Risk, Arbitrage, and Spatial Price Relationships: Insights from China's Hog Market under the African Swine Fever

Michael S. Delgado, Meilin Ma, and H. Holly Wang

Department of Agricultural Economics

Purdue University

NBER Meeting on Risks in Agricultural Supply Chains

May 21, 2021

PURDUE AGRICULTURE

AGRICULTURAL ECONOMICS

Motivation

- Spatial market integration occurs when all arbitrage opportunities are exhausted and the spatial market achieves Pareto efficiency (Barrett and Li, 2006)
  - A rich literature testing for market integration using time series data (e.g., Ravallion 1986; Shiue and Keller 2007)
- Lacking careful examination of dynamic spatial relationships of prices as the integration is being formed
  - Fundamental to how commodity demand and supply shocks spread over time and space
- Limited causal exploration for spatial market (dis)integration
  - Consumer preferences, producer risk attitudes, and political barriers may drive the integration (Fan, 2002; Goyat, 2011; Ruan et al, 2021)

A Natural Experiment

- The 2018 outbreak of African Swine Fever (ASF) in China helps study spatial dynamics during the (re-)establishment of market integration
- China had a highly integrated hog market prior to ASF shock
- A temporary ban on inter-province shipment of live hogs was imposed to stop the spread of ASF
- The ban broke the initial integration, resulting in considerable spatial price divergence

Research Question and Approach

- We examine and identify driving forces of spatial re-integration after the ban was lifted, using a unique and rich dataset of hog prices
- Use unique data of week-province specific hog prices from 2016 to 2020
- Our empirical strategy is multi-faceted
  - A innovative, generalized spatial model based on panel data
  - Reduced-form tests

Findings

- Prior to the shipping ban, geographic distances between provinces do not weaken inter-province price links
- Longer distances become a significant obstacle to price linkage post the ban; faster re-integration in hog prices between proximate provinces
- The negative effect of inter-province distances can be rationalized by a conceptual model of arbitrage under risks and imperfect information
- The findings highlight the value of providing transparent public information in enhancing market integration and efficiency of domestic trade

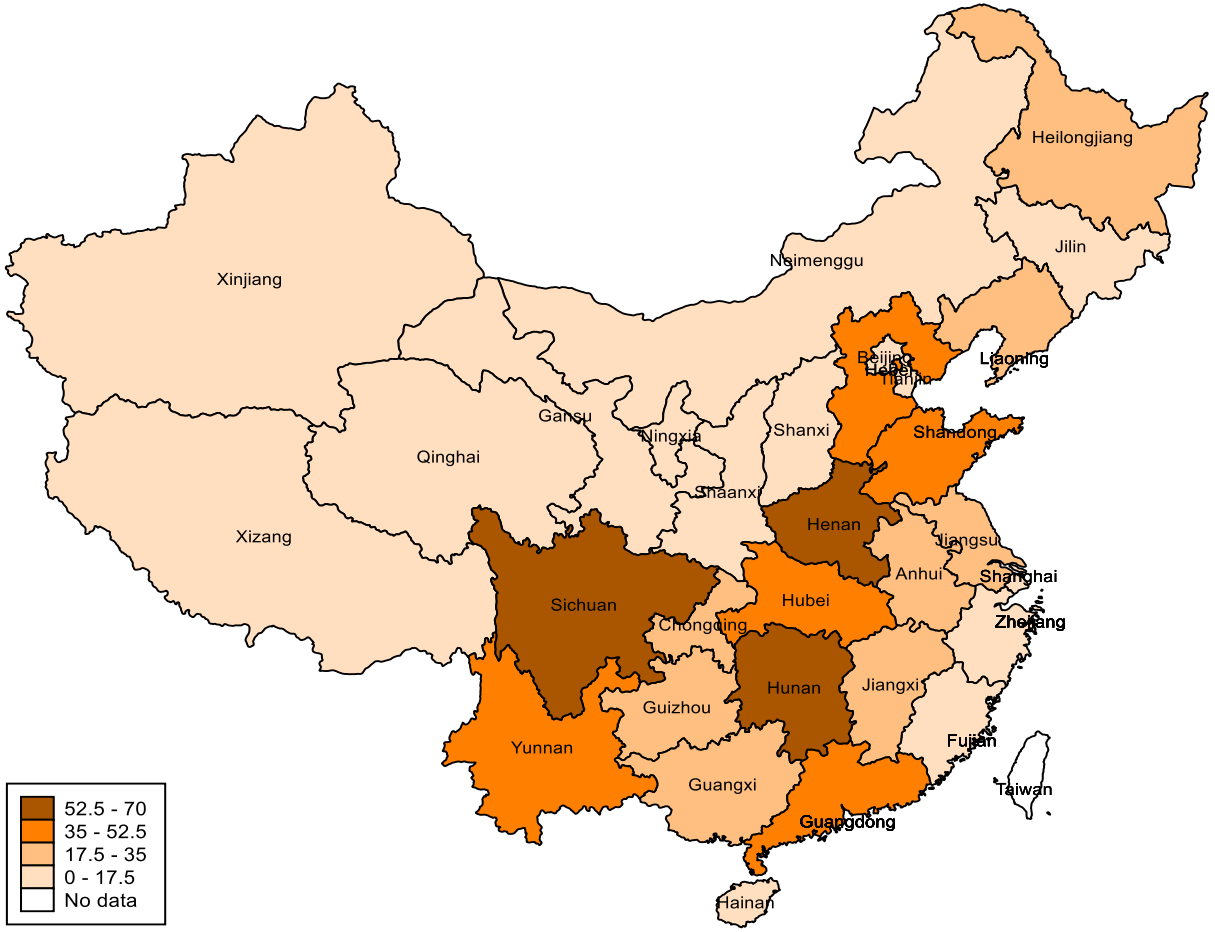
Roadmap

- China’s Hog Market
- African Swine Fever and Policies
- Conceptual Model
- Empirical Strategy
- Outcomes and Discussion

China's Hog Market

- China is the world's largest producer and consumer of hogs/pork
  - 500-600 million hogs are produced and consumed per year
  - Large producer provinces are not always large consumer provinces
  - Consumer preferences for "fresh" pork

2017 Hog Outputs across Provinces (*mil head*)

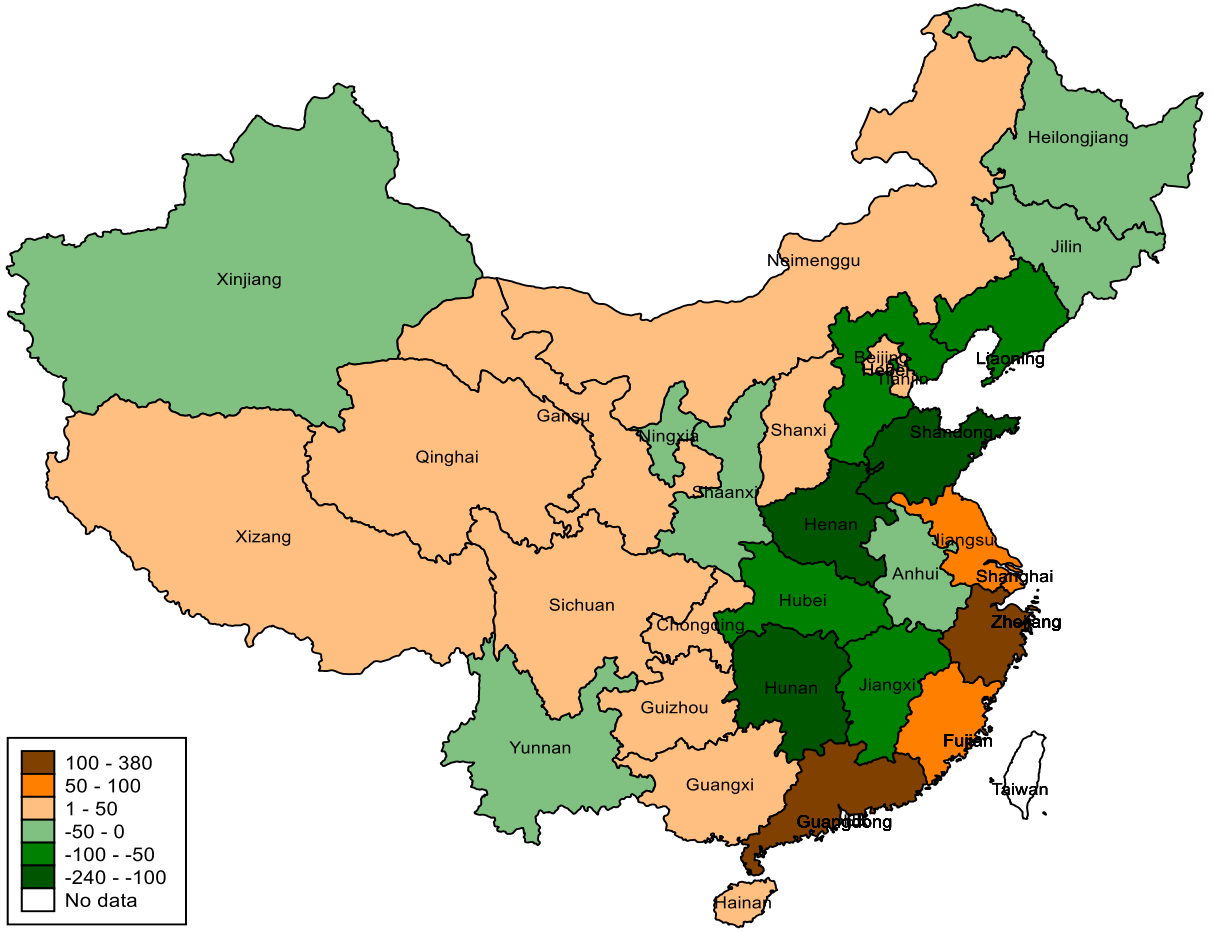


Delgado, Ma, and Wang (2021)

China's Hog Market

- China is the world's largest producer and consumer of hogs/pork
  - 500-600 million hogs are produced and consumed per year
  - Large producer provinces are not always large consumer provinces
  - Consumer preferences for "fresh" pork
- Large numbers of live hogs are transported across provinces, predominantly using open-air, trailer-trucks

2017 Hog Net Imports across Provinces (*10,000 MT*)



PURDUE AGRICULTURE
AGRICULTURAL ECONOMICS

Delgado, Ma, and Wang (2021)

China's Hog Market

- China is the world's largest producer and consumer of hogs/pork
  - 500-600 million hogs are produced and consumed per year
  - Large producer provinces are not always large consumer provinces
  - Consumer preferences for "fresh" pork
- Large numbers of live hogs are transported across provinces, predominantly using open-air, trailer-trucks
- Animal virus may spread through inter-province shipment of hogs
  - Trucks from various locations meet at a slaughter plant and may spread the virus to each other if ≥1 trucks carry the virus
  - Animal inspection stations on inter-province highways may spread virus among trucks

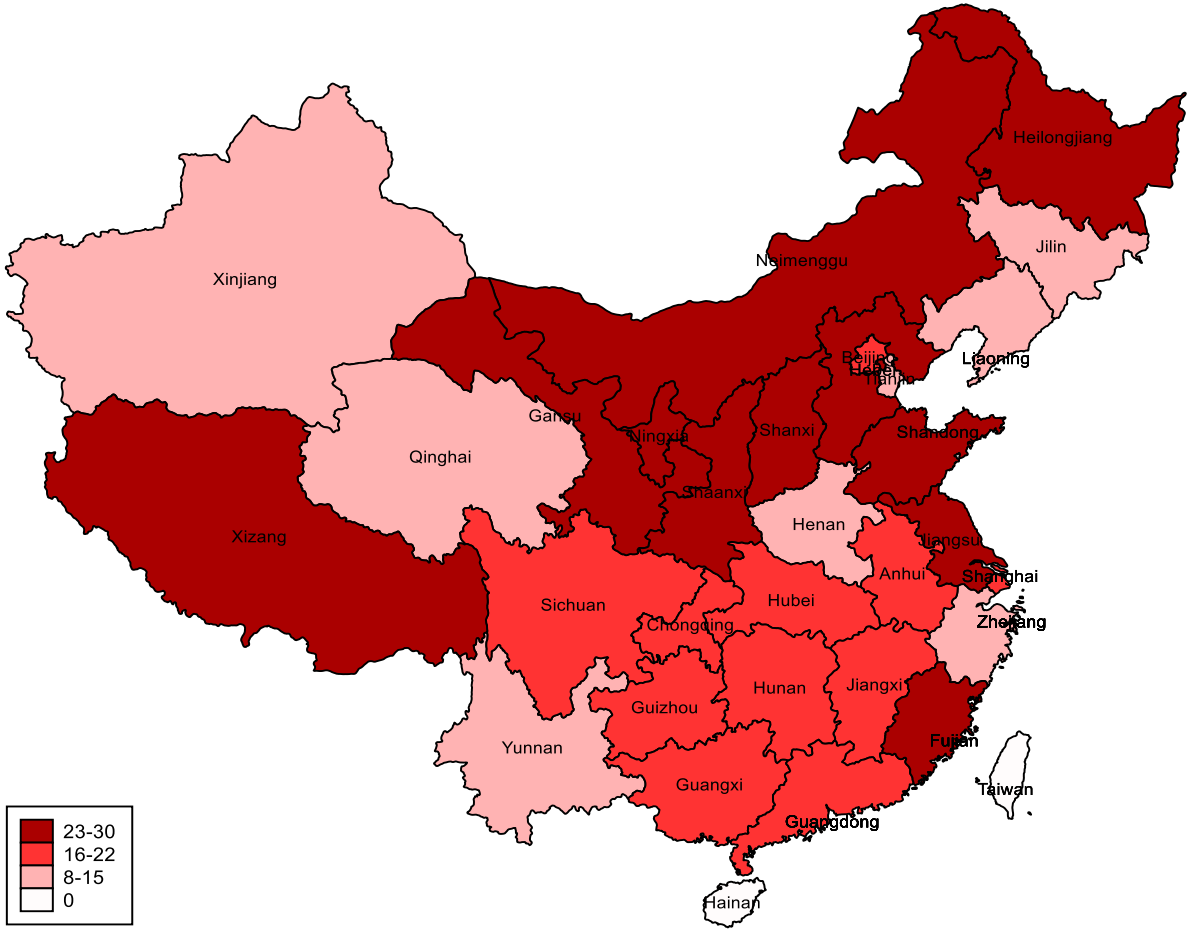
ASF Outbreak in China

- ASF is a highly contagious animal disease which is spread via the ASF virus
  - Infection through infected hogs, leeches, birds, mice, and contaminated water/feed
  - The virus is able to stay alive in the air for days and remain active in blood/organs/droppings
- ASF first happened in China early August 2018 and caused losses of tens of millions of hogs in the next two years
  - Hogs died of ASF or were culled (Ma et al., forthcoming)

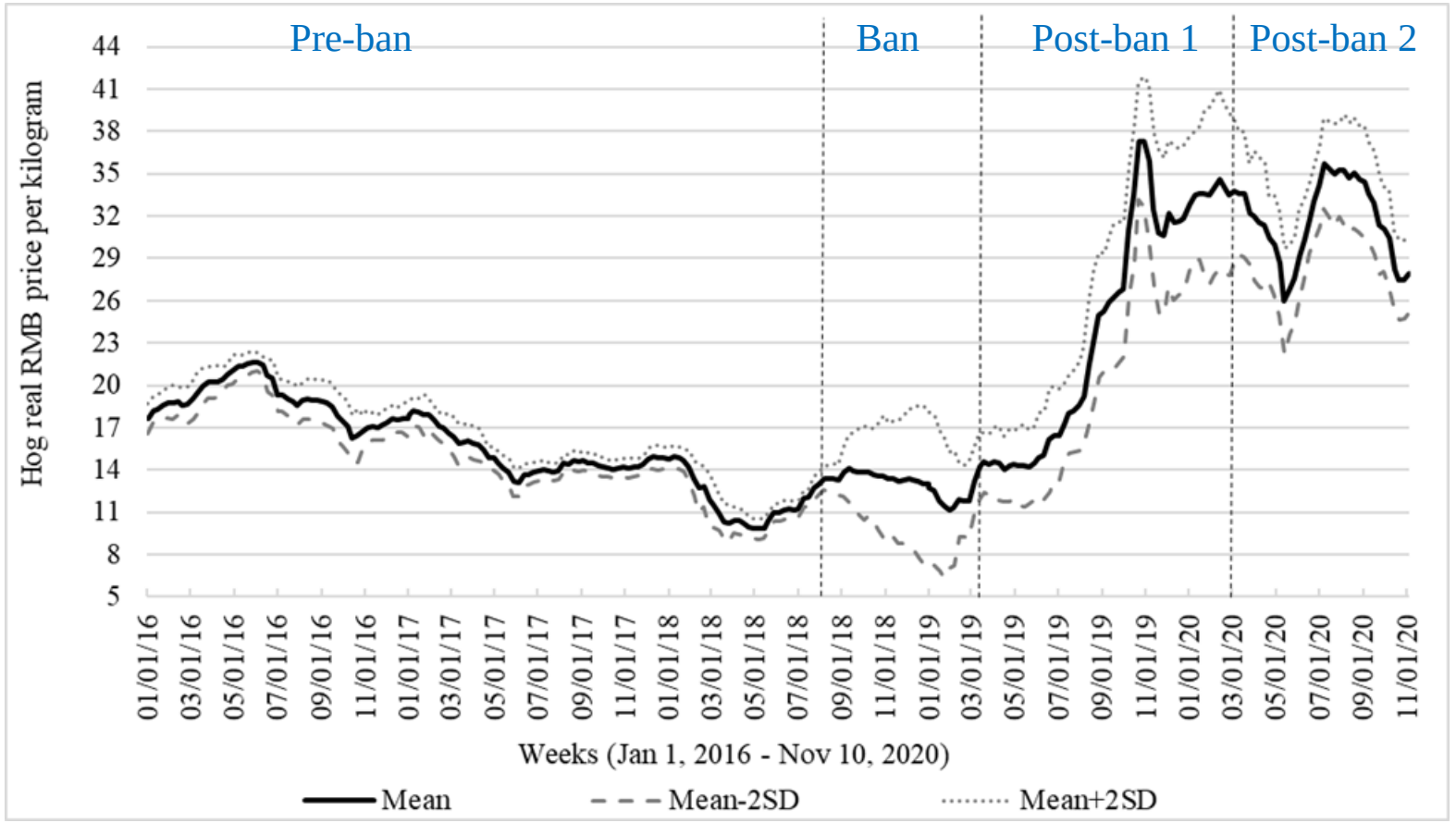
The Shipping Ban

- Starting from late August 2018, provinces gradually banned shipping live hogs from an “infected province” to other provinces
  - An infected province is one with >2 ASF cases
- By December, all mainland provinces except for Hainan, the island province imposed the ban
- By mid-March 2019, almost all of the bans were lifted
- Since then, the ban was occasionally imposed on specific counties where ASF was identified, but not at the province level

Ban Weeks across Provinces (Aug 2018 - Mar 2019)



Price Divergence Caused by the Ban



PURDUE AGRICULTURE
AGRICULTURAL ECONOMICS

Delgado, Ma, and Wang (2021)

Imperfect Public Information on ASF

- Continuing price increases post the ban implies continuing supply reductions
- Officially reported number of cases and losses were likely to be far below the actual number of cases and losses
- From 2018 to 2019, the number of officially confirmed cases is 144 and the number of infected hogs is ~2 million
- But the actual reduction in hog supply was ~100 million head scomparing 2019 to 2018

Explaining the Slow Re-Integration

- The substantial divergence in provincial-level prices implies obvious arbitrage opportunities across provinces, after the ban was lifted
- The divergence endured for over a year after the shipping ban was removed
- To explain in theory, we build a model of cross-provincial arbitrage under imperfect information on ASF

Model Setup

- In week t, a hog farmer in province i sells to a slaughter in province j, taking province-level prices as given
  - Home province price is p_{it}, and the price in the other province is p_{jt}
  - $\delta_{ijt} = p_{jt} - p_{it} \geq 0$ with transportation costs normalized to zero
- Quantity of hogs for the farm is pre-determined at q_t
- Tradeoff between exploiting price wedges across provinces and catching the virus, when public information of ASF is imperfect
- If not infected, gain $\delta_{ijt} q_t$; if infected by ASF, lose $p_{it} q_t$

Arbitrage Decision

- Expected return from arbitrage is $\Delta E(\pi_{ijt}) = q_t[p_{jt}(1-\theta_{ij}) - p_{it}]$
  - θ_{ij} is the probability of catching ASF in shipping hogs from province i to province j
  - The expected return decreases in θ_{ij}

- θ_{ij} increases in the distance between the two provinces
  - Longer distance, less private information, less accuracy of ASF information in province j
  - Longer distance, more stations, and higher probability of catching the virus during truck shipments (e.g., $\theta_{ij} = 1-(1-\theta)^K$)

- Hypothesis: arbitrage opportunity is less exploited as the inter-province distance increases in the post-ban periods

A Regional Policy

- In January 2019, a special region-level ASF policy was initiated by the central government
- Six southern provinces formed a co-managing agency to conduct actions over ASF and other animal diseases and share information
- Hypothesis: the distance matters less for provinces in the South region



Panel Data

- Balanced panel of weekly province-level hog prices from Jan 1, 2016 to Nov 10, 2020
  - 252 weeks and 29 provinces (2 mainland provinces excluded due to missing data)
  - Four periods: pre-ban, ban, post ban 1, and post ban 2

Variables	Mean	SD	Min	Max	Unit
Province hog price in Period 1	15.81	0.34	15.11	16.69	RMB/kg
Province hog price in Period 2	13.05	1.56	10.45	16.71	RMB/kg
Province hog price in Period 3	24.56	1.53	20.98	27.04	RMB/kg
Province hog price in Period 4	31.71	1.59	28.79	35.73	RMB/kg

Spatial Model

- Given the panel dataset, our goal is to characterize the spatial price relationships among the 29 provinces
  - Estimate inter-province price links using a spatial model

- In the traditional spatial model, the elements of spatial matrix follow a pre-specified spatial structure
  - E.g., geographic distances between provinces
  - Geographic distances may not be good basis for price links in the hog market
  - Complex spatial price relationships driven by factors other than distance

Spatial Model

- de Paula et al. (2018) develop a generalized spatial model
  - No pre-specified spatial structure, but allowing for data-driven spatial links
  - Take care of multivariate spatial connectivity
  - Estimated using a high-dimensional GMM method (adaptive elastic net GMM)
- The pre-determined spatial model is a special case of this new model
- Estimated inter-province price links allow us to further explore various determinants in each period of interest
  - Not possible in the traditional model where links are postulated

Spatial Model Setup

- A panel-data spatial model:

$$p_{it_m}^m - \overline{p_{t_m}^m} = \rho^m \sum_{j=1}^{j=29} w_{ij}^m \left(p_{jt_m}^m - \overline{p_{t_m}^m}\right) + v_i^m + \mu_{t_m}^m + \varepsilon_{it_m}^m$$

  - $m \in \{1,2,3,4\}$ denotes the four periods, each covering $i = 1,2,\ldots,29$ provinces
  - $t_m = 1,2,\ldots,T_m$ weeks per period
  - $p_{it_m}^m$ is period-specific price of province i, and $\overline{p_{t_m}^m}$ is the average price in that period
  - $\sum_{j=1}^{j=29} w_{ij}^m \left(p_{jt_m}^m - \overline{p_{t_m}^m}\right)$ is the spatial lag of prices
  - $w_{ij}^m \in (0,1)$ is the inter-province price link, v_i^m province FE, and $\mu_{t_m}^m$ month FE
  - Choose initial values based on AIC

Inter-Province Distance

- Consider two measurements of the inter-province distance
- First, D_{ij} is the geographical distance between province capital cities
  - Unit: 1000 kilometers
- Second, D_{ij} is the geographical "economic" distance between provinces
  - Use 2016 price wedges among provinces as a proxy
  - Take the mean price wedge as the average cost of arbitrage between two provinces, given that most province pairs are co-integrated in the pre-ASF period
  - Unit: real 2018 RMB/kilogram

Price Links and Distances

Table 2. Summary Statistics of Estimated Spatial Matrices and Distances

Variables	Mean	SD	Min	Max	Unit
Estimated w_{ij} in Period 1	0.16	0.14	0.00	0.98	-
Estimated w_{ij} in Period 2	0.27	0.25	0.00	1.00	-
Estimated w_{ij} in Period 3	0.51	0.31	0.00	1.00	-
Estimated w_{ij} in Period 4	0.32	0.14	0.00	0.84	-
Geographic D_{ij}	1.31	0.70	0.11	3.46	1000km
Economic D_{ij}	0.56	0.24	0.11	1.57	Real 2018 RMB/kg

Source: Authors' calculation. *Notes*: The number of observations is 812. Statistics are weighted by observations.

Additional Explanatory Variables

- We add a few other province-specific variables that help explain the variance in estimated price links
  - Hog outputs, net pork import, and weeks banned

Variables	Mean	SD	Min	Max	Unit
Province hog outputs	2.42	1.90	0.11	6.58	10 mil heads
Province importer (0,1 with 1=yes)	0.55	0.50	0.00	1.00	-
No. weeks province under ban	25.16	4.64	12	34	-

Reduced-Form Model

- Identify determinants of price links:

$$\ln\left(w_{ij}^{m}\right) = c + \alpha \ln\left(D_{ij}\right) + \beta \ln\left(\overline{p_{jm}}\right) + S_{ij} + \Gamma_{ij} + \Omega_{j} + F_{i} + e_{ij}^{m}$$

  - w_{ij}^{m} is the estimated period specific price link between provinces
  - D_{ij} is the geographical distance between province capital cities
  - $\overline{p_{jm}}$ is the period-specific average hog price in province j
  - Γ_{ij} is the number of weeks under the ban
  - S_{ij} is the southern-south indicator for a pair of provinces
  - F_{i} is province FE, e_{ij}^{m} clustered at the province level

Baseline Findings: Geographical Distance

	(1) Pre-ban	(2) Ban	(3) Post-ban 1	(4) Post-ban 2
Distance between	0.08	0.07	-0.10*	-0.27***
provinces *i* and *j*	(0.10)	(0.12)	(0.05)	(0.09) ← SE
	[0.42]	[0.56]	[0.05]	[0.00] ← *p*-value
#weeks under the ban		-0.02*	-0.02**	-0.01
provinces *i* and *j*		(0.01)	(0.01)	(0.01)
South-south (1, yes)			0.40**	-0.04
			(0.15)	(0.10)
Province *j* average price	6.29*	-1.27***	-1.29**	-0.98*
in the period	(3.16)	(0.45)	(0.51)	(0.57)
Pre-ban $\widehat{w_{ij}}$	NO	YES	YES	YES
Province *j* controls	YES	YES	YES	YES
Province *i* FE	YES	YES	YES	YES
R^2	0.57	0.48	0.64	0.36
# observations	812	812	812	812

Robustness Test 1: Additional FE

	(1) Pre-ban	(2) Ban	(3) Post-ban 1	(4) Post-ban 2	(5) Pre-ban	(6) Ban	(7) Post-ban 1	(8) Post-ban 2
Distance between	0.08	0.07	-0.10*	-0.27***	0.09	-0.12	-0.19***	-0.26***
provinces i and j	(0.10)	(0.12)	(0.05)	(0.09)	(0.10)	(0.09)	(0.06)	(0.08)
	[0.42]	[0.56]	[0.05]	[0.00]	[0.39]	[0.22]	[0.00]	[0.00]
#weeks under the ban		-0.02*	-0.02**	-0.01		-0.03**	-0.01***	-0.02
provinces i and j		(0.01)	(0.01)	(0.01)		(0.01)	(0.00)	(0.01)
South-south (1, yes)			0.40**	-0.04			0.15	-0.04
			(0.15)	(0.10)			(0.13)	(0.12)
Province j average price	6.29*	-1.27***	-1.29**	-0.98*				
in the period	(3.16)	(0.45)	(0.51)	(0.57)				
Pre-ban $\widehat{w_{ij}}$	NO	YES	YES	YES	NO	YES	YES	YES
Province j controls	YES	YES	YES	YES	YES	YES	YES	YES
Province i FE	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.57	0.48	0.64	0.36	0.59	0.60	0.67	0.42
# observations	812	812	812	812	812	812	812	812

Robustness Test 2: Economic Distance

	(1) Pre-ban	(2) Ban	(3) Post-ban 1	(4) Post-ban 2	(5) Pre-ban	(6) Ban	(7) Post-ban 1	(8) Post-ban 2
Distance between	0.18	0.22	-0.09*	-0.13	0.11	-0.17	-0.13**	-0.10
provinces i and j	(0.14)	(0.14)	(0.05)	(0.08)	(0.16)	(0.11)	(0.06)	(0.09)
	[0.19]	[0.14]	[0.10]	[0.12]	[0.50]	[0.12]	[0.04]	[0.27]
#weeks under the ban		-0.02*	-0.02**	-0.02*		-0.04***	-0.02***	-0.03*
provinces i and j		(0.01)	(0.01)	(0.01)		(0.01)	(0.00)	(0.02)
South-south (1, yes)			0.43**	0.08			0.27	0.16
			(0.17)	(0.09)			(0.18)	(0.10)
Province j average price	5.05*	-1.53**	-1.15**	-1.02				
in the period	(2.68)	(0.55)	(0.49)	(0.80)				
Pre-ban $\widehat{w_{ij}}$	NO	YES	YES	YES	NO	YES	YES	YES
Province j controls	YES	YES	YES	YES	YES	YES	YES	YES
Province i FE	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.57	0.48	0.64	0.36	0.59	0.60	0.66	0.41
# observations	812	812	812	812	812	812	812	812

PURDUE AGRICULTURE
AGRICULTURAL ECONOMICS

Policy Implications

- Inconsistency between public and private information about ASF led to uncertainty for producers and processors and efficiency loss
  - Market re-integration began relatively early where information transparency was greater
- The government should strive to maintain certainty and transparency in information regarding the disease outbreak if it wants to maintain safe trade within the region
- Developing cold chain logistics may be an effective measurement to the spread of animal epidemics in the future
  - Confined transportation and lower survival of virus

Further Discussion

- The value of providing high-quality public information applies to animal epidemics in general and to human epidemics involving travel within and across countries

- The generalized spatial model has broader applications
  - Used with regular panel data, no need for survey on network, etc.
  - Could be implemented in other context, including international trade and personal networks

References

Barrett, Christopher B., and Jau Rong Li. 2002. Distinguishing between Equilibrium and Integration in Spatial Price Analysis. American Journal of Agricultural Economics 84(2):292-307.

de Paula, Aureo, Imran Rasul, and Pedro Souza. 2018. Recovering Social Networks from Panel Data: Identification, Simulations and an Application. Working paper. https://ssrn.com/abstract=3322049

Fan, C. Cindy. 2002. The Elite, the Natives, and the Outsiders: Migration and Labor Market Segmentation in Urban China. Annals of the Association of American Geographers 92(1):103-24.

Goyat, Sulekha. 2011. The Basis of Market Segmentation: A Critical Review of Literature. European Journal of Business and Management 3(9):45-54.

Ma, Meilin, H. Holly Wang, Yizhou Hua, Fei Qin, and Jing Yang. Forthcoming. African Swine Fever in China: Impacts, Responses, and Policy Implications. Food Policy.

Ruan, Jianqing, Qingwen Cai, and Songqing Jin. 2021. Impact of COVID-19 and Nationwide Lockdowns on Vegetable Prices: Evidence from Wholesale Markets in China. American Journal of Agricultural Economics. https://doi.org/10.1111/ajae.12211

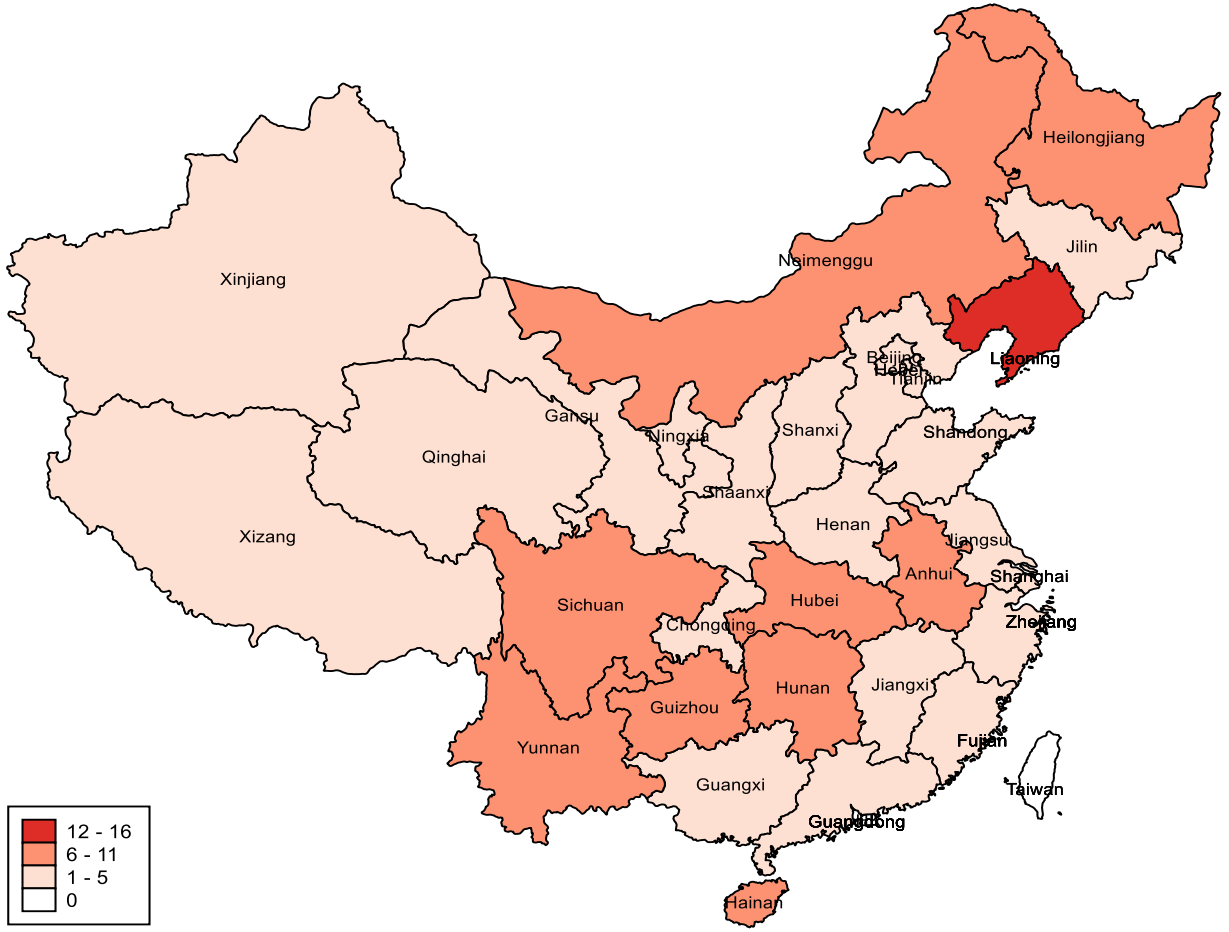
Ravallion, Martin. 1986. Testing Market Integration. American Journal of Agricultural Economics 68(1):102-9.

Shiue, Carol H., and Wolfgang Keller. 2007. Markets in China and Europe on the Eve of the Industrial Revolution. American Economic Review 97(4):1189-216.

Topics for Discussion

- Other drivers of integration?
- Measuring efficiency loss?

Officially Reported Cases across Provinces (2018-2020)

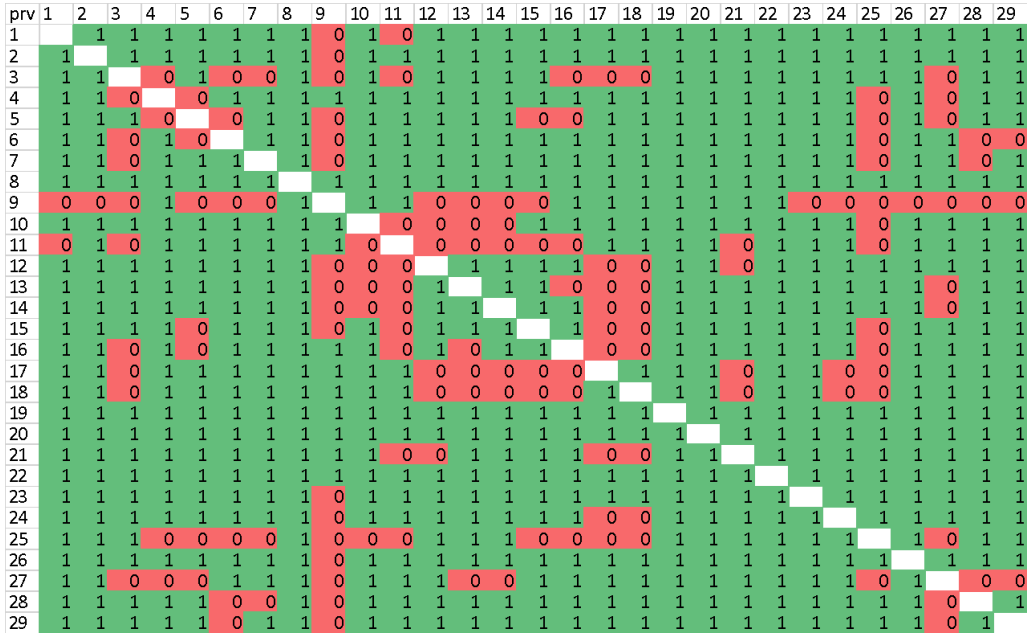


Correlation Coefficients of Key Variables

Table A2. Correlation Coefficients of Key Variables

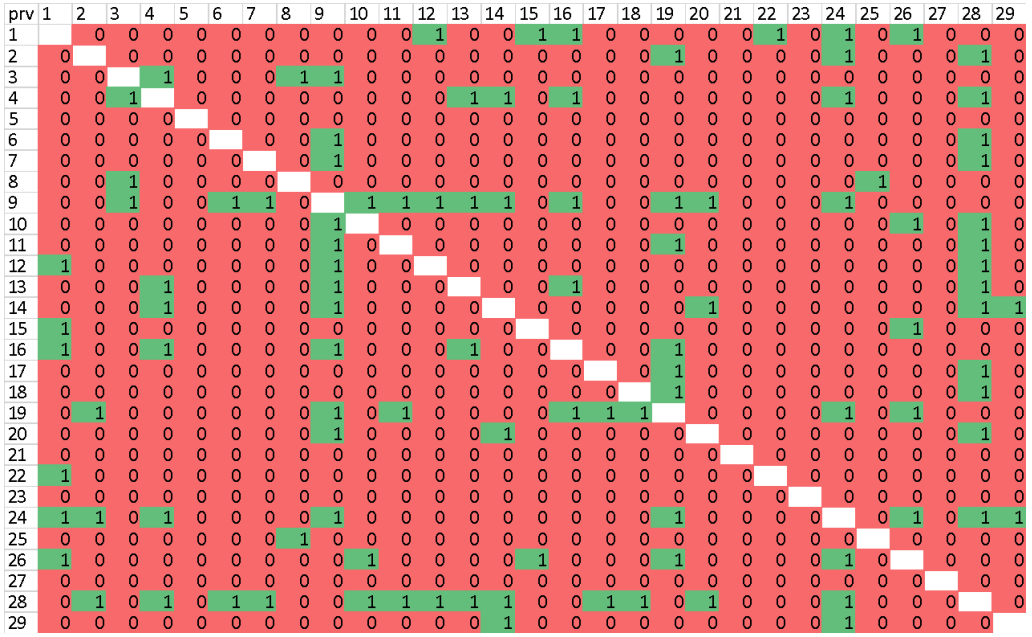
Variables	Estimated w_{ij} in Period 1	Estimated w_{ij} in Period 2	Estimated w_{ij} in Period 3	Estimated w_{ij} in Period 4	Geog. D_{ij}	Econ. D_{ij}
Estimated w_{ij} in Period 1	1.00					
Estimated w_{ij} in Period 2	0.20	1.00				
Estimated w_{ij} in Period 3	0.29	0.21	1.00			
Estimated w_{ij} in Period 4	0.08	-0.10	0.09	1.00		
Geographic D_{ij}	-0.19	-0.01	-0.20	-0.32	1.00	
Economic D_{ij}	0.01	0.17	0.02	-0.16	0.54	1.00

Cointegration Tests



prv	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1		1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1		0	1	0	0	1	0	1	0	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1
4	1	1	0		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
5	1	1	1	0		0	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1
6	1	1	0	1	0		1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0
7	1	1	0	1	1	1		1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
8	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	0	0	0	1	0	0	0	1		1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1		0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
11	0	1	0	1	1	1	1	1	1	0		0	0	0	0	0	1	1	1	1	0	1	1	1	0	1	1	1	1
12	1	1	1	1	1	1	1	1	0	0	0		1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	0	0	0	1		1	1	0	0	0	1	1	1	1	1	1	1	1	0	1	1
14	1	1	1	1	1	1	1	1	0	0	0	1	1		1	1	0	0	1	1	1	1	1	1	1	1	0	1	1
15	1	1	1	1	0	1	1	1	0	1	0	1	1	1		1	0	0	1	1	1	1	1	1	0	1	1	1	1
16	1	1	0	1	0	1	1	1	1	1	0	1	0	1	1		0	0	1	1	1	1	1	1	0	1	1	1	1
17	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0		1	1	1	0	1	1	0	0	1	1	1	1
18	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1		1	1	0	1	1	0	0	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1		1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1		1	1	1	1	1
25	1	1	1	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1	1		1	0	1	1
26	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
27	1	1	0	0	0	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0		0	0
28	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0		1
29	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	

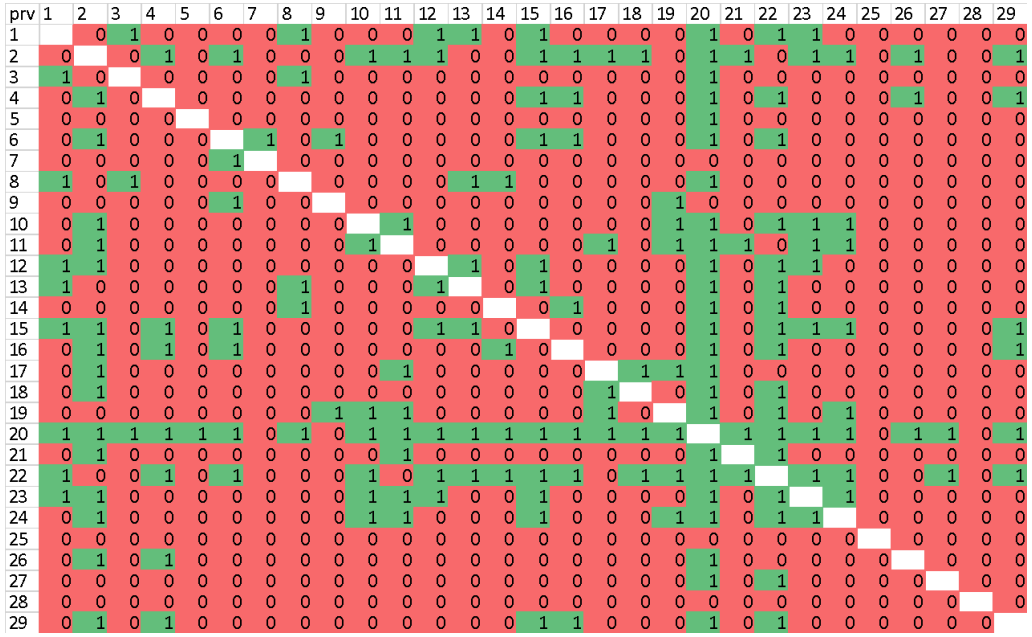
(a) Pre-ban period



prv	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0
2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0
3	0	0		1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1		0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0
5	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7	0	0	0	0	0	0		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
8	0	0	1	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	1	0	0	1	1	0		1	1	1	1	1	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0
10	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
11	0	0	0	0	0	0	0	0	1	0		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
12	1	0	0	0	0	0	0	0	1	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
13	0	0	0	1	0	0	0	0	1	0	0	0		0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
14	0	0	0	1	0	0	0	0	1	0	0	0	0		0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	1	0	0
16	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0		0	0	1	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	1	0	0	0	0	0	0	0	0	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0	0	0	1	0
19	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1		0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0		0	0	0	0	0	0	0	1	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
24	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0		0	1	0	1	1
25	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
26	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0		0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
28	0	1	0	1	0	1	1	0	0	1	1	1	1	1	0	0	1	1	0	1	0	0	0	1	0	0	0		0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	

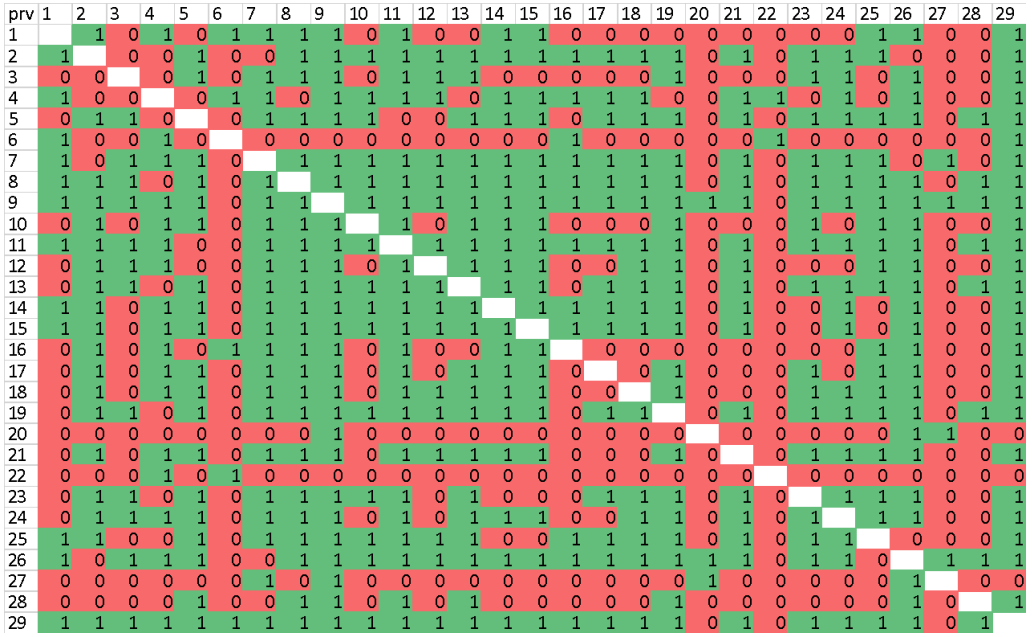
(b) Ban period

Cointegration Tests



prv	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		0	1	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0
2	0		0	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	0	1	1	0	1	1	0	1	0	0	1
3	1	0		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
4	0	1	0		0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1
5	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
6	0	1	0	0	0		1	0	1	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0
7	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	1	0	0	0	0		0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
10	0	1	0	0	0	0	0	0	0		1	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0
11	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	1	0	1	1	1	0	1	1	0	0	0	0	0
12	1	1	0	0	0	0	0	0	0	0	0		1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0
13	1	0	0	0	0	0	0	1	0	0	0	1		0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	1	0	0	0	0	0		0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
15	1	1	0	1	0	1	0	0	0	0	1	1	0		0	0	0	0	0	1	0	1	1	1	0	0	0	0	1
16	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0		0	0	0	1	0	1	0	0	0	0	0	0	1
17	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		0	1	0	1	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0		1	0	1	0	1	0	0	0	0	0
20	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1		1	1	1	1	0	1	1	0	1
21	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1		1	0	0	0	0	0	0	0
22	1	0	0	1	0	1	0	0	0	1	0	1	1	1	1	1	0	1	1	1	1		1	1	0	0	1	0	1
23	1	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	1	0	1		1	0	0	0	0	0
24	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	1	0	1		0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
26	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0		0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0		0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
29	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	

(c) Post-ban Period 1



prv	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		1	0	1	0	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1
2	1		0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	0	0	1
3	0	0		0	1	0	1	1	1	0	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	1	0	0	1
4	1	0	0		0	1	1	0	1	1	1	1	0	1	1	1	1	1	0	0	1	1	0	1	1	0	1	0	1	0	0	1
5	0	1	1	0		0	1	1	1	1	0	0	1	1	1	0	1	1	1	0	1	0	1	1	1	1	0	1	1
6	1	0	0	1	0		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1
7	1	0	1	1	1	0		1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1
8	1	1	1	0	1	0	1		1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1
9	1	1	1	1	1	0	1	1		1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
10	0	1	0	1	1	0	1	1	1		1	0	1	1	1	0	0	0	1	0	0	0	1	0	1	1	0	0	1
11	1	1	1	1	0	0	1	1	1	1		1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1
12	0	1	1	1	0	0	1	1	1	0	1		1	1	1	0	0	1	1	0	1	0	0	0	1	1	0	0	1
13	0	1	1	0	1	0	1	1	1	1	1	1		1	1	0	1	1	1	0	1	0	1	1	1	1	0	1	1
14	1	1	0	1	1	0	1	1	1	1	1	1	1		1	1	1	1	1	0	1	0	0	1	0	1	0	0	1
15	1	1	0	1	1	0	1	1	1	1	1	1	1	1		1	1	1	1	0	1	0	0	1	0	1	0	0	1
16	0	1	0	1	0	1	1	1	1	0	1	0	0	1	1		0	0	0	0	0	0	0	0	1	1	0	0	1
17	0	1	0	1	1	0	1	1	1	0	1	0	1	1	1	0		0	1	0	0	0	1	0	1	1	0	0	1
18	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	0	0		1	0	0	0	1	1	1	1	0	0	1
19	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1		0	1	0	1	1	1	1	0	1	1
20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1	1	0	0
21	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	0	0	0	1	0		0	1	1	1	1	0	0	1
22	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
23	0	1	1	0	1	0	1	1	1	1	1	1	0	1	0	0	0	1	1	1	0	1		1	1	0	1	0	1
24	0	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	0	1	1	0	1	0	1		1	1	0	0	1
25	1	1	0	0	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1		0	0	0	1
26	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0		1	1	1
27	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1		0	0
28	0	0	0	0	1	0	0	1	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1		1
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	

(d) Post-ban Period 2