# Spatial Analysis of U.S. Domestic Alfalfa Prices and Exports: A Spatial Econometric Modelling Approach

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***Selected Poster prepared for presentation at the 2021 Agricultural & Applied Economics Association Annual Meeting, Austin, TX, August 1 – August 3***

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## INTRODUCTION

Alfalfa exports have consistently increased since 2004 (see Figure 1), growing at an annualized rate of 16.0%, and more than 95% of these exports originate from the seven western states of Arizona, California, Idaho, Oregon, Nevada, Utah, and Washington (Putnam et al., 2013 and 2015).

Alfalfa exports surges due to the increase large corporate dairy farm corporates in China and water challenges in the Middle East (UAE and Saudi Arabia) (Putman, Matthews, and Sumner, 2016)

Price discovery and information flows in alfalfa markets face significant (McCullock, Davidson, and Robb, 2014).

Despite being an essential crop for the U.S. and a main feed for the dairy industry (Tejeda, Kim, and Feuz, 2015), limited research exists on alfalfa markets.

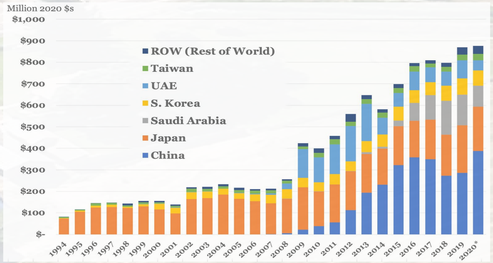



Figure 1: **U.S.** Alfalfa Exports (2020 $) by country, 1994 to 2020

## RESEARCH QUESTIONS

Is there any spatial relationship between States' domestic Alfalfa prices and Exports? How changes in neighboring states affect other states?

How are export surges and prices changes in exporting states are impacting their non exporting neighbors?

What are the direct and indirect impacts of increasing a state's percentage of production exported on their direct neighbors and the neighbors of their neighbors?

## RESEARCH OBJECTIVES

Using a spatial econometric modelling approach, our study:

- Propose to quantify the impact of alfalfa exports (percentage of production exported) and other factors (dairy cow inventories, corn prices, milk prices, cattle prices, hay stocks) across states to evaluate the spatial dependence of monthly alfalfa prices.
- Using 2020 value, evaluate the estimated impact of states' percentage of production exported on domestic Alfalfa prices.

## MATERIALS AND METHODS

### Data

We use a balanced data set of 27 selected alfalfa producing states over the 1994-2020 period.

Data were obtained form the United States Department of Agriculture-National Agricultural Statistics Services (USDA-NASS), the Livestock Marketing Information Center (LMIC), the United States Department of Agriculture-Foreign Agricultural Services (USDA-FAS), and the United State Census (U.S. Census).

### Methods

**Estimation of Monthly Alfalfa Domestic Export Volumes**

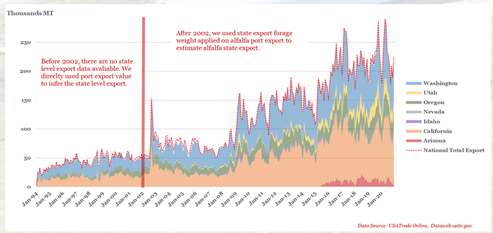



Figure 2: Monthly estimated Alfalfa Domestic Export volumes of Seven Western States, 1994 to 2020

**Variables Used to Estimate our Model**

**Table 1: Descriptive statistics (sample) of variables utilized using the data of 27 selected exporting States**

| Variable Names | Definition | Mean | Std. Dev. |
|---|---|---|---|
| Palfalfa($/ton) | State monthly Alfalfa Price* | 163.17 | 47.82 |
| %ProdExport (%) | Percent of Alfalfa Production Exported | 2.01 | 6.99 |
| Alfaprod (1,000 tons) | State Annual Alfalfa Production | 2483 | 1571 |
| Haystock(1,000 tons) | State Semi-annual All Hay On-Farm Stocks | 1669.06 | 1831.18 |
| Alfaexport (1,000 tons) | Monthly Estimated State Alfalfa Hay Exports Quantity | 4.42 | 14.65 |
| Dairycowin (1,000 head) | Annual Dairy Cow Inventory; Some States (Monthly) | 302.79 | 381.62 |
| Pmilk ($/cwt) | State Monthly Milk Price* | 20.72 | 3.35 |
| Pcattle ($/cwt) | State Monthly Cattle Calf Price* | 160.82 | 44.23 |
| Pcorn ($/bu) | State Monthly Corn Price* | 4.54 | 1.44 |
| Ppifuel | National Monthly Producer Price Index - Petroleum refineries-Diesel fuel (1982=100) | 76.30 | 42.49 |
| Precip(in) | State Monthly Average Precipitation | 2.40 | 1.78 |
| | * December 2020 dollars | | |

**Spatial Econometric Modelling Approach**

A spatial panel model approach is implemented and estimated to evaluate the impact of alfalfa exports and competing feed prices.

We utilized a local spatial model, the Spatial Durbin Error Model (SDEM), and a global spatial model, the Spatial Durbin Model (SDM). We also evaluated our model using two weight matrices (Contiguity and Inverse distance).

## RESULTS

Alfalfa exports and domestic alfalfa prices have both been increasing over the last 27 years. National real alfalfa prices have increased about 14% while alfalfa exports have increased more than 9-fold. Exports have grown from about 2% to 15% of production in the seven western states over this period.

### Direct, Indirect and Total Impacts

**Table 2: Direct, indirect and total impacts using the SDEM spatial model (Local Spatial Model)**

| | SDEM Spatial Model | | | | | |
|---|---|---|---|---|---|---|
| | Inverse Distance Weight | | | Contiguity Weight | | |
| | Direct Impact | Indirect Impact | Total Impact | Direct Impact | Indirect Impact | Total Impact |
| %ProdExport | 0.3463 *** (0.0618) | 0.6449 *** (0.1907) | 0.9912 *** (0.2035) | 0.4375 *** (0.0616) | 0.3349 ** (0.1664) | 0.7723 *** (0.1912) |
| Haystock | -0.0013 *** (0.0003) | -0.0018 *** (0.0005) | -0.0030 *** (0.0006) | -0.0013 *** (0.0002) | -0.0006 (0.0005) | -0.0019 *** (0.0005) |
| Dairycowin | 0.0029 (0.0051) | 0.0795 *** (0.0141) | 0.0823 *** (0.0175) | -0.0074 (0.0052) | 0.02093 * (0.0116) | 0.0135 (0.0153) |
| Pmilk | -0.2323 (0.1780) | 0.7091 *** (0.2720) | 0.4768 ** (0.2263) | -0.2734 * (0.15607) | 0.8413 *** (0.2559) | 0.5679 ** (0.2289) |
| Pcattle | 0.1046 *** (0.0152) | 0.0963 *** (0.0224) | 0.2009 *** (0.0179) | 0.10319 *** (0.0143) | 0.0665 *** (0.0227) | 0.1697 *** (0.0185) |
| Pcorn | 2.0594 *** (0.5356) | 9.79371 *** (0.7993) | 11.8531 *** (0.6396) | 1.8391 *** (0.4597) | 9.9979 *** (0.7413) | 11.8371 *** (0.6473) |
| Ppifuel | 0.1791 *** (0.0231) | -0.0803 ** (0.0316) | 0.0988 *** (0.0220) | 0.1648 *** (0.0197) | -0.0840 *** (0.0297) | 0.0808 *** (0.0225) |
| Precip | -0.1339 (0.22285) | -1.5866 *** (0.4955) | -1.7205 *** (0.47493) | -0.3426 (0.2120) | -1.2930 *** (0.4395) | -1.6356 *** (0.4286) |

Note: significant at 0.1 probability level; ** significant at 0.05 probability level; *** significant at 0.0 probability level;

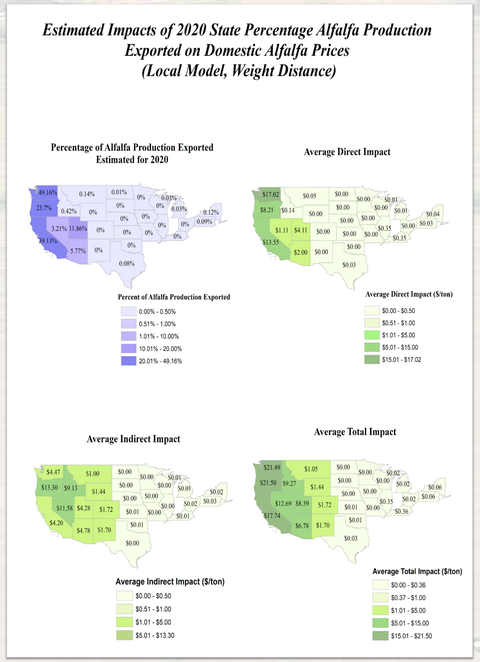
**Table 3: Direct, indirect and total impacts using the SDM spatial model (Global Spatial Model)**

| | SDM Spatial Model | | | | | |
|---|---|---|---|---|---|---|
| | Inverse Distance Weight | | | Contiguity Weight | | |
| | Direct Impact | Indirect Impact | Total Impact | Direct Impact | Indirect Impact | Total Impact |
| %ProdExport | 0.4395 *** (0.0672) | 1.7004*** (0.4487) | 2.1399*** (0.4789) | 0.4498 *** (0.0684) | 0.6978 * (0.3937) | 1.1476 *** (0.4319) |
| Haystock | -0.0013 *** (0.0003) | -0.0008 (0.0006) | -0.0021 *** (0.0006) | -0.0013 *** (0.0002) | -0.0005 (0.0006) | -0.0018 *** (0.0006) |
| Dairycowin | 0.0032 (0.0054) | 0.1525 *** (0.0286) | 0.1557 *** (0.0322) | 0.0018 (0.0054) | 0.1129 *** (0.0263) | 0.1147 *** (0.0301) |
| Pmilk | 0.1226 (0.1647) | 0.1043 (0.2816) | 0.2269 (0.2518) | -0.0166 (0.1477) | 0.4072 (0.2740) | 0.3905 (0.2572) |
| Pcattle | 0.1201 *** (0.0138) | 0.0641 *** (0.0227) | 0.1842 *** (0.0198) | 0.1054 *** (0.0128) | 0.0662 *** (0.0220) | 0.1716 *** (0.0200) |
| Pcorn | 3.6828 *** (0.4861) | 8.1647 *** (0.8035) | 11.8474 *** (0.7049) | 3.2149 *** (0.4286) | 9.2311 *** (0.7701) | 12.4461 (0.7180) |
| Ppifuel | 0.1692 *** (0.0196) | -0.0505 * (0.0297) | 0.1186 *** (0.0240) | 0.1560 *** (0.0167) | -0.0753 *** (0.0277) | 0.0807 *** (0.0245) |
| Precip | -0.2119 (0.2147) | -2.2014 *** (0.6989) | -2.4132 *** (0.7008) | -0.3805* (0.2044) | -2.2039 *** (0.7603) | -2.5844 *** (0.7601) |

Note: significant at 0.1 probability level; ** significant at 0.05 probability level; *** significant at 0.0 probability level;

## RESULTS

### Alfalfa Production Exported Impacts by State




## CONCLUSIONS

The increase of the percentage of Alfalfa production exported has a positive impact on Alfalfa domestic price.

Quantifying the impact of exports on regional alfalfa prices as proposed is important for producers and municipalities to make informed policy decisions.

These estimates are also important for identifying appropriate compensation to producers for policies like the recent Market Facilitation Program.

Given that many urban areas in the West are eyeing irrigation water sources to meet the water demands of their growing populations, policy questions are being raised with alfalfa and the water it takes to produce it being exported abroad.

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