, ** p<0.05, *** p<0.010.

Table 7: Natural Disasters as Instrumental Variable for Subsidies

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Log (Total Farm Exports)					
Log (Total Subsidy$_{it}$)	0.384	0.0401	-0.758	0.332	0.109	0.164
	(0.31)	(0.03)	(0.53)	(0.78)	(0.31)	(0.62)
Log (Total Subsidy$_{i(t-1)}$)	-2.133	0.417	1.032	1.292**	0.666**	0.637***
	(0.84)	(0.82)	(1.12)	(2.18)	(2.22)	(3.20)
Log (Distance$_{ij}$)	-1.877***	-1.880***	-1.880***	-1.881***	-1.880***	-1.878***
	(8.54)	(8.59)	(8.61)	(8.60)	(8.59)	(8.59)
Log (GDP$_{it}$)	-0.683	-0.262	0.162	-0.303	-0.267	1.203
	(0.53)	(0.20)	(0.12)	(0.27)	(0.23)	(1.15)
Border$_{ij}$	0.986***	0.983***	0.986***	0.980***	0.982***	0.981***
	(2.60)	(2.59)	(2.60)	(2.58)	(2.59)	(2.59)
N	27141	27141	27141	27141	27141	27471
Underidentification test (P-value)	1.60 (0.21)	1.36 (0.24)	23.03 (0.00)	181.93 (0.00)	430.93 (0.00)	181.929 (0.00)
Weak identification test (Cragg-Donald Wald F statistic)	13.2	22.68	40.83	136.26	95.20	136.259
IV	1	2	3	4	1, 2, 3, 4	1, 2, 3, 4
Gravity Equation Includes						
a_{jt}	Yes	Yes	Yes	Yes	Yes	Yes
b_i	Yes	Yes	Yes	Yes	Yes	Yes
c_{rt}	Yes	Yes	Yes	Yes	Yes	No
τ_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^2_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^3_{it}	Yes	Yes	Yes	Yes	Yes	Yes
τ^4_{it}	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors are clustered for state-importer pairs. Limited Information Maximum Likelihood (LIML) estimation. *t*-statistics are in parentheses. * p<0.10, ** p<0.05, *** p<0.010.. Instrumental variables (IV) include:

1. Log (Number of Disasters in a State)
2. Number of the disaster-affected counties/Number of total counties
3. Log (1+(Number of disaster-related direct & indirect deaths/State Population))
4. Log (1+(Number of disaster-related direct & indirect injuries/State Population))

---

[1] This figure is calculated using the Farm Subsidy Database of the Environmental Working Group. https://farm.ewg.org/

[2] The impact of decoupled payments on production is found to be small (see, Burfisher, Robinson, and Thierfelder 2000; Young 2000; Adams et al. 2001; Goodwin and Mishra 2005, 2006; Mcintosh 2007; and Serra, Goodwin, and Featherstone 2011). See also Hennessy (1998) for the wealth and insurance effects of the decoupled program.

[3] From 1996 to 2002, the names "production flexibility contract" (PFC) and "market loss assistance payment" (MLA) were used for DP and CCP, respectively.

[4] In February 2016, 163 WTO members agreed to remove government export subsidies from agricultural products, with developing countries agreeing to phase out subsidies in 2018. Yet the agreement does not address domestic agricultural subsidies used by the US and EU, among others.

[5] We also considered the responsiveness of dairy exports to dairy subsidies. However, the ITA database does not offer data on dairy exports comparable to agricultural and livestock exports. The dairy exports data available in another data source, U.S. Trading Online, are based on harmonized system, and are not comparable to the ITA classifications.

[6] The difference between ITA and USDA estimates of exports is quite large on a percentage basis for the states with known exporter terminals (e.g., California, Connecticut, Louisiana, Massachusetts, New Jersey, Texas and Washington). Some of the inland states that have large production of crops that are likely be co-mingled have quite large negative differences between ITA and USDA exports (e.g., Indiana, Iowa and Minnesota).

[7] The Conservation Reserve Programs (CRPs), 12% of all subsidy payments, are aimed at encouraging farmers to retire erodible lands. These programs are not subject to debate of causing any production and trade distortion. Thus, we did not include this program in our sample and hereafter our total subsidy refers to total payments without CRP.

[8] Illinois, Texas, and Iowa are among the top five largest recipients for every single year in our sample period, while Rhode Island and New Hampshire are among the five that received the lowest support in almost all years.

[9] The ten largest trading partners are Germany, Turkey, Indonesia, Egypt, Taiwan, South Korea, Canada, Mexico, Japan, and China.

[10] Note that we model subsidy as a component of bilateral trade cost. This is a common practice in the empirical literature. See for example (Koo et al. (1999)).

[11] See Cesur et al (2017) and Cesur et al (2018) who use a similar approach in analyzing the effects of natural gas infrastructure extension (akin to subsidy payments in our setting) across Turkish provinces on infant mortality and adult mortality, respectively.

[12] To receive subsidy payments under the crop insurance program, farmers must purchase insurance policies. To the extent that farmers in different states do not *systematically* differ in their attitudes toward risk, we expect subsidy payments under the crop insurance program to negatively correlate with crop production and exports at the state level. According to the US Department of Agriculture (USDA), farmers in about 65% of total planted acreage of field crops purchased insurance policies under the program in 1998.

[13] See again Cesur et al (2017) and Cesur et al (2018) who use region-by-year fixed effects to address the regional spillovers. We use the Farm Resource Regions (FRR) of the USDA. Each of the regions comprises similar types of farms, as well as similar physiographic, soil, and climatic traits (USDA 2000). A state may contain counties that belong to different FRR regions. In this case, we assign that state to a region that encompasses the largest number of counties. Due to this rule, no state is assigned to the Northern Great Plains. For more, see Online Appendix table A2.

[14] This problem could potentially downwardly bias our subsidy estimates because some coastal states with low farm production and thus low subsidies will have high exports, and some inland states with high farm production and thus high subsidies will have low exports. However, this reasoning holds if the dependent variable is in levels, not in logs.

[15] Note also that measurement error in the dependent variable could lead to larger standard errors (Wooldridge 2002).

[16] Excluding states' GDP from gravity model, or using GDP per capita instead of GDP, or scaling exports with population make no demonstrable difference in our main subsidy effects.

[17] This figure is a multiplication of the value of US annual farm exports of $38.2 billion with 0.40. Note that US$38.2 billion is the value of US annual farm exports that we compute using our sample of exports by 45 US states to 100 foreign destinations, from 1999 to 2011. This number is much smaller than the value of US annual agricultural exports (more than US$100 billion) provided by the USDA, because the USDA definition of agricultural products covers a much larger range of products and includes all the US agricultural exports to the world.

[18] Decoupled programs include both DP and CCP. Data on CCP are available only for a short period, which prevented us from performing the same analysis that we do for DP.

[19] The elasticity of *output* or *acreage* with respect to decoupled payments is small, typically in the range 0.022%-0.043% for oilseeds, corn, soybeans, and wheat. See Burfisher Robinson, and Thierfelder (2000), Goodwin and Mishra (2005, 2006), and Serra et al. (2005).

[20] There could be some potential time-varying confounders that affect both subsidies and the measurement error, such as GDP or agricultural GDP. Controlling for the latter two hardly makes a difference to our key elasticity estimate.

[21] The dataset records information for each disaster event with detailed information on geography (county of the incident) and time (month of the incident) for each state in a given year. We sum up the number of events and number of counties affected, the number of deaths and injuries for a given state and year to obtain state-year observations.

[22] Note that natural-disaster-related variables are different than the subsidy payments for disasters. The latter are paid for losses caused by diseases and natural disasters, which means disaster subsidy payments are expected to be positively correlated with natural disasters. The literature agrees that disaster subsidy payments do not cause much distortion. However, natural disasters have links with other subsidies in that they may influence commodity prices, which could, in turn, trigger price-related subsidy payments. In particular, natural disasters could increase the commodity prices, and thus, reduce the subsidy payments to support the gap between market prices and loan prices. Indeed, our first-stage estimations, reported in Online Appendix Table A5, present negative effects of natural disasters on subsidy payments, a result that is likely to be driven by the reduced price-related payments.

[23] Our instrumental variables estimation method is Limited Information Maximum Likelihood (IV-LIML). The first-stage F-statistics of the excluded instruments are generally high and do not suggest a weak instruments problem. We feel that the exclusion restrictions for our instruments are unlikely to be violated given the large set of fixed effects involved with the estimation. See Online Appendix table A5 for the first-stage estimates of our preferred models.

[24] Region-by-year fixed effects assume that the disaster severity is the same in a given year in each state of the region.

[25] Admittedly, this specification will not capture non-contiguous states that produce competing products. If states that produce identical and competing products do so in the same region, then this specification will suffice.

[26] Export subsidies may constitute time-variant omitted variables as they might push higher production resulting from domestic subsidies to world markets (Diao, Somwaru and Roe 2001). Note that the most important export-promotion programs in the United States are export credit guarantees and direct export subsidies, including the Export Enhancement Program (EEP) and Dairy Export Incentive Program (DEIP). The EEP has been rarely used since 1995 and was repealed in the 2008 farm bill. DEIP is not a concern as export data do not include dairy component.

[27] We find that in our sample one-third of the zeroes are associated with state-importer pairs for which we can identify with certainty that a state could produce exportable agricultural products *and* an importer had a demand for them, given that the state-importer pair recorded at least one positive trade value over the sample period. However, two-thirds of the zero export flows are associated with state-importer pairs whereby we cannot identify any positive trade in the sample period. In many cases a state may have zero exports to a destination because it hardly produces any agricultural product and/or the destination has no demand for the agricultural product produced by that state (i.e., Montana hardly exports rice or Muslim countries hardly import pork). These zeroes are present in the data regardless of the level of bilateral trade costs and state farm subsidies. Arguably the latter type of zeroes is less likely to create an omitted variables problem in estimation because in that case farm subsidies have no bearing on exports, and thus, have little links with zero trade flows. To the extent that the latter type of zeroes is predominant in our sample, we feel relatively better off with using only positive export flows in our estimation. See also Baldwin and Harrigan (2011) and Lovely and Pham (2015), who analyze different types of zeroes in their samples.