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Exploring 200 years of U.S. commodity market integration: A structural time series model approach

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ABSTRACT

This paper uses a structural time series model to explore U.S. commodity market convergence, efficiency, and intertemporal smoothing from 1750–1949. I find near-continuous convergence that is largely concentrated in the frontier, broad antebellum efficiency gains, and intertemporal smoothing from the 1880s onward among the most perishable goods. The results reveal new periods of integration across all three metrics and underscore the rapid rate of integration on the frontier.

1. Introduction

Economic historians have long recognized commodity market integration as an important driver of pre-modern welfare improvements (Williamson and O'Rourke, 1999). Regional specialization in crops glutted local markets and undersupplied distant ones, while seasonal production cycles oversupplied markets in one season and left them bare the next. These patterns resulted in low incomes and high consumption costs. Arbitragers alleviated these issues by spatially and intertemporally smoothing supply, and they became better at this as transportation and storage costs fell over time (Coleman, 2009; Williams and Wright, 1991). As arbitrage improved, so did the terms of trade for farmers and consumers which, in turn, caused real wages to increase.

Scores of papers have been written about spatial integration in the European setting (see Federico (2012) for a review on the topic), but those that study the U.S. tend to do so as a sidenote in a Trans-Atlantic setting (Jacks, 2005, 2006) or focus on a handful of decades (Slaughter, 2001).[1] Even fewer have studied intertemporal smoothing in Europe or elsewhere (Craig and Holt, 2017; Goodwin et al., 2002), and none that I am aware of have studied smoothing over more than a few decades. To explore these aspects further, I use a structural time series model to decompose a panel of monthly wholesale commodity prices into trend, cycle, and seasonal components. The trend component is used to measure convergence, the degree to which price differentials exist across markets; the cyclical component is used to measure efficiency, the speed with which markets return to equilibrium following a shock; and the seasonal component is used to study intertemporal smoothing, the ability of arbitragers to store over time. I find near-continuous

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[1] Grubb (2010) and Federico and Sharp (2013) are among the rare examples whose primary focus is on the U.S. using more than a half-century of data.

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convergence that is largely concentrated in the frontier, broad antebellum efficiency gains, and intertemporal smoothing from the 1880s onward among the most perishable goods.

To estimate these changes, I construct an unbalanced panel of 42 goods and 70 locations for a total of 715 series. The shifting frontier means the panel is highly unbalanced, so I break the sample into five separate baskets of goods and locations that change along with the geographic expansion of the U.S. This large dataset provides three major advantages: first, the monthly frequency means that I can test for efficiency and seasonal smoothing over reasonable horizons; second, the broad panel of locations allows me to check for regional differences in integration; and third, the wide basket of goods means that I can check if certain goods integrated at faster rates than others or were subject to unobserved quality changes.

The trend components demonstrate near-constant convergence. The results newly document convergence among the colonies prior to the Revolution, fail to find convergence immediately following the adoption of the Constitution, and revise the early 1800s as a period of stagnation rather than divergence. These revisions of previous findings are due to a temporal disaggregation of results around the War of 1812 (Jacks, 2005). I also find convergence for the remainder of the sample, that most convergence is concentrated in the frontier, and that perishable goods converge at faster rates (Craig and Holt, 2017; Goodwin et al., 2002).

The results for the cyclical components newly uncover broad antebellum efficiency gains. By studying a basket of goods that extends beyond wheat, this paper overturns previous findings that the period was one of stagnation (Jacks, 2005). The early twentieth century also exhibits some gains, but the data were too noisy to find statistically significant improvements within most regions.

The seasonal components show surprisingly stable amplitudes over time, except for the most perishable goods. Among perishable goods, seasonality increased during the mid-1800s as falling transportation costs resulted in even greater gluts at regional entrepots. This seasonality began to decline in the late 1800s with the introduction of centralized cold storage units (Craig and Holt, 2017; Goodwin et al., 2002), and they declined even further after rural electrification allowed for a broad diffusion of refrigeration and production-smoothing technologies. Seasonal amplitudes also differed by region due to differences in interest rates, storage capacity, regional supply, and weather patterns. That these differences in amplitudes persisted even after regional interest rates converged suggests particular caution is required when using seasonal price swings to estimate historical interest rates (Keller et al., 2020; McCloskey and Nash, 1984).

2. Data

There are three major data requirements involved in demonstrating changes in arbitrage over time. First, the data must contain a broad panel of goods to provide robustness against potentially unobserved changes in quality (Persson, 2004; Pippenger and Phillips, 2008). Second, the panel must span a wide geography to provide estimates of spatial arbitrage. Third, the data must correspond to the frequency over which arbitrage actually occurs (Ejrnæs et al., 2008).

To address these requirements, I source data from three related branches of research. First, the United States Department of Agriculture (USDA) began recording monthly state-level prices starting in 1908. Second, agricultural economists extended some of these series back into the 1850s using newspaper reports on wholesale prices (Hale, 1930; Houk, 1942; Merchant, 1933; Mortenson et al., 1933; Peterson, 1929; Ronk, 1934; Strand, 1942). Third, economic historians collected data back to the colonial era under the aegis of the International Scientific Committee on Price History (Berry, 1943; Bezanson and Gray, 1937; Bezanson et al., 1935; Cole, 1938; Crandall, 1934; Stoker, 1932; Taylor, 1931, 1932b, 1932a; Warren and Peasron, 1932). To compare prices across locations, I convert colonial currencies to U.S. dollar equivalents using exchange rates from McCusker (1978) and Bezanson (1951) and convert Confederate currency using exchange rates from Weidenmier (2002).[2] Combining these sources results in a highly unbalanced panel of 570,037 monthly price observations for 72 locations and 103 goods spanning from 1700 to 1950.[3]

I balance the panel by breaking the analysis into five distinct periods, each with its own stable basket of goods and locations. The endpoints of each period are selected based on discrete jumps in the availability of data which result from wars and the expansion of the frontier.[4] Fig. 1 plots these jumps using the average number of series observed for each of the nine regions defined in Fig. 2. The timing of the first (1750–1774) and second periods (1786–1819) is shaped by the paucity of price and colonial exchange rate data during the Revolutionary War. The third period (1820–1854) begins as data in the West South Central and East North Central regions become consistently observed for the first time in the panel. The fourth period (1855–1909) adjusts for a further expansion of the frontier into the West North Central and Pacific regions, a return of New England into the dataset, and a worsening of data availability in the South following the start of the Civil War. The fifth period (1910–1949) begins with a large jump in data availability as every mainland state becomes observed.[5]

I also impose three restrictions on these baskets to ensure a standard of quality. First, I restrict the dataset to series with observations in at least two locations, to provide a measurement of integration; second, I require observations in at least two-thirds of the periods, to minimize dependence on interpolation; and third, I require data to be observed within a year of the endpoints, to reduce the need for extrapolation. The result is 715 price series covering 385,224 monthly observations across 70 locations and 42 goods from 1750

[2] See the Appendix for more information on exchange rates.

[3] See the Appendix for more detailed citations.

[4] Bai-Perron (2003) tests did not provide consistent breakpoints across the many goods in the panel, so endpoints were chosen based on data availability instead.

[5] For expositional purposes, periods have been rounded up to the nearest half decade, where possible. In fact, prices were observed on the Atlantic as early as 1748, until the start of the American Revolutionary War in 1775, in the East North Central as early as 1816, in the West North Central in 1851, in New England in 1852, and in all other regions in 1908.

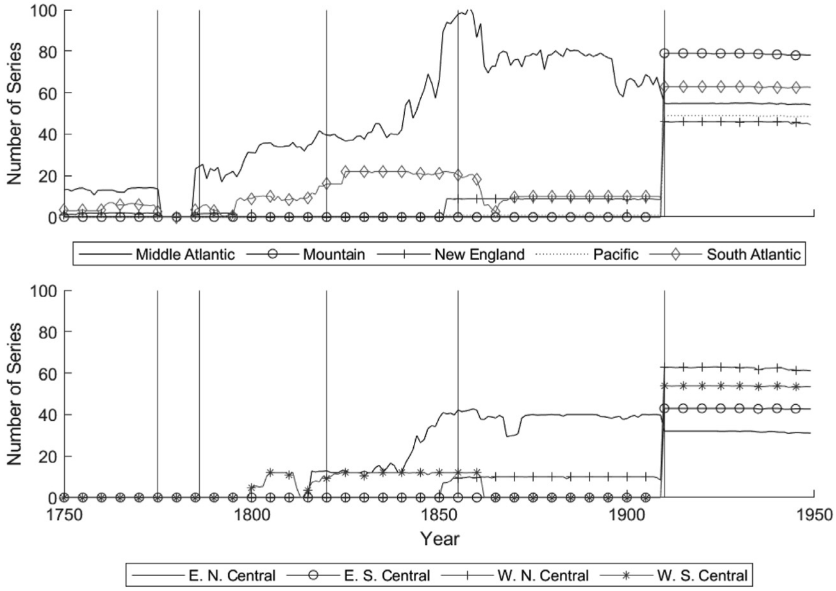

Fig. 1. Average Number of Series per Year by Region. Notes: The figure depicts the number of series observed in each region in the unbalanced panel over time. The vertical lines demark breakpoints between the five baskets used for analysis, with the American Revolution not represented by any basket. Source: See Appendix.

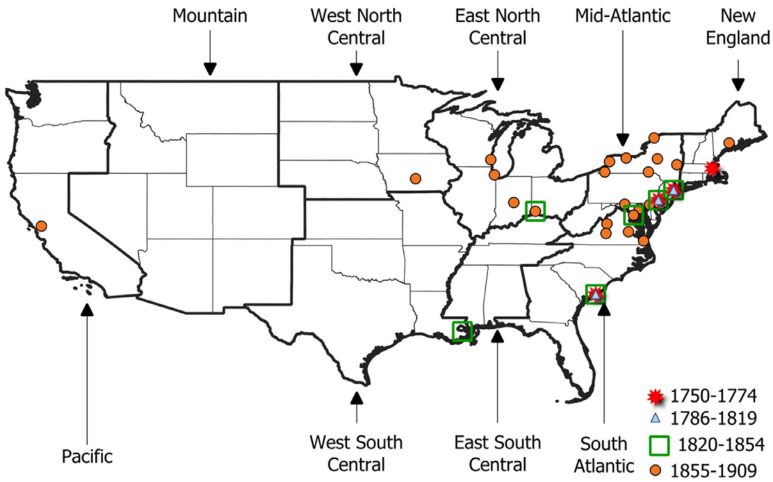

Fig. 2. Map of Data Availability. Notes: This figure provides a map of locations observed in each period. These locations are aggregated into nine Census regions delineated by darker shaded boundaries. All contiguous states are observed from 1910–1949, so no markers are provided for that period. For expositional purposes, I adjust Census regions by including Maryland, Delaware, and West Virginia in Middle Atlantic region instead of the South-Atlantic region. Source: See Appendix.

to 1949.[6] A summary of these series is presented in Table 1. The first two periods (1750–1775 and 1785–1819) are comparatively sparse, covering at most four locations and seven goods, but they shed light on an understudied period in U.S. history. The third and fourth periods (1820–1909) bring much broader coverage with locations on the frontier and over 15 goods. The last period (1910–1949) represents 22 goods across the 48 mainland states and is the most complete. The unbalanced and balanced panels, as well as any replication files, can be accessed online at (Harrison, 2023).

A dataset of this scope needs aggregation and weighting to succinctly summarize results. I provide both regional and good-level aggregation for all metrics, but I focus on regional aggregation when estimating metrics of spatial arbitrage and good-level aggregation when estimating measures of intertemporal arbitrage. This is because spatial arbitrage often depends on location-specific factors, such as regional transportation costs, and intertemporal arbitrage often depends on good-specific factors, such as perishability. I aggregate

[6] There are 26 locations in the dataset before 1910, after which all 48 mainland states are observed.

Table 1
Number of goods and locations by period.

Period	Locations (grouped by region)	Goods
1750–1774	*Middle Atlantic*: New York City (5), Philadelphia (7) *New England*: Boston (2) *South Atlantic*: Charleston (3)	Corn (2) flour (2) molasses (3), pork (3), rice (2), sugar (2), wheat (3)
1786–1819	*Middle Atlantic*: New York City (5), Philadelphia (6) *South Atlantic*: Charleston (2)	Corn (3), flour (2), molasses (2), pork (2), rice (2), wheat (2)
1820–1854	*East North Central*: Cincinnati (13) *East South Central*: New Orleans (12) *Middle Atlantic*: New York City (19), Philadelphia (19) *South Atlantic:* Charleston (11) Virginia (3)	Bacon (6), butter (5), coffee (5), copper (2), corn (5), cornmeal (2), cotton (4), flour (5), lard (5), linseed oil (4), nails (3), pork (4), potash (2), rice (3), rum (2), sugar (5), tallow (4), wheat (4), whiskey (5), wool (2)
1855–1909	*East North Central*: Cincinnati (9), Chicago (1), Indiana (15), Wisconsin (14) *Middle Atlantic*: Albany* (5), Baltimore* (5), Binghamton* (7), Buffalo* (8), Elkton* (3), Hagerstown* (4), Jamestown* (5), Maryland (10), Ogdensburg* (7), Rochester* (10), Utica* (7) *New England*: Maine (9) *Pacific:* San Francisco (1) *South Atlantic*: Arlington* (2), Goochland* (1), Norfolk* (1), Roanoke* (1), Virginia (5) *West North Central*: Iowa (10)	Apples (2), bacon (2), barley (4), beans (4), butter (15), chickens (3), clover seed (3), corn (17), eggs (15), hay (7), hogs (4), lard (4), oats (16), pork (4), potatoes (11), rye (6), timothy seed (5), wheat (16), wool (2)
1910–1949	*East North Central*: Illinois (10), Indiana (10), Michigan (9), Ohio (9), Wisconsin (9) *East South Central*: Alabama (9), Kentucky (16), Mississippi (9), Tennessee (9) *Middle Atlantic:* Delaware (9), Maryland (9), New Jersey (9), New York (9), Pennsylvania (17), West Virginia (9) *Mountain*: Arizona (8), Colorado (9), Idaho (9), Montana (17), Nevada (9), New Mexico (9), Utah (9), Wyoming (9) *New England*: Connecticut (9), Maine (9), Massachusetts (9), New Hampshire (8), Rhode Island (9), Vermont (9) *Pacific*: California (17), Oregon (15), Washington (17) *South Atlantic*: Florida (9), Georgia (17), North Carolina (9), South Carolina (20), Virginia (9) *West North Central*: Iowa (9), Kansas (9), Minnesota (17), Missouri (9), Nebraska (9), North Dakota (9), South Dakota (8) *West South Central*: Arkansas (9), Louisiana (17), Oklahoma (19), Texas (9)	Apples (4), barley (8), butter (5), butterfat (4), calves (48), cattle (47), chickens (46), corn (48), cotton (5), cottonseed (5), eggs (48), hay (4), hogs (48), lambs (48), milk (11), milk cows (6), oats (10), potatoes (29), rye (8), sheep (47), sweet potatoes (22), wheat (10), wool (10)

Notes: Locations are aggregated by italicized region. The numbers in parentheses indicate the number of series that belong to each location or good. Not all goods are observed in all locations. An asterisk indicates that prices were collected at a "district" level of roughly 5–10 counties with the listed city or county being the major source of data within that district. Source: see Appendix.

results into the nine Census regions depicted in Fig. 2 and the 42 goods listed in Table 1. In addition, I account for the fact that some goods were crucial to the U.S. economy (for example, cotton) and others were less pivotal (for example, timothy seed) by weighting goods by their trade share.[7]

Subsets of this data have been used in previous studies of market integration, but this paper vastly expands upon their scopes and provides a unified methodology. USDA surveys from 1910 onward have been used to study market integration by Federico and Sharp (2013) and Solakoglu and Goodwin (2005); however, they use annual data while I use monthly. This allows me to study improvements in efficiency and intertemporal smoothing over time horizons that were relevant for trade. Historical extensions of USDA surveys at a monthly frequency have been used for similar purposes by (Jacks, 2005, 2006), but he focuses only on wheat while I analyze a broad basket of goods. This brings additional robustness to the results. Subsets of the International Scientific Committee on Price History data have previously been used to study market integration, but they are at the annual frequency (Grubb, 2010; Slaughter, 2001), or focus on a narrow subset of goods (Federico, 2007, 2011; Jacks, 2005, 2006). This paper expands on these studies by combining monthly data for a large variety of goods over a long period. This allows me to robustly study all three forms of market integration — convergence, efficiency, and intertemporal smoothing over the broad scope of U.S. history.

3. Empirical strategy

In commodity markets, arbitragers reconcile mismatches between supply and demand by trading goods across space or storing them over time. Previous research has centered almost exclusively on spatial arbitrage using measures of convergence and efficiency. In contrast, comparatively few studies have examined the ability of agents to store commodities over time, and these have focused on a narrow set of decades and goods (Craig and Holt, 2017; Goodwin et al., 2002). I build upon previous work by measuring both spatial and intertemporal arbitrage over two centuries using a structural time series decomposition.

[7] See the Appendix for more details on weights.

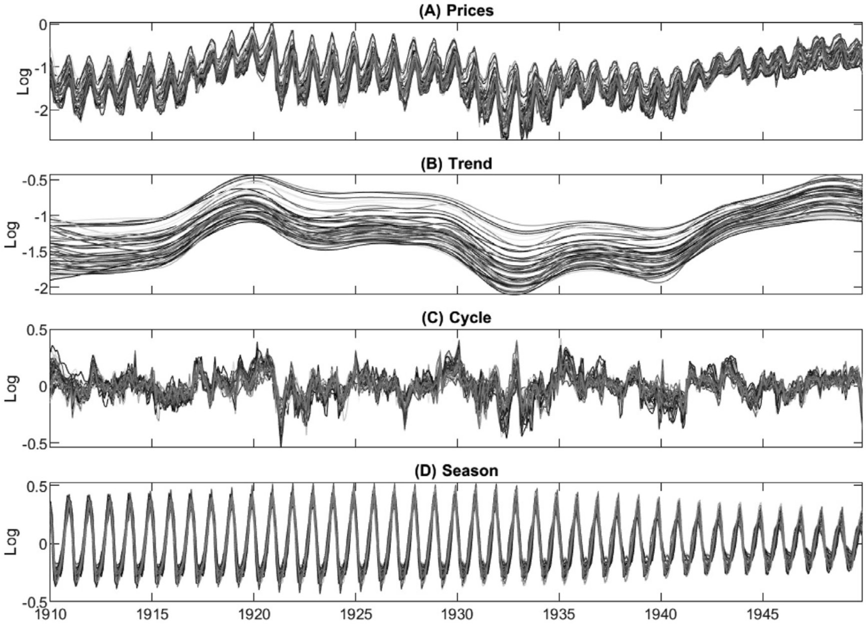

Fig. 3. Structural Time Series Decomposition for Egg Prices 1910–1949. Notes: Each series corresponds to egg prices for one of the 48 contiguous states. Panel A represents raw (log) prices, panel B represents the trend component, panel C depicts the cyclical component, and panel D the seasonal component of prices from the structural time series decomposition, $p_{ijt} = p^T_{ijt} + p^C_{ijt} + p^S_{ijt} + e_{ijt}$. Source: See Appendix.

The decomposition uses state space methods to break prices into three components: a trend, to measure convergence; a cycle, to measure efficiency; and a seasonal, to measure intertemporal smoothing, as

$$p_{ijt} = p^T_{ijt} + p^C_{ijt} + p^S_{ijt} + e_{ijt} \tag{1}$$

where p is the log price of good i in location j at time t. The trend is extracted using a smooth local linear trend, the stochastic cycle is modeled as AR(1), and the seasonal is composed of monthly dummies each subject to a quasi-random walk as in Harrison and Stevens (1976). A major benefit to this methodology is that it is more robust to the panel's missing observations and changing seasonal amplitudes than most other popular decomposition techniques, such as X-13 ARIMA and Tramo-Seats. Fig. 3 provides an example of the three structural components for egg prices: the trend components exhibit convergence as the dispersion between them narrows, the cyclical components display improved efficiency as series begin to co-move more closely with the national commodity cycle, and the seasonal components demonstrate intertemporal smoothing as the magnitude of seasonal fluctuations attenuates. Motivated by this apparent integration, I measure the levels and rates of change across each of the three components for the entire panel as described below.

To measure the degree of convergence among trend components, I calculate the magnitude of their log deviation from the national average for each good, $Y^T_{ijy} = |p^T_{ijy} - \bar{p}^T_{iy}|$, where y indexes the year and T indexes the trend component.[8] I aggregate this measure by region using region-year fixed effects, β^T_{ry}, from the regression,

$$Y^T_{ijy} = \beta^T_{ry} + u^T_{ijy} \tag{2}$$

and plot the resulting coefficients. Assuming each bilateral trading pair faces identical iceberg transportation costs across all goods, this measure allows us to compare the level of integration across markets in the sample. However, it should be noted that this assumption is a vast oversimplification, even today, despite it being commonly assumed in the international trade literature. Therefore, comparing results across regions should be viewed as only an approximation. To determine if different regions experienced statistically significant declines in dispersion over time, I estimate the stochastic rate of change as,

$$\Delta Y^T_{ijy} = \alpha^T_r + e^T_{ijy} \tag{3}$$

where α^T_r are region-specific fixed effects. To ensure the results are not driven by unobserved changes in the quality of goods, I check the residuals for any remaining differences in the rates of change by good,

$$\hat{u}^T_{ijt} = \theta^T_i + \epsilon^T_{ijt} \tag{4}$$

[8] Annual aggregation is performed to limit the serial correlation present in the trend component. The aggregation is performed using a simple average.

where θ_i^T are good-specific fixed effects. As is demonstrated in Section IV, the estimation of (4) suggests that the results are not driven by unobserved changes in quality and that the assumption of shared iceberg transportation costs is reasonable. As a result, I do not remove any goods from the panel for the trend analysis.

To estimate the degree of efficiency, I measure the extent of co-movement among cyclical components using a Bayesian dynamic factor model for each good (Kim and Nelson, 1999),

$$p_{ijt}^C = \lambda_j F_{it} + \varepsilon_{ijt}$$

where each good-specific factor, F_{it}, is extracted from the data using state-space methods and can be interpreted as a nation-wide commodity cycle for each good.[9] If markets are perfectly efficient, arbitragers would instantaneously exploit an idiosyncratic shock in a given location, ε_{ijt}, thereby restoring prices back to the national commodity cycle, F_{it}. In such a case, short-run prices would exhibit perfect co-movement and all the variance in p_{ijt}^C would be driven by F_{it}. However, if arbitragers had difficulty exploiting idiosyncratic shocks (for example, through slow transportation or costly trade), prices would no longer return to their equilibrium as quickly, thereby eroding the share of variance explained by the shared commodity cycles in favor of the idiosyncratic shocks, ε_{ijt}.[10] I calculate the share of variance attributable to each component as,

$$1 = \frac{Var\left(\lambda_j F_{it}\right)}{Var\left(p_{ijt}^C\right)} + \frac{Var(\varepsilon)}{Var\left(p_{ijt}^C\right)} \equiv Y_{ijy}^C + \omega_{ijy}$$

within 17-year rolling windows, W_y, where $t \in W_y$.[11] Following previous literature, I use the share of variance attributable to the good-specific factors, Y_{ijy}^C, as a measure of the level of efficiency (Andersson and Ljungberg, 2015; Chilosi et al., 2013; Federico et al., 2021; Uebele, 2011). As these measures are heavily influenced by region-specific trade costs, I aggregate them by region as

$$Y_{ijy}^C = \beta_{ry}^C + u_{ijy}^C \tag{5}$$

where C indexes the cyclical component. I then estimate their stochastic rate of change by region as,

$$\Delta Y_{ijy}^C = \alpha_r^C + u_{ijy}^C \tag{6}$$

To ensure the results are not driven by unobserved changes in the quality of goods, I check the residuals for any remaining differences in the rates of change by good, as

$$\hat{u}_{ijy}^C = \theta_i^C + \epsilon_{ijy}^C \tag{7}$$

In Section V, I find that livestock have statistically faster rates of convergence during the final period of the sample (1910–1949). This may be driven by unobserved changes in quality or by livestock-specific changes in transportation costs. However, I cannot rule out unobserved quality changes because livestock grading began standardization around 1916 and became federally determined by the USDA in 1926 (Perry et al., 2005). As a result, I drop livestock (calves, cattle, chickens, hogs, lambs, and sheep) from the final period of analysis for the cyclical component.

I estimate the intra-year amplitude of the seasonal components as $Y_{ijy}^S = \max_{t\in y}(p_{ijt}^S) - \min_{t\in y}(p_{ijt}^S)$. To aggregate results by region, I cannot simply run a regression with regional fixed effects because there is an imbalance in the faction of perishable goods across regions. To address this, I remove any good-specific seasonality by first running the regression

$$Y_{ijy}^S = \phi_{iy}^S + \epsilon_{ijy}^S \tag{8}$$

where ϕ_{iy}^S are good-year specific fixed effects. After de-meaning by good-year, I calculate the residualized seasonal deviations by region as

$$\hat{\varepsilon}_{ijy}^S = \beta_j^S + e_{ijy}^S \tag{9}$$

where β_j^S are region-specific fixed effects. These amplitudes are remarkably stable for most goods, so I forgo any formal analysis of their trends over time.

What might drive changes in these measures of convergence, efficiency, and intertemporal smoothing? Convergence can be attributed to a fall in transportation costs or by government policies, such as price setting or trade barriers (Jacks, 2006). Improvements in efficiency can be linked to faster transportation or communication speeds (Coleman, 2009; Steinwender, 2018), but it can also be tied to a fall in transportation costs if it causes markets to trade with each other more frequently.[12] Lastly, changes in intertemporal smoothing can be driven by storage costs, interest rates, or the length of a production season, but it can also be tied to transportation costs if it impacts the magnitude of seasonal supply shocks (Williams and Wright, 1991).

Given these drivers of integration, we may expect to see the patterns in Fig. 3 echoed across other periods. The first period (1750–1774) saw heavy British investments into colonial ports. To the degree that this allowed either larger or more ships to dock, we should

[9] I adapt code from Jackson et al. (2016).

[10] The common and idiosyncratic shocks are allowed to have persistence, specified as AR(1) processes.

[11] I employ the orthogonalization method of Kose et al. (2003) so the covariance between F_{it} and e_{ijt} is zero by construction.

[12] This has been demonstrated by a large literature on threshold autoregression models (TARs), which has been applied to historical markets by Jacks (2005), among others.

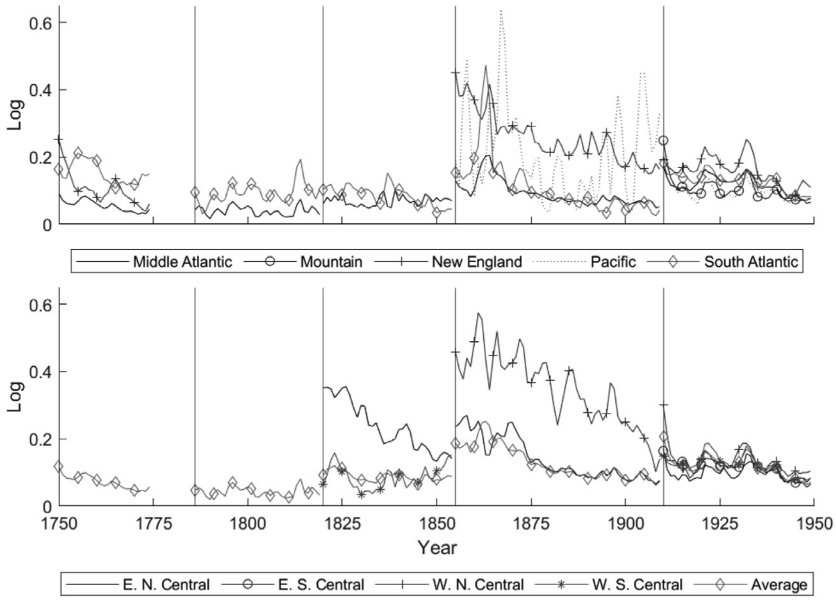

Fig. 4. Magnitude of Trend Deviations from the National Average. Notes: The series come from plotting the coefficients from the regression $Y^T_{ijy} = \beta^T_{ry} + u^T_{ijy}$ where Y^T_{ijy} is the magnitude of log deviations of the trend component from the national average for good i in location j in year y, and β^T_{ry} are region-year fixed effects. Observations are weighted by national trade share. Unweighted results are qualitatively similar and are available in the Online Appendix. Vertical lines demarcate changes between different baskets of goods and locations. Note that it is not appropriate to compare magnitudes or rates across baskets. Source: See Appendix.

expect to see improvements in convergence and efficiency, respectively. The second period (1786–1819) saw the forging of a national currency, the removal of trade barriers between states, freedom from mercantilist policies, and a reduction in piracy. Research has found these did not result in large improvements in efficiency (Grubb, 2010), but I am unaware of any studies that have estimated their impact on convergence. The third period (1819–1854) was defined by river, canal, steamboat, and telegraphic advancements which coincided with massive convergence (Jacks, 2005, 2006,; Slaughter, 2001) paired with relative stagnation in efficiency (Jacks, 2005, 2006). The fourth period (1855–1909) experienced the rise of railroads, oceanic steamships, improved commodity grading, instantaneous communication speeds, grain silos, and refrigerated railcars which resulted in massive convergence (Federico and Sharp, 2013; Jacks, 2005, 2006; Jackson et al., 2016,), improved efficiency (Craig and Holt, 2017; Goodwin et al., 2002; Solakoglu and Goodwin, 2005), and improved intertemporal smoothing among animal products (Craig and Holt, 2017; Goodwin et al., 2002). The fifth period (1910–1949) saw the rise of automobiles, electrification, cold storage, government intervention, and advanced animal husbandry practices that coincided with moderate convergence (Federico and Sharp, 2013); however, I am not aware of any research that has estimated efficiency or intertemporal smoothing during this period.

4. Trend convergence

Of the three metrics of arbitrage, trend convergence has the largest impact on welfare. Regional specialization in agriculture meant that price convergence was intimately linked to improvements in the terms of trade for both local farmers and distant consumers (Williamson and O'Rourke, 1999). One benefit of this dataset's diverse basket of goods is that it captures these improving terms of trade across many regions of specialization.

I plot the magnitudes of log deviations of the trend component from the national average from (2) in Fig. 4 and present their corresponding stochastic rates of convergence from (3) in Table 2. Note that it is inappropriate to compare magnitudes and rates across periods since the basket of goods and locations changes over time. However, it is still appropriate to compare magnitudes and rates of convergence within periods under the assumption that all goods are traded and face the same bilateral iceberg transportation costs between markets. Under these assumptions, Fig. 4 shows that the magnitude and rates vary widely across regions within any given period.

The first period (1750–1774) shows that the two most geographically distant regions, New England and the South Atlantic, begin with the largest deviations from average at roughly 15 percent each, while the most geographically centered region, the Middle Atlantic, exhibits the smallest deviations at roughly 5 percent. Throughout the period, New England has a rate of convergence of roughly 0.80 percentage points per year while the remaining regions do not display any statistically significant improvement. This indicates a substantially improved ability to arbitrage along the Atlantic coast. As this is the first paper to find convergence during this period, it is worth dwelling upon two possible confounding factors. First, the results may be susceptible to idiosyncratic changes in quality because they are only based on two New England goods: wheat and molasses. This seems to be an unlikely confounder

Table 2
Annual rates of trend convergence, by region (in percent).

	1750–1774	1786–1819	1820–1854	1855–1909	1910–1949
East North Central	–	–	−0.62**	−0.30***	−0.23**
East South Central	–	–	–	–	−0.25***
Middle Atlantic	−0.20	−0.04	0.02	−0.14**	−0.25***
Mountain	–	–	–	–	−0.47***
New England	−0.80**	–	–	−0.53***	−0.21**
Pacific	–	–	–	0.25	−0.40***
South Atlantic	−0.06	0.02	−0.17	−0.11	−0.26***
West North Central	–	–	–	−0.59*	−0.50***
West South Central	–	–	0.26	–	−0.20**
Average	−0.25**	−0.04	−0.01	−0.19***	−0.32***

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. I report the coefficients on the regional fixed effects from the regression $\Delta Y^T_{ijy} = \alpha^T_r + e^T_{ijy}$, where Y^T_{ijy} is the magnitude of log deviations of the trend component from the national average for good i in location j in year y and α^T_r are regional fixed effects. Observations are weighted by trade share and results are multiplied by 100 to be interpreted as annual percent changes. Unweighted results are qualitatively similar and are provided in the Online Appendix. White-Huber-Eicker robust standard errors are used. Note that it is not appropriate to compare rates across periods due to the change in baskets. The data sources are described in detail in the Appendix.

because similar rates of convergence are observed across many other goods that were excluded from the basket due to excessive missing observations, including flour, pork, sugar, and cotton. Second, the results may simply reflect a coincidence of supply and demand fluctuations across autarkic markets. This is unlikely because Boston (the only market observed in New England during this period) depended upon produce imported from the other colonies both for subsistence and for trade (Friedmann, 1973; Morison, 1922; Rothenberg, 1979).

New England is not observed in the second period (1786–1819), but the Middle and South Atlantic regions continued to exhibit stagnation at roughly four and nine percent deviations from average, respectively. This study is the first to show a lack of convergence immediately following the adoption of the Constitution (1786–1800), which suggests that its abolition of trade barriers across states did not have a substantial impact. This lack of convergence may be driven by low pre-existing tariffs between the states or by the fact that other trade barriers, such as inspection laws and fees, continued even after the adoption of the Constitution (Grubb, 2010). The findings during the second-half of this period (1800–1819) contrast with Jacks (2005), who finds substantial nationwide divergence. This discrepancy is likely driven by differing geographic and temporal aggregations during the War of 1812.[13] Fig. 4 shows the blockade resulted in a brief doubling of price deviations in the South Atlantic, while the aggregated results in Jacks (2005) represent the blockade as a secular doubling of the nationwide average relative trade costs from 1800–1820.[14] Thus, this period may be better viewed as one of stagnation punctuated by war rather than one of divergence.

In the third period (1820–1854), price deviations are low across all oceanic regions at roughly ten percent from average, and none of them exhibit statistically significant rates of convergence. In contrast, the landlocked East North Central region (representing only Cincinnati in this period) begins with a price deviation of roughly 35 percent, but its fast rate of convergence (0.62 percentage points per year) reduces this disparity by more than half throughout the period. That most of this convergence was accomplished by 1840, before any major rail construction was completed in the region, underscores the role of river and canal improvements in bettering the terms of trade of settlers on the frontier (Donaldson and Hornbeck, 2016; Fogel, 1964; Haites et al., 1975). These findings match those in Jacks (2005) and Slaughter (2001), but this paper demonstrates that almost all convergence is being driven by the landlocked frontier.

In the fourth period (1855–1909), the Middle and South Atlantic regions start with the smallest price deviations from average at roughly 13 percent and exhibit the slowest convergence at roughly 0.14 percentage points per year, the East North Central has approximately double this magnitude and rate, and the West North Central and New England (representing only Iowa and Maine in this period, respectively) exhibit about four times these magnitudes and rates. Dispersion levels converge at a largely constant rate throughout the period, which suggests the steadily improving TFP of railroads played a large role in improving arbitrage for the inland towns in the dataset (Fishlow, 1964, 1965; Jenks, 1944; Swisher, 2014). These findings support the constant convergence found by Federico and Sharp (2013) as opposed to the post-1870 stagnation found in Jacks (2005), and they further demonstrate this convergence was shared across most regions.[15]

The two exceptions to this shared convergence were the Civil War and the vagaries of the Pacific region. The Civil War substantially increased deviations in the South Atlantic and had notable impacts in almost every other region; however, these deviations quickly

[13] The English blockaded the southern states in late 1812, specifically targeted Charleston in early 1813, and the entire Atlantic coastline in 1814. As a result, trade fell from $114 million in 1811 down to $20 million by 1814 (Benn, 2003).

[14] A visual inspection of wheat prices during this period confirms that they only substantially diverge during the War of 1812.

[15] This difference is likely driven by the fact that Jacks (2005) only observes wheat, which I estimate as converging in only two of five regions during this period.

returned to their pre-war levels.[16] Meanwhile, the Pacific region, representing only San Francisco wheat in this period, largely serviced foreign markets in the Pacific until a series of poor harvests and wars in Europe made Britain a stable source of demand from about 1870 to 1890. California rose to become one of the largest wheat exporters to Britain until increased foreign competition and better uses for Californian land drove wheat acreage to decline by about 83 percent between 1899 and 1909 (H. Davis, 1894; Paul, 1958). This rise and fall of the Californian wheat market matches the patterns of convergence and divergence observed in Fig. 4.

In the final period (1910–1949), most regions exhibit similar deviations from average, starting at about 20 percent and ending with about eight. Convergence occurred across all regions at an average rate of 0.32 percentage points per year, with "frontiers" in the West North Central, Mountain, and Pacific regions exhibiting the fastest rates. Overall, the results correspond closely to those in Federico and Sharp (2013); in particular, both show temporary divergences caused by the nominal distortions in government-set rail rates during the post-WWI inflation and Depression deflation.

I next check to see if the results were influenced by idiosyncratic changes in the quality of goods by running the residualized regression (4).[17] The results demonstrate that butter and eggs converge at a faster rate than other goods; however, this is because advances in cold storage allowed them to be traded long distances for the first time (Craig and Holt, 2017; Goodwin et al., 2002). Of the remaining period-goods, fewer exhibited statistically significant convergence than the number of type I errors that would be expected at conventional significance levels. This suggests that unobserved changes in good quality do not overly influence the results.

Secular changes in quality may have also occurred – for example, the rise of forward and futures markets necessitated a more uniform grading of qualities across most goods in the late 1800s. This secular change might result in differing rates of convergence across goods if the degree to which qualities changed varied across goods; however, this was again not apparent in the residualized rates of convergence. Even if the changes in quality were similar across goods, a secular change should result in price convergence across all regions. This can be ruled out before the Civil War when many regions remained stagnant, but it may still be possible in the postbellum period. Therefore, we cannot entirely rule out that some of the postbellum convergence was driven by secular changes in quality.

5. Cyclical efficiency

Convergence does not guarantee that spatial arbitrage improved; for example, two autarkic markets can have similarly priced goods by coincidence of supply and demand. However, we can use efficiency as a secondary metric because markets that spuriously exhibit convergence will still fail to respond to the same shocks. This metric of efficiency can improve if a decline in transportation costs leads to a greater frequency of trade or if an increase in information and transportation speeds allows arbitragers to exploit shocks with greater rapidity. This smoothing of shocks reduces the deadweight loss incurred by unexploited differences between supply and demand across markets (Steinwender, 2018).

I begin by using (5) to calculate the level of co-movement by region and plotting the results in Fig. 5. Note that it is not appropriate to compare magnitudes or rates across periods because goods and locations change across baskets. I also calculate each region's stochastic rate of change using (6) and present the results in Table 3.

As in Jacks (2005) and Grubb (2010), no improvements in efficiency are apparent before the 1820s. This provides additional evidence that dollarization had no immediate impact on efficiency (Grubb, 2010). This could be because it took many decades for the dollar to become the de facto medium of exchange (or even unit of account) after official dollarization. However, it should be noted that the small sample size of goods, locations, and months during these periods make it especially difficult to detect changes in efficiency.

In the third period (1820–1854), the coastal regions all had similar levels of efficiency and show substantial rates of improvement. Their lack of trend convergence in the previous section suggests that the efficiency gains are attributable to something other than falling trade costs; for example, they could result from the faster transportation and communication speeds afforded by the broad introduction of the telegraph and steam engine. In contrast, the landlocked East North Central region started the period with notably lower levels of efficiency, but it improved more rapidly than other regions with the aid of falling transportation costs. Overall, the average rate of change was a 0.75 percentage point increase in co-movement per year. These findings revise our understanding of this period from one of puzzling discordance between swift convergence and stagnant efficiency to one in which convergence was limited to the frontier while technology broadly improved efficiency (Jacks, 2005).[18]

The fourth period (1855–1909) was largely one of stagnation. The frontier regions of the East North Central and West North Central exhibited the highest efficiency, with the Middle Atlantic and New England regions close behind. This inversion of rankings is likely due to the increasing focus of the basket toward agricultural goods produced on the frontier. The South Atlantic region, in contrast, exhibited little efficiency during the Civil War since its arbitragers could not exploit shocks across the warring sides.[19] Lastly, the Pacific region exhibited virtually no co-movement with the other markets despite its convergence toward the Atlantic

[16] The Confederate data contains substantial measurement error. Some errors suggest trend dispersion was biased upwards; for example, much of the data was obtained from Richmond, which was often more isolated from trade than other areas (Peterson, 1929). In contrast, some errors suggest it is biased downwards, such as a plethora of missing observations, which were likely induced by insufficient supply.

[17] Results are available in the Online Appendix.

[18] The difference between studies is largely driven by the sole focus on wheat in Jacks (2005) which was too bulky to be traded in great quantities during this period. Indeed, I fail to find statistically significant changes in wheat during this period.

[19] The 17-year rolling windows make the effects of the Civil War appear over an artificially long duration.

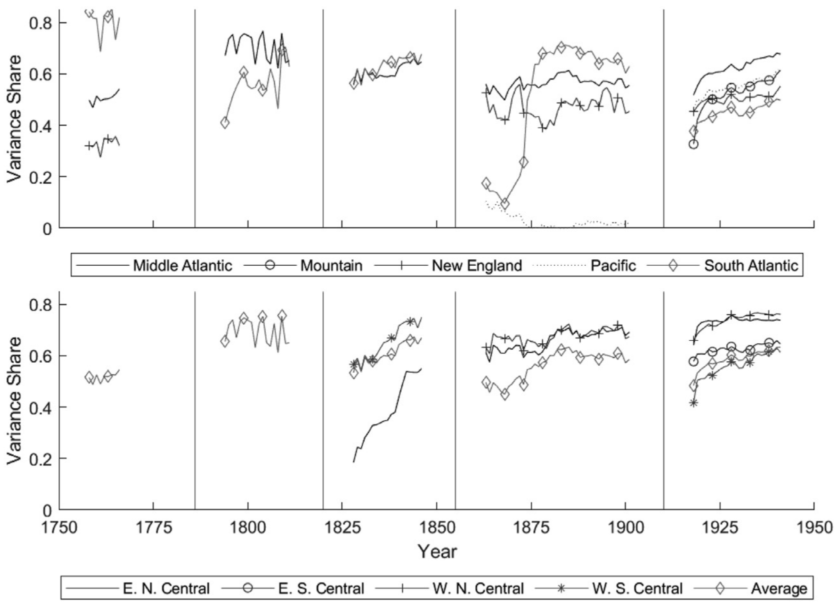

Fig. 5. Average Factor Variance Share, by Region. Notes: The series come from plotting the coefficients from the regression $Y^C_{ijy} = \beta^C_{ry} + u^C_{ijy}$, where Y^C_{ijy} is the variance share of a good-specific dynamic factor for good i in location j in year y, and β^C_{ry} are region-year fixed effects. Observations are weighted by national trade share. Unweighted results are qualitatively similar and are available in the Online Appendix. Vertical lines demarcate changes between different baskets of goods and locations. Note that it is not appropriate to compare magnitudes or rates across baskets. Source: See Appendix.

Table 3
Annual rates of change in efficiency, by region (in percent).

	1750–1774	1786–1819	1820–1854	1855–1909	1910–1949
East North Central	–	–	2.03***	0.21	0.26
East South Central	–	–	–	–	−0.43
Middle Atlantic	0.52	−0.11	0.50**	−0.02	0.05
Mountain	–	–	–	–	0.81***
New England	0.00	–	–	−0.19	0.04
Pacific	–	–	–	−0.22	−0.19
South Atlantic	−0.28	1.28	0.63*	1.04**	0.13
West North Central	–	–	–	0.11	0.23
West South Central	–	–	1.01	–	0.12
Average	0.38	−0.03	0.75***	0.21**	0.13

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. I report the coefficients on the regional fixed effects from the regression $\Delta Y^C_{ijy} = \alpha^C_r + u^C_{ijy}$ where Y^C_{ijy} is share of cyclical variance explained by the dynamic for good i in location j in year y and α^C_r are regional fixed effects. Observations are weighted by trade share and results are multiplied by 100 to be interpreted as annual percent changes. Unweighted results are qualitatively similar and are provided in the Online Appendix. White-Huber-Eicker robust standard errors are used. Note that it is not appropriate to compare rates across periods due to the change in baskets. The results in the final period (1910–1949) do not include livestock due to changes in quality grading. The data sources are described in detail in the Appendix.

market from 1870–1890. This lack of co-movement can be explained by wheat's five-month voyage around Cape Horn eroding any possibility of exploiting short-run shocks (Paul, 1958).

The fifth period (1910–1949) exhibited broad improvements across all regions; however, this is likely due to unobserved changes in product quality. The results from the residualized regression, (7), find 13 of 23 goods during this period exhibited statistically significant residualized trends.[20] Of these, six were for livestock (calves, cattle, chickens, hogs, lambs, and sheep), while the reminder had no consistent categorization. The pattern among livestock may be due to a standardization in their grading of quality, which began around 1916 and became federally determined by the USDA in 1926 (Perry et al., 2005). As a result, I drop livestock from the

[20] The regression results are available in the Online Appendix. Before 1910, there were about as many statistically significant results as would be expected due to type I errors.

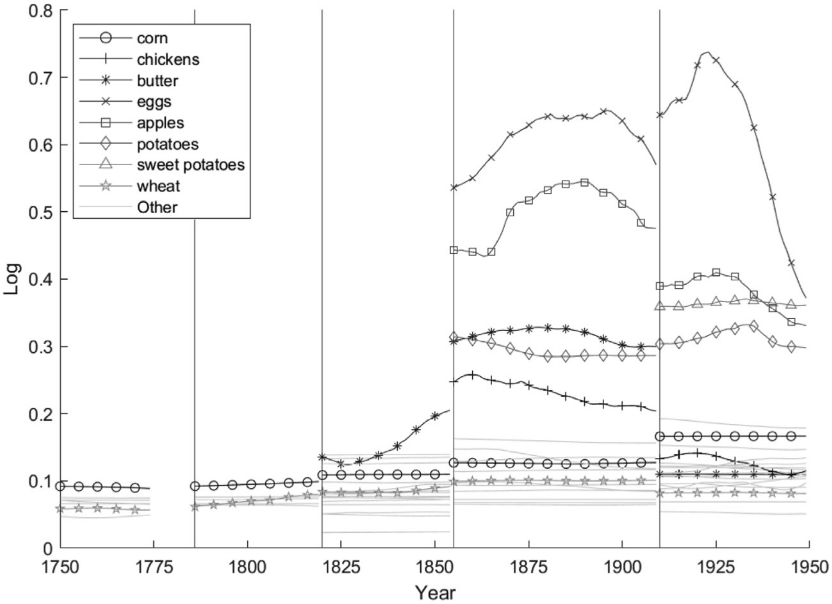

Fig. 6. Amplitudes of Seasonal Deviations from the Trend, by Good. Notes: The series come from plotting the coefficients from the regression $Y^S_{ijy} = \phi^S_{iy} + \epsilon^S_{ijy}$, where Y^S_{ijy} is the seasonal amplitude of prices for good i in location j in year y, and ϕ^S_{iy} are good-year fixed effects. Vertical lines demarcate changes between different baskets of goods and locations. Observations are unweighted. Note that it is not appropriate to compare magnitudes or rates across baskets. Source: See Appendix.

final period of analysis in Fig. 5 and Table 3. The results show that co-movement increased in most regions, but the sample was too small and noisy to obtain statistical significance in all but the Mountain region. There are two possible sources for these aggregate gains. First, the previous section demonstrated that this is a period of broad convergence, so it is possible that markets are simply trading with each other more frequently. Second, it may be that transportation and communication lags declined with the broad diffusion of the automobile and telephone, among many other technologies.

We must also worry if the estimated rates of efficiency are biased due to a smoothing of idiosyncratic shocks through temporal or spatial aggregation (Gonzalo, 1993). Temporal aggregation is unlikely to be a major issue because almost all prices were collected on the day nearest to the middle of the month as possible.[21] Spatial aggregation remains a potential issue because data was variously aggregated to the city, sub-state, and state levels. This aggregation is stable within each period, so it would only affect the level, not change, in efficiency. In addition, I do not find any consistent evidence that the state-level data exhibits lower price variance than the city-level data.

6. Seasonal smoothing

I now turn from spatial to intertemporal arbitrage, which is important to farmers who face gluts during the harvest season and consumers who deal with shortages thereafter. Through storage, farmers can be paid more for their seasonal produce and consumers can enjoy greater stability in prices. The extent of intertemporal smoothing depends on many factors, but chief among them are storage costs, interest rates, spoilage rates, and the seasonal patterns of supply (Williams and Wright, 1991). The importance of this intertemporal arbitrage has been generally overlooked in the literature, and those who have examined it have tended to look at a handful of goods over a few short decades (Craig and Holt, 2017; Goodwin et al., 2002).

To explore the importance of good-specific factors such as perishability, I begin by aggregating seasonal amplitudes by good as in (8) and plotting them in Fig. 6. Note that it is inappropriate to compare amplitudes or their rates of change across baskets. Despite this caveat, it is apparent that amplitudes varied widely across goods, with grains exhibiting around 7.5 percent seasonal swings from their trends and perishable animal and vegetable products showing upwards of 50 percent deviations at times. Most amplitudes were remarkably steady which suggests that aggregate storage costs remained constant despite the proliferation of warehouses and grain elevators. In contrast, amplitudes of highly perishable products, such as butter, apples, and eggs, rise and fall dramatically over time. Their amplitudes rose from 1830–1880 as falling transportation costs led to more seasonal production being shipped to regional entrepots (Berry, 1943), fell from 1880 to 1910 with the advent of cold storage (Craig and Holt, 2017; Goodwin et al., 2002), and fell again after 1930.

[21] The three exceptions to this were the pre-1910 data for Maryland, which averaged quotations from the 10th to 15th of each month; Indiana, which averaged weekly prices; and Chicago, which averaged daily prices. My own calculations show that the results do not substantially change when dropping these locations from the sample.

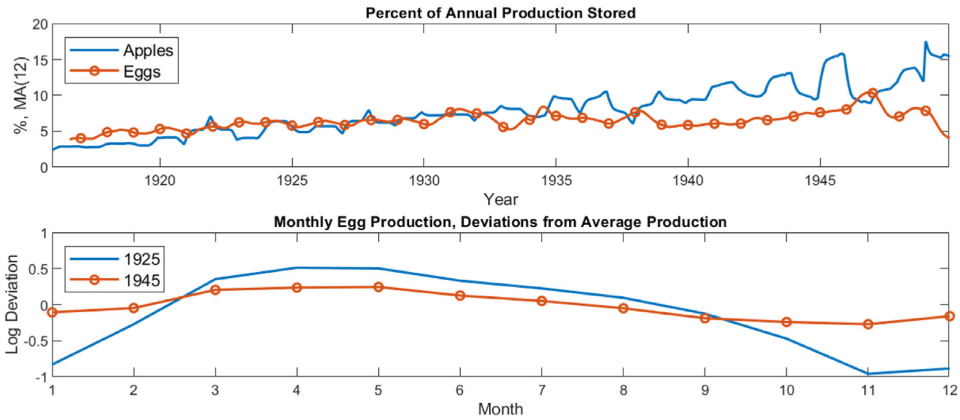

Fig. 7. Seasonal Storage and Production of Apples and Eggs. Notes: The top panel depicts the 12-month moving average of the fraction of annual production of eggs and apples that is stored. The bottom panel depicts log deviations from the average level of egg production. Monthly dried egg storage is not observed, so I assume it has the same seasonal patterns as frozen eggs. This does not greatly affect the results as dried egg production remains trivial until WWII. I also assume that eggs were of medium size with a liquid or frozen equivalent of 1.16 pounds per dozen and that one barrel of apples is equivalent to three bushels. The bottom panel depicts the seasonality of egg production in 1925 and 1945. Sources: Cold storage and apple production 1915–1929: (United States Department of Agriculture 1930). Cold storage and apple production 1930–1933: (United States Department of Agriculture 1933). Cold storage and apple production 1934–1949: annual editions of the Bureau of Economic Analysis' (BEA) Survey of Current Business. Annual egg production: (United States Department of Agriculture 1953). Annual dried egg production: Koudele and Heinsohn (1960). Monthly egg production estimates: Kimball et al. (1953) and (United Sates Department of Agriculture 1952).

Table 4
Residualized seasonal amplitudes, by region (in Percent).

	1750–1774	1786–1819	1820–1854	1855–1909	1910–1949
East North Central	–	–	1.74*	1.71**	1.50**
East South Central	–	–	–	–	1.40*
Middle Atlantic	−0.31	−0.32	−1.26**	−0.82	−0.76
Mountain	–	–	–	–	0.54
New England	0.49	–	–	−4.73***	−3.65***
Pacific	–	–	–	0.86	0.21
South Atlantic	0.8	1.59*	−1.18	−0.61	−0.50
West North Central	–	–	–	4.25***	1.28**
West South Central	–	–	4.60***	–	0.05

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Estimates come from first demeaning the results by good using the regression $Y^S_{ijy} = \phi^S_{iy} + \epsilon^S_{ijy}$ where Y^S_{ijy} is the seasonal amplitude of prices for good i in location j in year y, and ϕ^S_i are good-specific fixed effects. Once demeaned by good, I report the coefficients on the regional fixed effects from $\hat{\epsilon}^S_{ijy} = \beta^S_j + e^S_{ijy}$. The results are multiplied by 100 to be interpreted as percent deviations. Observations are unweighted. White-Huber-Eicker robust standard errors are used. The data sources are described in detail in the Appendix.

This newly discovered smoothing after 1930 is attributable to the rural electrification of the New Deal, as propagated through two different channels. The first channel, improved storage, is apparent in the top panel in Fig. 7 which shows a six-fold increase in apple storage. This coincided with a switch from cold storage in large, centralized warehouses to a decentralized system of specialized units near rural orchards (Anderson, 1972; Hukill and Smith, 1946). The second channel, smoothed seasonal production, is apparent in the bottom panel of Fig. 7 which plots a two-thirds decline in the seasonal amplitude of egg production between 1925 and 1945. This occurred as rural farmers began using artificial light to overcome the seasonal reproductive cycle of the hen (Freidberg, 2008). Thus, rural electrification allowed seasonal smoothing across many goods through different channels.

I next use (9) to aggregate residualized results by region and present the results in Table 4. Frontier regions, such as the East North Central and West North Central tended to have higher amplitudes while locations along the Atlantic tended to have lower ones. Much of this variation may be explained by large seasonal supply shocks on the frontier which were induced through the combination of high agricultural labor shares and high transportation costs. However, some regional differences may also be explained by differing interest rates presenting arbitragers with varying intertemporal opportunity costs. For example, Bodenhorn and Rockoff (1992) and Davis (1965) find higher interest rates in the frontier regions which Keller et al. (2020) find strongly correlate with the seasonal amplitudes of prices. The results cannot be driven entirely by interest rates, however, as region-varying amplitudes persisted into the 1900s when regional interest rates had largely converged. This underscores the difficulties of using seasonal amplitudes of prices alone to infer the relative magnitudes of historical interest rates and suggests that regional supply shocks and transportation costs need to be taken into account to obtain reliable estimates (Keller et al., 2020; McCloskey and Nash, 1984).

7. Conclusion

This paper decomposes a broad panel of commodity prices into trend, cycle, and seasonal components to explore 200 years of convergence, efficiency, and intertemporal smoothing, respectively. I find near consistent improvements in convergence, efficiency gains from 1820–1855 and from 1910 onward, and improvements in intertemporal smoothing after the late 1800s. I exploit the broadness of the panel to discover that almost all improvements in spatial arbitrage can be explained by regional (rather than good-specific) factors while intertemporal arbitrage is impacted by both regional and good-specific factors. These advances in arbitrage led to large improvements in the terms of trade and diminishments in deadweight loss.

The convergence results newly demonstrate that prices converged prior to the Revolution, did not converge after the adoption of the Constitution, and stagnated rather than diverged during the early 1800s. Further, most of the convergence occurred in frontier regions and only perishable products consistently exhibited convergence rates that differed from regional averages. The efficiency findings newly demonstrate aggregate gains after 1910 and revise the antebellum period from one of stagnation to one of improvement. The intertemporal smoothing results newly show that seasonality was surprisingly stable for most goods, but that rural electrification had a large impact among highly perishable goods such as apples and eggs. In addition, seasonal smoothing differed by region but could not be easily tied to regional interest rates without controlling for a host of confounding factors.

This paper also provides some methodological insights. First, it demonstrates a useful connection between the trend, cycle, and seasonal components and different arbitrage activities. Second, it demonstrates the value of leveraging a wide panel of goods to test if results are biased by idiosyncratic, unobserved quality changes. Third, it shows the usefulness of decomposing results by region even within intranational settings.

More broadly, this paper brings focus to historical U.S. commodity market integration amid a literature dominated by European and trans-Atlantic integration. This is underscored by the fact that much of our previous understanding of intranational U.S. integration came from Jacks (2005, 2006) who had no explicit focus on U.S. markets. The U.S. results largely match the post-Napoleonic European convergence; however, greater stress is placed on the lowering of trade barriers in the European context while it is placed on the integration of the frontier in the U.S. Eventually, European markets began to diverge after the 1880s due to protectionist backlashes while the integration of the frontier continued unabated within the U.S. (Federico, 2012). This can help explain some of the long-term differences in the growth rates across the two geographies.

Data availability

Code and replication files can be found at 10.3886/E182670V2

Acknowledgements

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eeh.2023.101514.

Appendix

Weights

Weighting by consumption shares would pose many issues. First, historical consumption data is sufficiently sparse that weights cannot be found for all goods. Second, the basket would have to be split between goods that are for consumption (e.g. whiskey) and those that are for production (e.g. copper, cotton, or milk cows). Third, consumption was highly regional; for example, the North Atlantic consumed large amounts of fish and the North East Central region consumed a lot of pork. Fourth, consumption patterns changed substantially over time (Hoover, 1960).

Instead, I weight goods by their value share of trade.[22] Shares in the fifth period (1910–1949) are based on domestic rail traffic, so they may understate the importance of goods that made disproportionate use of water transportation, such as grains. Lacking information on domestic trade shares in prior periods, I weight by U.S. foreign trade shares which are representative of domestic trade to the extent that most farm goods were grown internally and eventually intended for export. However, these shares may underrepresent perishable goods that were unsuitable for lengthy foreign voyages, such as butter and eggs. Another shortfall is that

[22] Detailed weights are available in the Online Appendix.

this does not account for the fact that some goods, such as wheat, are often processed into lower weight-to-value goods, such as flour, before shipping, making them more important than is indicated by their trade share alone.

Data Sources

The pre-1860 data were largely collected from price histories compiled by Cole (1938) which includes prices for Boston (Crandall, 1934), New York City (Warren and Pearson, 1932; Stoker, 1932), Philadelphia (Bezanson et al., 1935; Bezanson and Gray, 1937), New Orleans (Taylor, 1931), Charleston (Taylor, 1932a,b), and Cincinnati (Berry, 1935). The one other source of pre-1860 data comes from a book on Virginia farm prices by Peterson (1929).

I calculate exchange rates between colonial currencies using McCusker (1978) from 1750–1775 and Bezanson (1951) from 1780–1790. Bezanson (1951) provides monthly exchange rates between Pennsylvania paper currency and British pounds from November 1780 to December 1790. These exchange rates are extrapolated to the other colonies by using the mint parity between colonial currencies.[23] The assumption that colonial currencies could be exchanged at the rate of mint parity is at least somewhat supported anecdotally. According to Bezanson (1951), any discount from par on state notes was so volatile that merchants often disregarded calculations of the discount in all but large transactions.

A large portion of the data from 1855–1910 comes from a spate of studies encouraged by O.C. Stine, head of the USDA Division of Statistical and Historical Research from the 1920s to 1940s (Pearson and Brandow, 1939). The data in these studies are available at the district (or even city) level in Maryland (Hale, 1930), New York (Ronk, 1934), and Viginia (Peterson, 1929). Agricultural experiment stations also published state-level price histories in Iowa (Strand, 1942), Indiana (Houk, 1942), Maine (Merchant, 1933), and Wisconsin (Mortenson et al., 1933). Many of the Iowa series ended earlier than 1909, so I collected monthly prices from contemporaneous issues of *The Cedar Rapids Gazette*. In addition, the Chicago data were obtained through the National Bureau of Economic Research (NBER) Macrohistory Database (NBER, 2021), the San Francisco wheat data was made available by Jacks (2005), and the post-1860 Cincinnati prices were from White (1935).

The data after 1910 come from USDA reports that I mostly identified through a useful bibliography of agricultural history by Hallberg (2007). Some of these reports were nation-wide by commodity, including potatoes (U.S. Department of Agriculture, 1954), sweet potatoes (U.S. Department of Agriculture, 1955), hogs (U.S. Department of Agriculture, 1960b), cattle (U.S. Department of Agriculture, 1960a), calves (U.S. Department of Agriculture, 1961), sheep and lambs (U.S. Department of Agriculture, 1963), and chicken and eggs (U.S. Department of Agriculture, 1965). In contrast, some of these reports covered many goods by location, such as for California (California Crop and Livestock Reporting Service, 1960), Georgia (Harrington and Elrod, 1956), Kentucky (Card and Koepper, 1953), Louisiana (Montgomery, 1960), Minnesota (Marquardt, 1959), Montana (Taylor et al., 1954), Oklahoma (Collins and Hall, 1958), Oregon (Leatherman and Moore, 1954), Pennsylvania (Pennsylvania Crop Reporting Service, 1959), South Carolina (South Carolina Agricultural Experiment Station, 1956), and Washington (Washington State Department of Agriculture, 1960). All the sources used to construct the dataset are listed below.

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[23] These mint parities can be found in the preface to Cole (1938)'s statistical appendix.

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