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

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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, temporary spatial price divergence

Research Question and Approach

- We examine and identify driving forces of spatial re-integration, after the shipping ban was lifted
- Use unique data of week-province specific hog prices from January 2016 to November 2020
- Our empirical strategy is multi-faceted
  - A innovative, generalized spatial model based on panel data to estimation spatial price links
  - Reduced-form tests to find determinants of price links

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

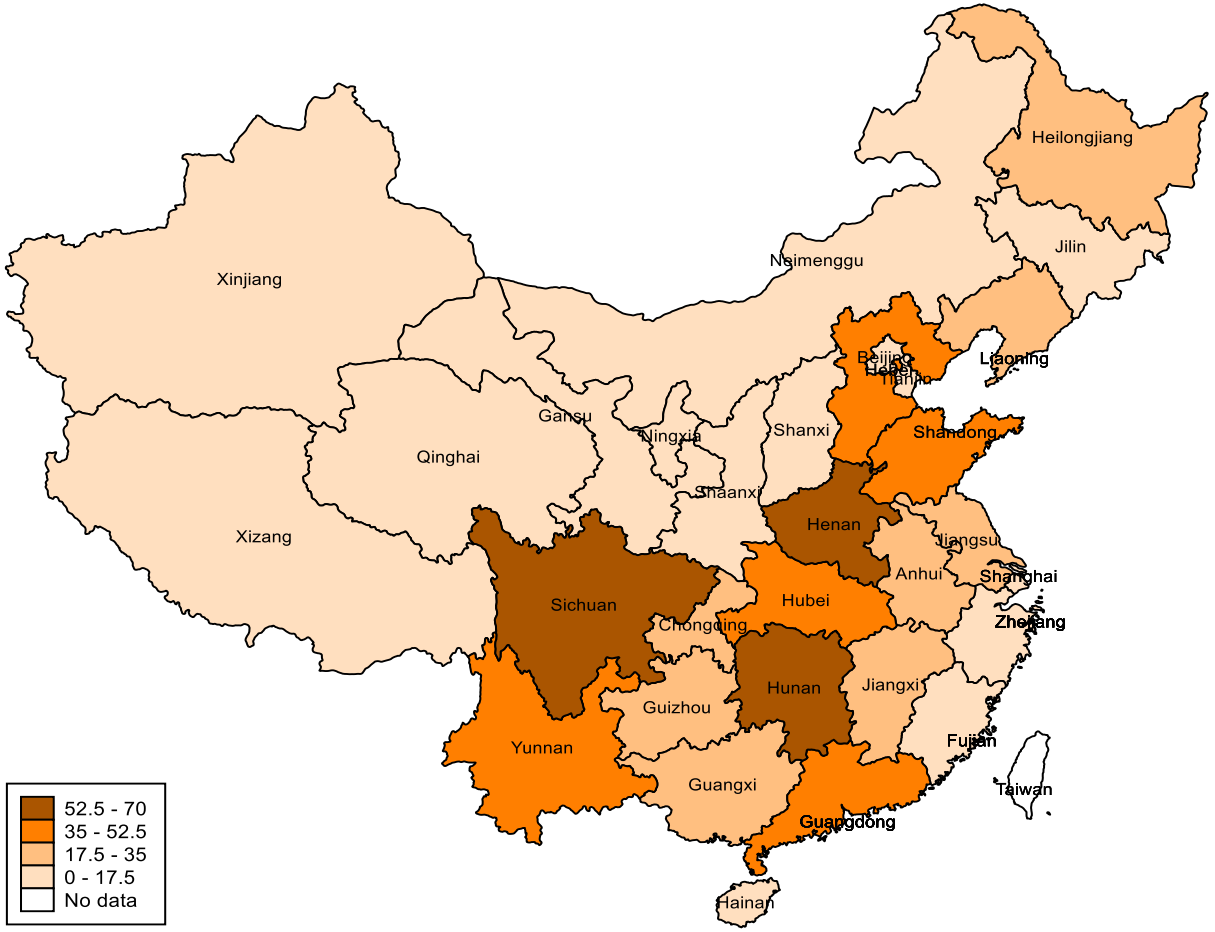
Roadmap

- 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*)



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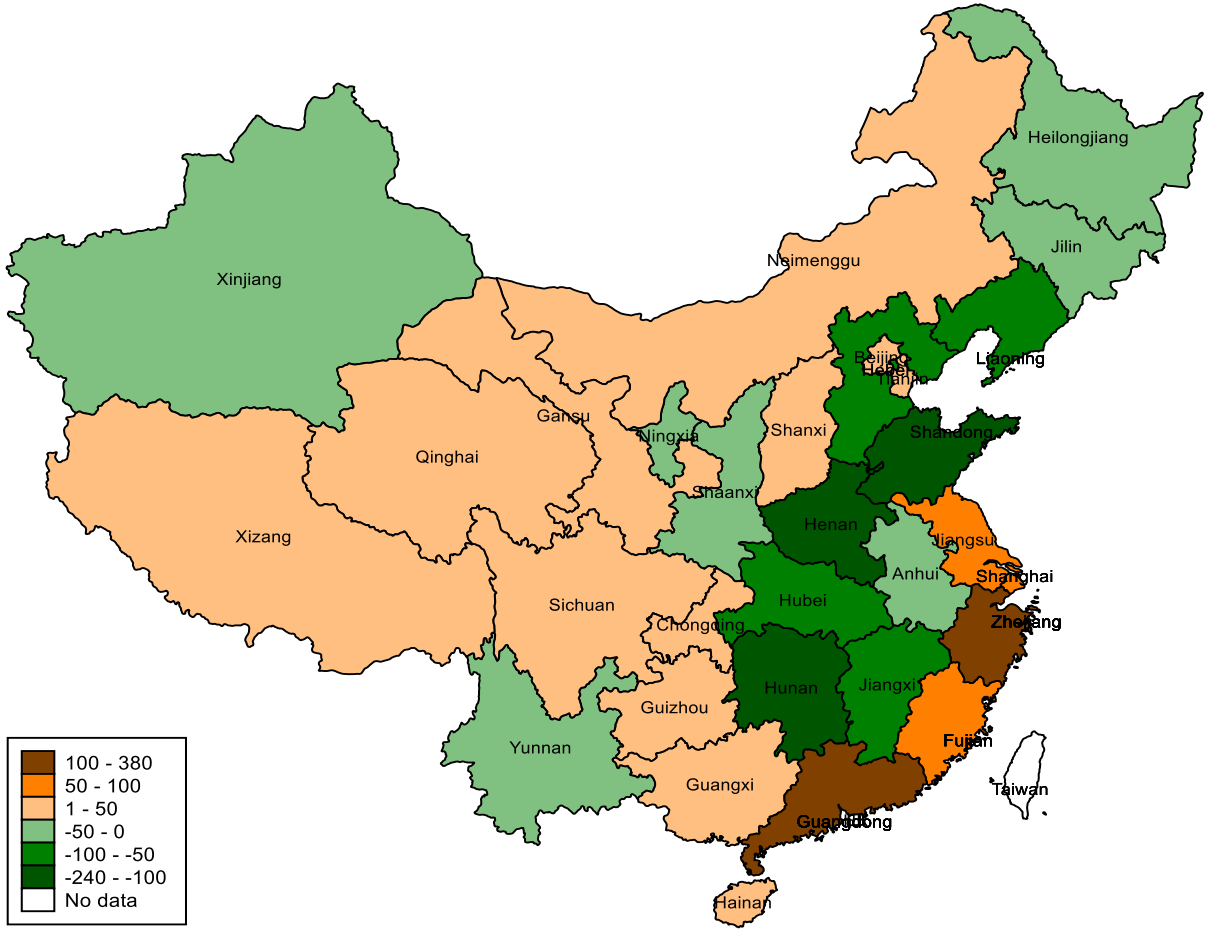
China's Hog Market

- 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
  - Large numbers of small/medium-sized hog farms and slaughter plants trade with each

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



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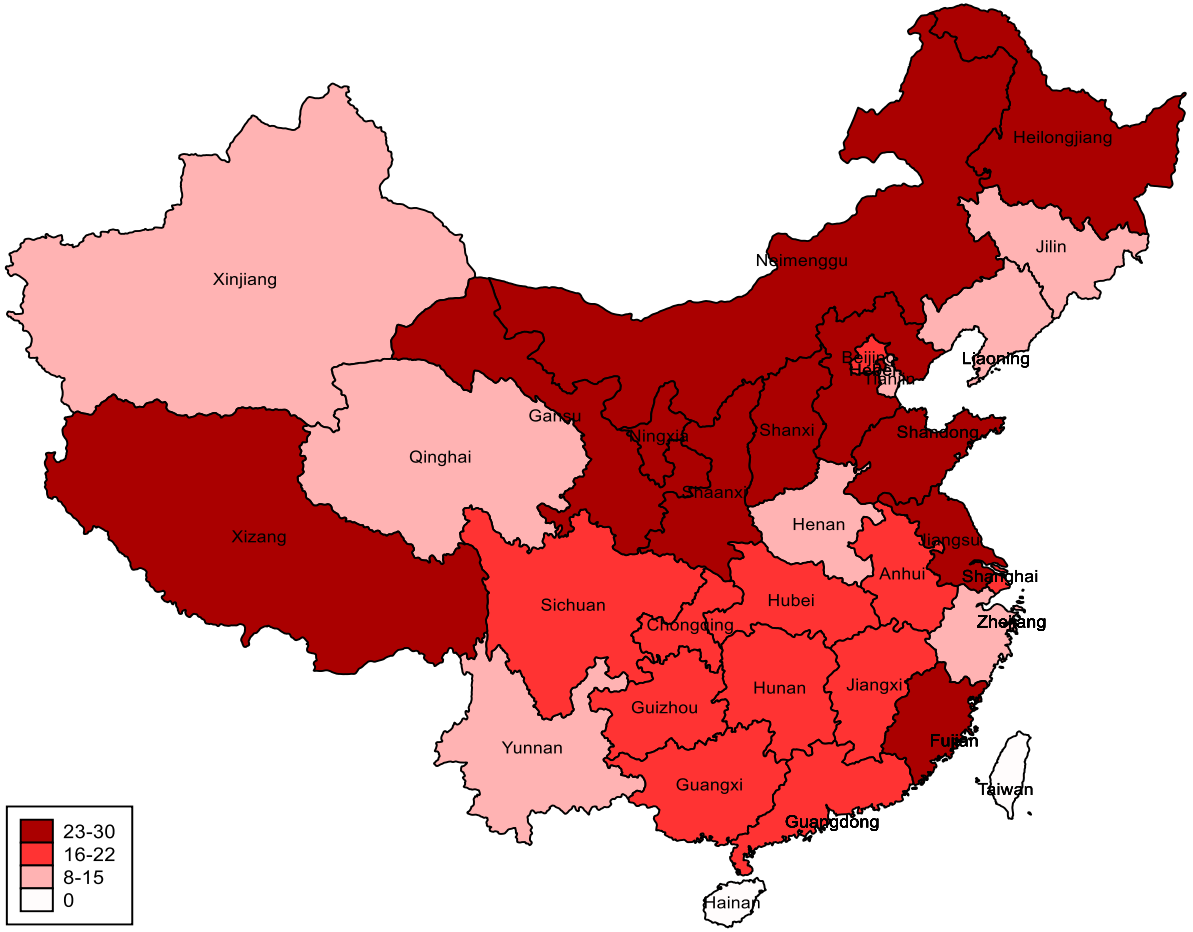
ASF Outbreak in China

- 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 was first found in NE China early August 2018
- ASF caused losses of tens of millions of hogs in the next two years
  - Hogs died of ASF or were culled by the government (Ma et al., forthcoming)

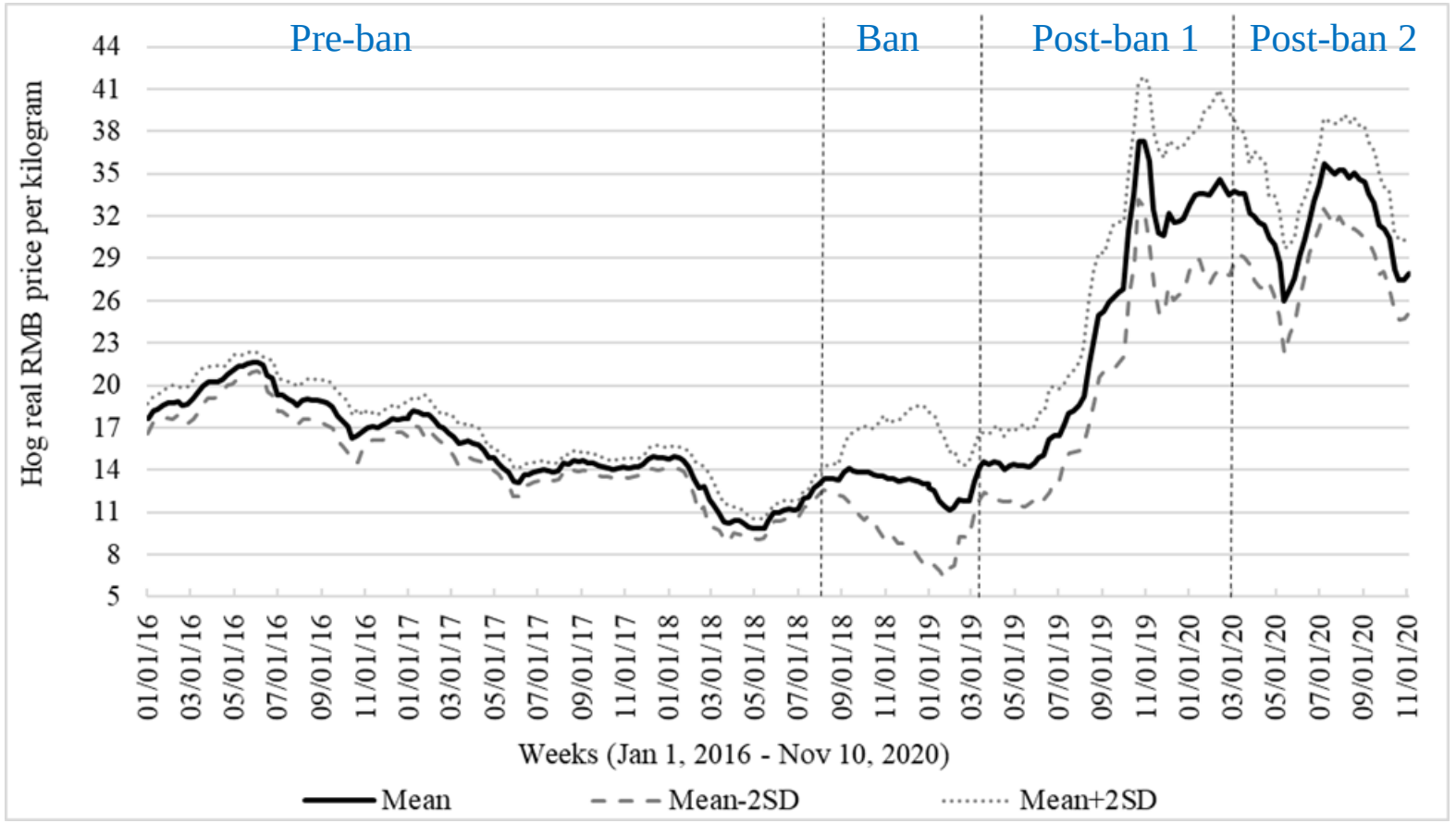
The Shipping Ban

- 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
- 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 infected counties or neighbor with an infected province
- By December, all mainland provinces except for Hainan, 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



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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

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 comparing 2019 output to 2018

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}
  - $\delta_{ijt} = p_{jt} - p_{it}$ net transportation costs and is positive
- 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 in the post-ban periods

Panel Data of Hog Prices

- A balanced panel dataset 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 first 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 the 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 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 south-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

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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

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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 and efficient within the region
- Developing cold chain logistics may help mitigate 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

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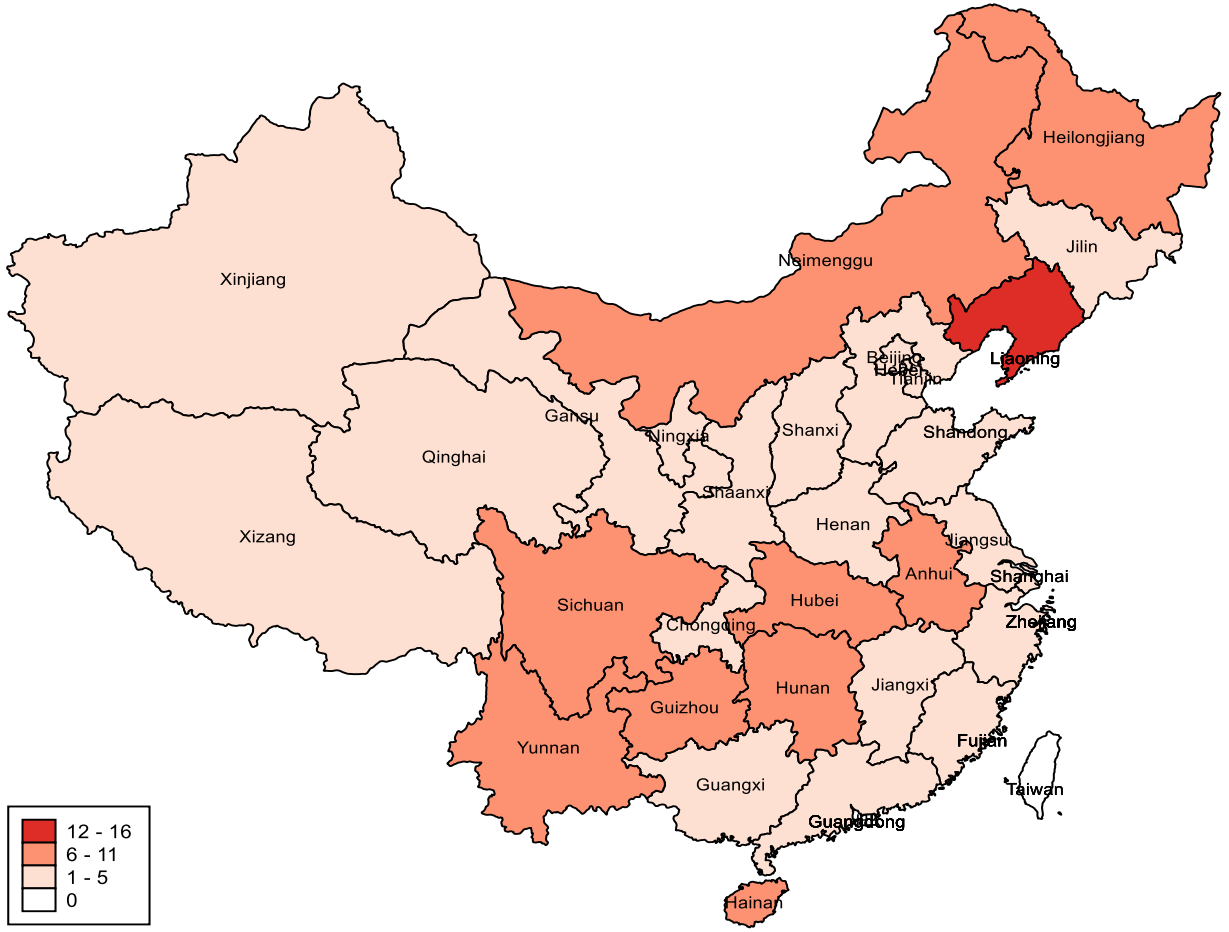
Topics for Discussion

- Other drivers of integration?
- Measuring efficiency loss?

Officially Reported Cases across Provinces (2018-2020)



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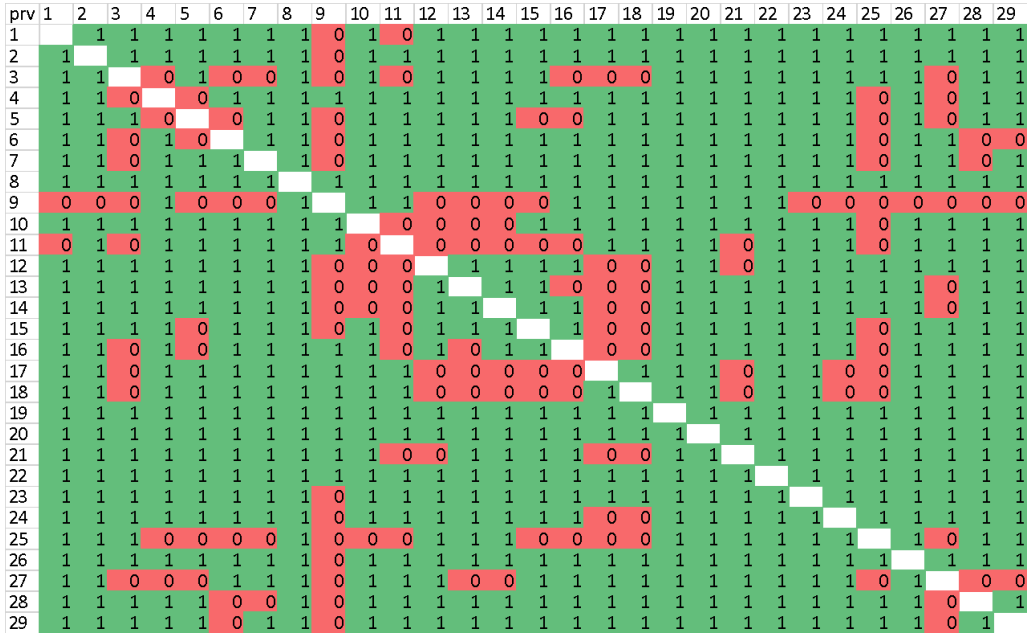
Correlation Coefficients of Key Variables

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 (*Periods 1 and 2*)



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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	1	0	1	1
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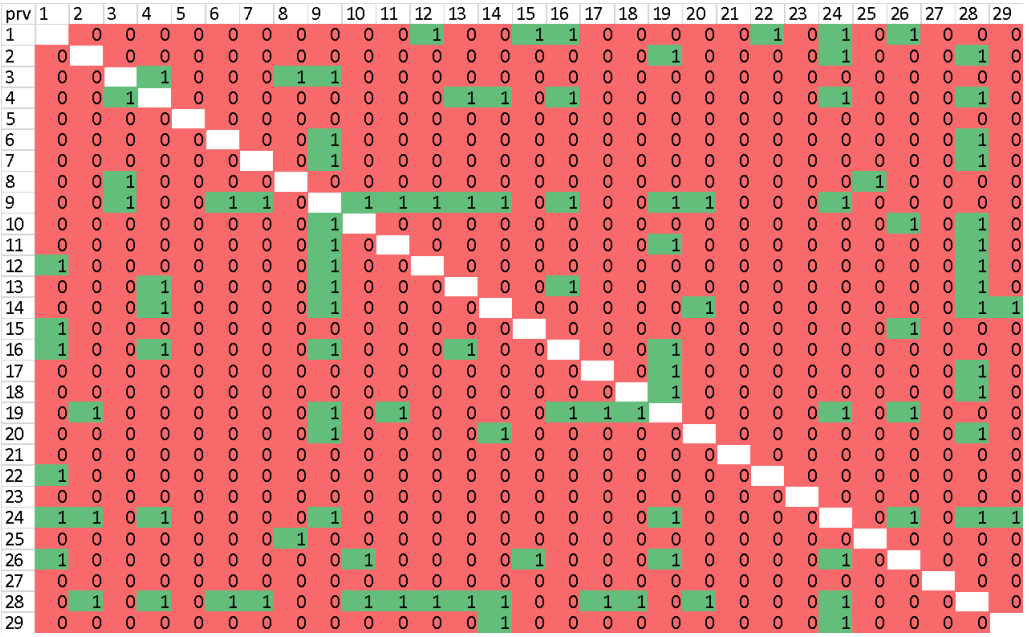
27	1	1	0	0	0	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1		0	0
28	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0		1
29	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	

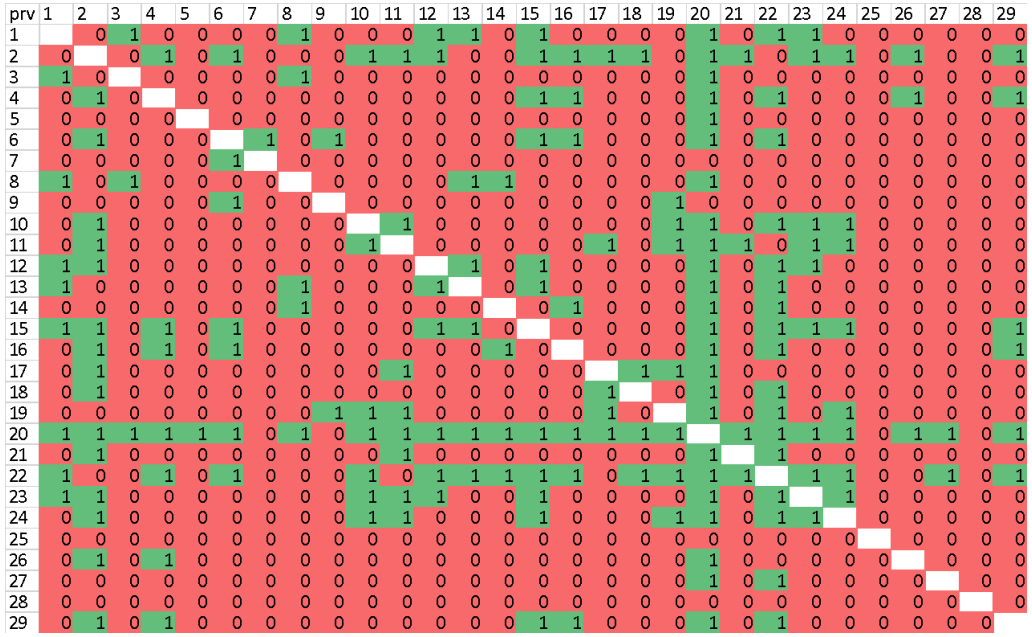
(a) Pre-ban period



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	0	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	

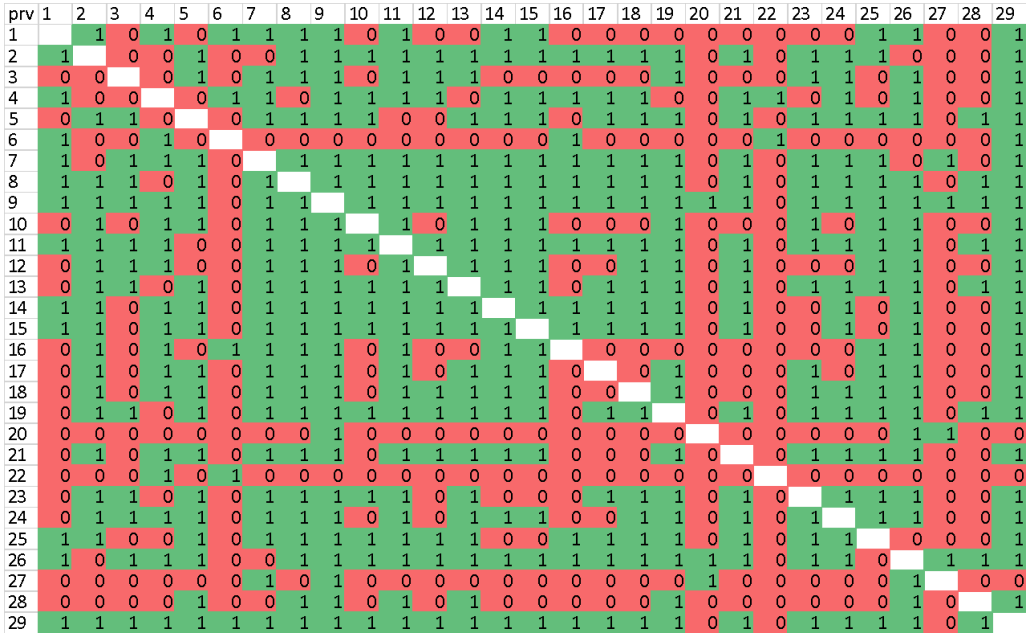
(b) Ban period

Cointegration Tests (*Periods 3 and 4*)



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	0	1	1	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		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	

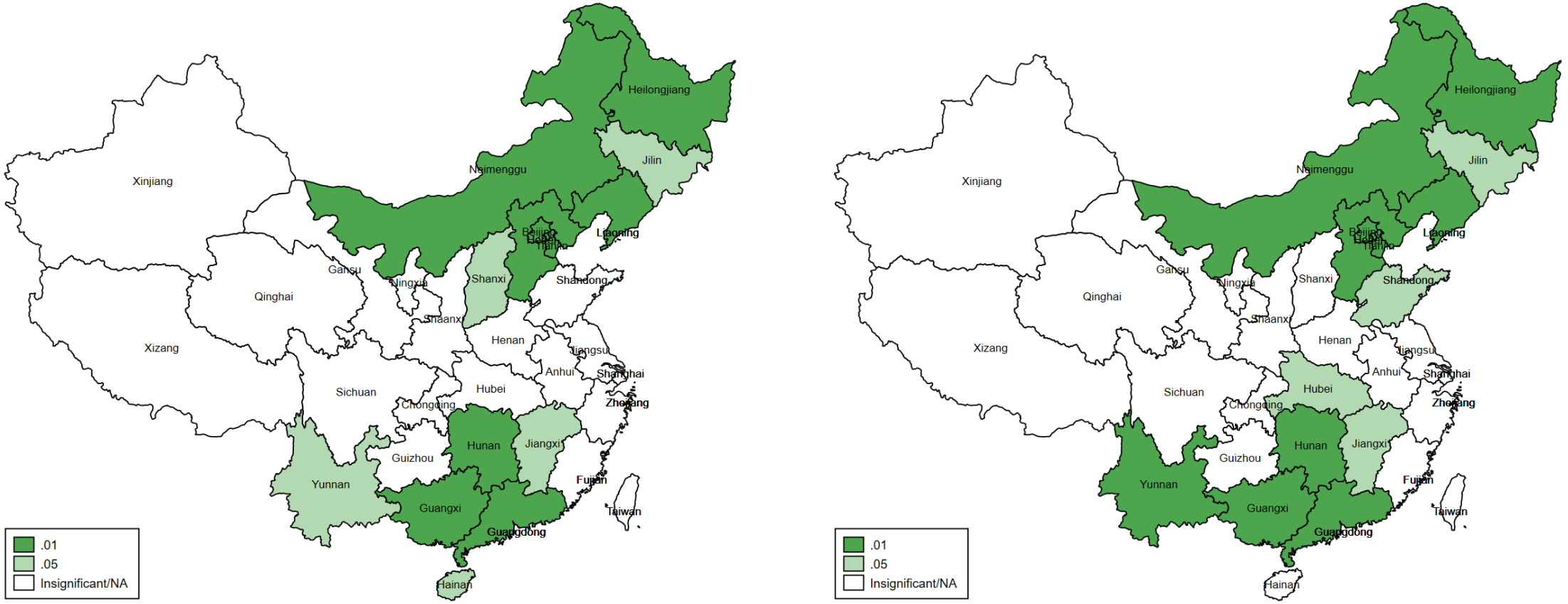
(c) Post-ban Period 1



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	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	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	1	1	0	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	1	0	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	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	0	1	1	0	1		1	1	0	0	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

Local Spatial Autocorrelation Clusters (*Periods 1 and 2*)



Local Spatial Autocorrelation Clusters (*Periods 3 and 4*)