Process Innovation and Product Diffusion Through Trade: A Study of US Automobile Exports from 1913 to 1940*

Dong Cheng†, Mario J. Crucini‡, Hyunseung Oh§, and Hakan Yilmazkuday¶

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Abstract

The first half of the twentieth century provides an unparalleled opportunity to explore the impact of technological innovation in the worldwide diffusion of a new and highly traded good, automobile, because the United States was dominant in both production and trade of passenger vehicles. We scrape historical data on quantity and value of passenger vehicles exported from the United States to approximately 170 destinations, annually from 1913 to 1940. We model the rise of the automobile from global obscurity to a fixed point which depends on per capita national wealth, and with the transition path depending on the evolution of the relative price of the automobile and its pass-through to destination markets.

Keywords: Diffusion, Motor vehicle, Durables, Exports

*PRELIMINARY AND INCOMPLETE.

†Department of Economics, Vanderbilt University. E-mail: dong.cheng@vanderbilt.edu.
‡Department of Economics, Vanderbilt University. E-mail: mario.crucini@vanderbilt.edu.
§Department of Economics, Vanderbilt University. E-mail: hyunseung.oh@vanderbilt.edu.
¶Department of Economics, Florida International University. E-mail: hyilmazk@fiu.edu.

1 Introduction

The first half of the twentieth century was the dawn of a new age in personal transportation services with the introduction of the passenger automobile.[1] The international diffusion of automobiles, however, was far from symmetric. The US produced 4,359,000 vehicles in 1928, compared to a total of 896,782 vehicles in the 11 industrial countries for which we have automobile production data.[2] Considering that the population of the US was slightly less than half the foreign aggregate (121 million compared to 252.5 million), the US produced about 10 times as many passenger vehicles per capita as those foreign nations (36 versus 3.5 per 1,000 population). Because the US specialized toward automobile production, it was naturally also the dominant exporter during the interwar period. Total US auto exports in 1928 exceeded the entirety of the next largest auto producer, Canada.[3]

In this paper, we study the impact of process innovation on trade by looking into the world-wide diffusion of US automobiles, in a period under which the transition to a moving assembly line for mass production actively took place.[4] While the usage of the assembly line stages as one of the most important moments in pre-WWII US economy, there has not been many empirical studies on its economic significance due to data availability issues. One contribution that we make to the literature is to collect auto production and export data in this period from various sources and to put them into a unifying framework.

First, we create a new US auto export panel from the Foreign Trade and Naviga-

[1]The world's first mass production of automobiles using an assembly line was the *Curved Dash Oldsmobile* of Ransom E. Olds in 1901, followed by the *Model T* of Henry Ford in 1913.

[2]These countries are XXX, XXX, XXX, XXX.

[3]Even this comparison understates US dominance because there were subsidiaries of US companies produced more automobiles abroad than did foreign subsidiaries operating within the US.

[4]While Henry Ford's model T takes the biggest credit, the history of mass production dates all the way back to 1785 when the French made interchangable parts for musket locks.

tion of the United States (FTNUS), an official annual report from the Secretary of Commerce.[5] Specifically, we use data on the number and US dollar value of passenger vehicles exported from the US to approximately 170 countries, annually from 1913 to 1940. In section **??**, we summarize their time series and cross-sectional properties.

Second, we collect US auto production data from various sources, including "90 Years of Ford" (by George H. Dammann, Motorbooks International, 1993), "Standard Catalog of Ford, 1903-1990" (by Robert Lichty, Krause Publications, 1990), "Cars of the Classic 30's" (by Auto Editors of Consumer Guide, Publications International, Ltd, 2004).

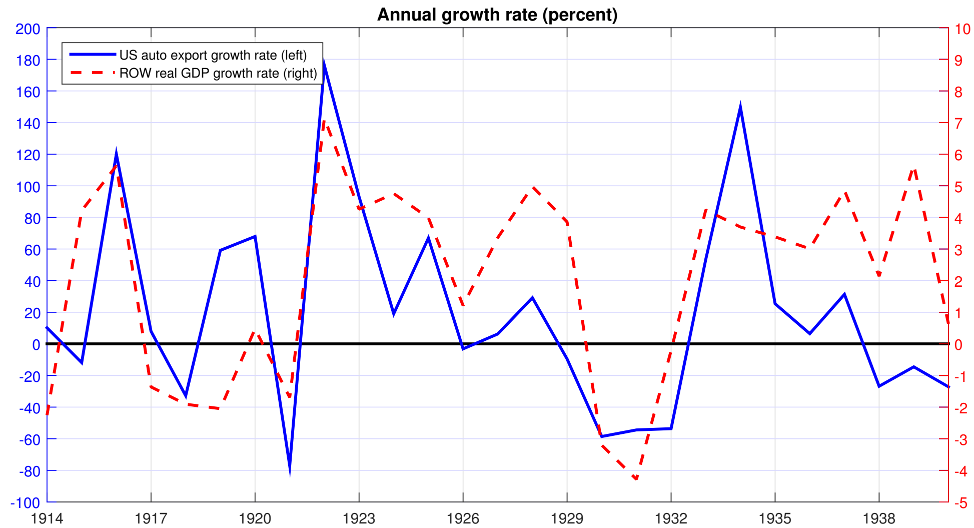
Third, we also collect foreign auto production data during this period. [WHAT ARE THESE?]

As the focus turns to more structural analysis, the sample narrows to 23 nations for which we also have macroeconomic data on GDP, consumption, price indices and nominal exchange rates.[6] This allows us to relate the export sector to the broader macroeconomy while also capturing a significant share of US automobile export values and volumes. We also make use of some automobile Census of Manufacturing data originally collected by Bresnahan and Raff (1991). These data were further augmented by Lee (2016) and incorporated into a growing archive of similar data being developed by Vickers and Ziebarth (2017). These plant-level data are available at two-year intervals: 1929, 1931, 1933 and 1935. Currently we use these data to gauge the magnitude of markups by comparing US factory gate prices and unit values of exports in the FTNUS. The data appendix provides more details on variable definitions and

[5] This panel is a small part of a much larger archival project developing a comprehensive historical archive of US imports and exports at the line-item level with the goal of improving our understanding of the relationship between manufacturing production and international trade during the interwar period.

[6] The 23 nations are: Argentina, Australia, Brazil, Canada, Chile, Colombia, Denmark, France, Greece, Italy, Japan, Mexico, New Zealand, Norway, Peru, Philippine Islands, Portugal, Spain, Sweden, Switzerland, United Kingdom, Uruguay and Venezuela.

Figure 1: Annual growth rates of US auto export volume and ROW real GDP



Note: US auto export refers to exports to 23 destination markets. The ROW real GDP is constructed as the sum of the real GDP of 23 countries in constant 1990 International Geary-Khamis dollars.

sources.

There are two interesting narratives of automobile production and trade during the interwar period. The first narrative builds from modern business cycle methods applied to post-World War II data. Modern data consistently show that durable good purchases are leading indicators of business cycles and account for a disproportionate share of the cyclical variability of aggregate demand. The business cycle approach emphasizes stock-flow dynamics in that small changes in the desired stock lead to large adjustments in the flow of durable purchases (Baxter, 1996). Consistent with this narrative is the fact that the peak of US automobile exports occurs in 1928, one year before the business cycle turning point of foreign real GDP (1929) and collapses in the early 1930s.

Figure 1 presents a more complete view of the cyclical relationship: it plots the annual growth rate of the number of passenger vehicles to 23 destination markets along with the growth rate of aggregate real Gross Domestic Product of these same

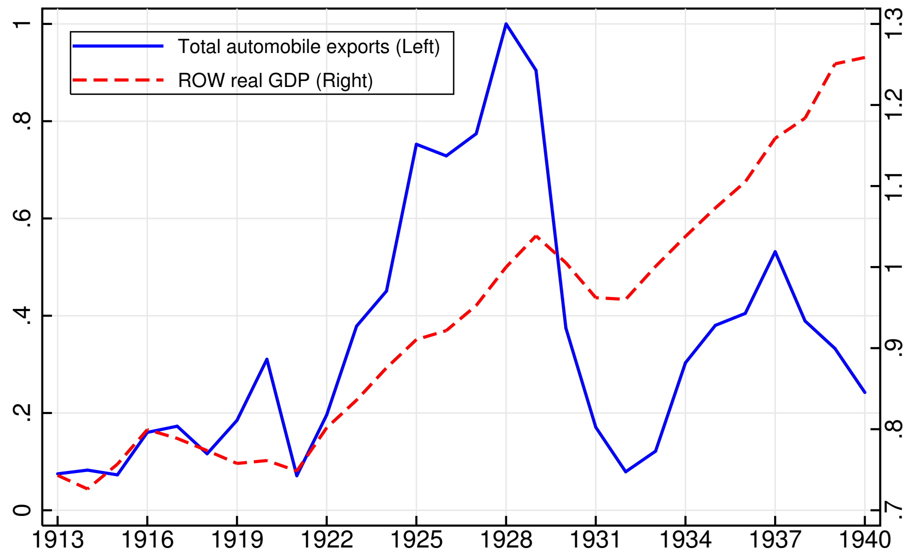
23 destination markets from 1914 to 1939. Hereafter we refer to the aggregates of destination markets as the Rest of the World (ROW).[7]

Two observations are immediate. First, it is clear that annual fluctuations of US automobile exports are intimately tied to the state of the ROW business cycle. The correlation of these two growth rates is 0.63 over the entire period and rises to 0.87 in the period from 1922 to 1934. The most obvious explanation for this correlation is the fact that increases in income lead to increases in the demand for imports, an empirical regularity also found in the post-World War II era. This import demand-driven explanation dovetails nicely with Bernanke (1995)'s argument for the need to study the Great Depression experiences of countries other than the US. The second observation is more of a challenge: the standard deviation of export growth is a remarkable 20 times greater than GDP, 57.6% versus 3.1%. A common explanation for this amplification mechanism is that a large change in the flow of durables is needed to obtain the desired increase in the stock of automobiles as income rises.

The second narrative is the focus of this paper. Namely, the introduction of product and process technologies made the automobile an increasingly affordable alternative to the horse and carriage and public transportation. Distinct from business cycle narratives which characterize high-frequency variation around a either a constant fixed point or a deterministic growth path, the diffusion narrative allows us to characterize the move from one stationary point to another. That is, to capture the rise of the automobile from global obscurity to a fixed point which the stock of automobiles per capita in the long-run depends on per capita national wealth and long-run price differences such as may be attributable to official and natural barriers to trade – tariffs and distance. In the theoretical model that we employ, the transition

[7]The ROW real GDP is constructed as the sum of the real GDP of 23 countries in constant 1990 International Geary-Khamis dollars.

Figure 2: US auto export volume and ROW real GDP in levels



Note: US auto export refers to exports to 23 destination markets. The ROW real GDP is constructed as the sum of the real GDP of 23 countries in constant 1990 International Geary-Khamis dollars.

path from one fixed point to the next (i.e., horse and buggy to combustion powered automobiles) depends on the evolution of the relative price of the automobile and its pass-through to destination markets. In contrast to business cycle analysis, which is intended to match annual growth rates of Figure 1, the diffusion narrative is intended to account for the secular trend component of automobile exports.

The relationship between GDP and automobile exports looks very different in levels than in annual growth rates. Figure 2 plots the same series as in Figure 1 in levels, normalized to 1 in 1928, which is the business cycle peak of automobile exports. This figure depicts a secular globalization boom and bust. Three observations about this bivariate relationship will guide our empirical and theoretical analysis. First, because automobiles are almost non-existent at the turn of the century, it make little sense to compare automobile export growth to the roughly 30% cumulative growth in output in the destination markets. Second, the 6% Great Depression contraction (1928 to 1933) pales in comparison to the factor of 12 decline in exports over the same period. Third, the export decline in the late 1930s contrasts with the smooth growth path of destination GDP from 1933 onward. It is worth noting the export decline does appear to match the business cycle recession in the US, though it is not immediately obvious why this is so since the relatively mild foreign contraction should have helped sustain US exports relative to domestic aggregate demand. Potentially government policies such as exchange rate depreciations, tariff and quotas on automobiles the lead up to World War II may account for this puzzle.

Our formal analysis of the diffusion of the automobile is conducted in a partial equilibrium framework and purposely draws on conventional modeling choices employed in the trade and macroeconomics literature. We model the switch from the horse and carriage to the automobile by employing an Armington aggregator of home (automobile) and foreign (horse and carriage) goods. This departs from the more common approach of assuming a continuum of varieties which is better suited for the study of a steady-state in which a large number of varieties are traded across a large number of countries than the current context where a new product replaces an old one. A second, and crucial departure from existing work, is that the model requires knowledge about the level of the price of the automobile relative to the price of the horse and carriage. This is because in the case of a symmetric Armington specification (i.e., no taste bias between the two vintages), a relative price of unity is the point at which half of the old vintage stock is displaced by automobiles. The speed of diffusion around this dynamic inflection point depends on the elasticity of substitution between the two products. With a common international Armington aggregator elasticity the rate of change of the stock of automobiles (the quantity measure of diffusion of the automobile) depends on the rate of decline of the relative price of the automobile in the U.S and how that price decline transmits to foreign destination markets. The benchmark relative price is the US time series profile of the factory gate price which we take to be driven mostly by technological progress from 1913 to 1930.

For the purposes of our analysis of foreign diffusion it is also important to consider how these US prices pass-through into destination markets. We allow for a rich menu of variation from the Law-of-One-Price: i) a constant component to markups specific to each destination market; ii) tariff wedges due to policy choices (some of which change abrupty within sample); iii) trade costs (i.e. distance); iv) taste bias and v) a residual. The residual captures persistent time variation specific to destinations as might be associated with incomplete pass-through, possibly interacting with destination exchange rate policy (i.e., the well-known departures from the Gold Standard by a number of countries, mostly in the mid- to late-1930s).

We begin with a standard reduced form estimation of a logistic function for the stock of automobiles for 23 countries over the period 1913 to 1940. These reduced form equations provide estimates of three parameters. The first parameter is the predicted long-run level of diffusion measured as the number of automobiles per capita. The remaining two parameters identify the year in which the diffusion reaches the mid-point to that level along the transition path. We find significant variation in both parameters across countries. The variation in the long-run level of adoption is strongly positively correlated with the level of per capita income in the destination country. The role of income is taken to reflect non-homothetic demand for transportation services. The role of relative prices is delivered by the Armington model, that countries with lower relative prices of automobiles should consume more of the them relative to the horse and carriage. Using the aggregate of destination markets, the half-point in the diffusion cycle of the automobile is 1927.

The parameters from this conventional reduced form estimation do not recover the structural parameters of the theoretical model so we turn to a structural estimation in the core empirical section.

2 The birth of an industry

The key innovation that launched the automobile industry from obscurity to prominence, of course, was the combustion engine and ability to the transmit its power to the wheels. The move from horse-power in the literal sense of horses pulling carts, carriages and wagons with simple axles and large wooden wheels to horse-power in the figurative sense with combustion engines moving pistons and gears and transmissions transposing that power to the the rear axle to turn pneumatic tires mounted on metal wheels.

The displacement of the horse and carriage by the automobile was a long process, even in the United States where the diffusion first took hold. The Studebaker Company experience provides direct evidence on this point; it was the largest producer of wagons and buggies at the end of the 19th century, producing about 75,000 wagons and buggies in 1895 at a time when total US automobile production was in the thouands.[8] Even as late as 1907, Ford production had only reached a meager 14,887 passenger automobiles and the next largest manufacturer, Buick, had produced far fewer, 4,641. Once the expansion of the automobile industry took hold, the horse and carriage industry collapsed. The number of carriage companies operating in the United States fell from about 4,600 in 1914 to 150 in 1925 and to less than 90 by 1929. While Studebaker attempted to reinvent itself as an automobile producer, it never acheived the dominance it had enjoyed producing the earlier vintage of transportation

[8] http://studebakermuseum.org/wp-content/uploads/2016/08/fourth-grade-teachers-guide.pdf

services.

While Ford's first factories were assembly plants with chassis and running gears supplied from the Dodge brothers and bodies from the C.R. Wilson Carriage Company, by 1907 Ford was making almost all major components (except tires which continued to be supplied by the Firestone Company). In other words, Ford decided to *in-source* his inputs. This required enormous investments of capital and skilled labor by Ford, but gave him more control over the development of his production process and was likely instrumental in facilitating a number of complementary technological changes – including the introduction of assembly-line production – that helped to propel Ford and the United States automobile industry to world-wide dominance.

Another factor in the rapid expansion of the Ford Company was Ford's insistence that the company focus on a four cylinder model with very little in the way of product variety. Ford believed this would lead both to greater production efficiency and to the development of a mass market for his product. His insistence on this focus and the desire of business partners to move into the six cylinder market, lead to the dissolution of his earlier (i.e., pre-1903) partnerships. Ford dropped the six cylinder model in 1907 and would not produce another one until 1941 (except through the acquisition of Lincoln in 1922). In October of 1907, Ford introduced the famous Model T and it would dominate his production plans and world markets for the next two decades. We see that his product strategy was highly complementary to his production strategy: assembly line production and avoiding custom design and short production runs that characterized most industries of the day.

In 1913, Henry Ford introduced a moving assembly-line production of the Model T chassis, reducing the hours required for production from 12.5 to 1.5, a factor of more than 8 (Baldwin et al., 1987).[9] Between 1913 and 1914 the unit values of exports

[9]The History Channel online states the assembly line was introduced in December of 1913 and

fell by 12.8%; they fell by another 38% over the next two years.[10] This timing seems broadly consistent with the introduction of the assembly line and its diffusion across existing and new plants.

Coming on the eve of World War I, these developments were timely and placed the Ford Motor company in a position to satisfy war-time production demands along with the capacity to supply vehicles to the increasingly prosperous citizenry in the United States as Europe struggled to recover from the devastation of the war. Foreign producers were much more modest in production scale compared to Ford, GM and Chrysler, which thus created a large world market into which Ford quickly expanded as one of the first truly multinational US companies. By 1920 it is estimated that half of the stock of automobiles in the world were Model Ts. By 1929, Ford production peaked at 1.7 million units, more than 100-fold increase from 1907. Because of this, the Ford Motor Company will play a unique role in our globalization narrative.

In particular, we emphasize that Ford (and its domestic competitors) had humble beginnings competing with the horse and carriage for short-haul trips by passengers and with limited cargo. Production numbers of the horse and carriage are difficult to come by, but the number of carriage companies operating in the United States fell from about 4,600 in 1914 to 150 in 1925 and then to less than 90 by 1929. Keeping in mind that aggregate real output grew quickly during this period, the decline is remarkable and consistent with our view that the diffusion of the automobile came largely at the expense of the horse and carriage.

By 1929, the US automobile industry had achieved a considerable amount of consolidation (the first year for which we have Census data). In 1929 General Motors market share was 34% while Ford Motor Company was second with a 26% market

cut man hours from 12 to 2.5.

[10]Our export unit values indicate a 57% decline in automobile prices between 1914 and 1920, relative to the US consumer price index.

share. Chrysler's market share was significantly lower at 7.6%, but it rose dramatically to 22% by 1935. The rise of Chrysler was mostly at the expense of smaller producers, earning these dominant firms the name: the Big Three. The Big Three were almost entirely focused on passenger vehicle production through the 1920s, with commercial vehicles becoming marginally important by 1935 when they accounted for between 10% and 15% of production (highest for Ford and lowest for Chrysler). Our focus is on the dominant product, the passenger vehicle.

3 International diffusion of the automobile

This section provides new estimates of the international diffusion of the automobile. The most comprehensive existing estimates of which we are aware are those of Comin and Hobijn (2010) which are part of their CHAT database.[11] The CHAT database provides data on the number of passenger cars (excluding tractors and similar vehicles) as measured by registration and licensing records. Our estimates, in contrast use US export data and foreign production along with a stock-flow model of accumulation. Where both estimates are available, we compare them and highlight the advantages and disadvantages of the two estimation approaches.

At first blush, registration data seems an obvious and direct way to measure the stock of automobiles within a country. However, as with the stock–flow estimates, there are some limitations. The raw count of registrations clearly give an upwardly biased estimate of the utility flow from the stock because its fails to account for depreciation.[12] This is because a newly purchased vehicle gets the same weight in the

[11]CHAT stands for: "Cross-country Historical Adoption of Technology,"a dataset that contains information on the diffusion of about 104 technologies in 161 countries during the last 200 years.

[12]In principle it is conceivable micro-data on registrations would report the year the vehicle was produced which could then be used to weight the registration data to more closely mimic the stock-flow approach.

registration data as an old vehicle whereas (at a depreciation rate of 0.2), a vehicle that is five years old should receive a weight of about 0.6 using the standard stock-flow method. Registration data may alternatively lead to downward bias in actual stocks because of lags of introduction of registration requirements or lax enforcement of existing ones. The US is a good case in point. While automobile production starts in the late 1800s, California was the first state to introduce registration requirements and did so only in 1901. Most US states did not introduce registration as a legal requirement until the 1930s. Less is known about the timing of the introduction of registration requirements and their enforcement in other nations.

3.1 Estimation of stocks from flows

Estimation of automobile stocks using the stock-flow method is given by the following equation:

$$A_{jt} = \begin{cases} (1-\delta)A_{jt-1} + X_{j,t}, & \text{without domestic production,} \\ (1-\delta)A_{jt-1} + X_{j,t} + Y_{jt}, & \text{with domestic production } Y_{jt}, \end{cases} \tag{1}$$

where A_{jt} is the stock of automobiles in country j, year t, and X_{jt} are the additions to the stock via imports from the US, Y_{jt} is domestic production and δ is the depreciation rate. To implement the estimation of stocks from the available data, we make the following assumptions:

1. When registration data is lacking, we set the initial condition for the stock of automobiles, $A_{j,0}$ to zero in 1913.

2. Where no domestic production data is found, we assume it is zero. This allows us to use destination exports as the gross additions to the stock in each destination market. For most nations of the world (there are over 100 destination markets

in the full panel) this is literally true and even industrialized countries had production levels that paled by comparison with the United States. In 1928, the United States produced 4,359,000 vehicles, compared to 242,000 in Canada, 210,000 in France , 90,000 in Germany and 55,000 in Italy (Delong (1997)). The dominance of the US industry in production and global trade is truly staggering.

3. No re-exports. For the export to add to the stock of destination automobiles, it must not be re-exported to a third country. We have no information on the extent of re-exports and they may become important as the global tariff war and competitive depreciations create arbitrage opportunities to cross-border trade (smuggling) across nations.

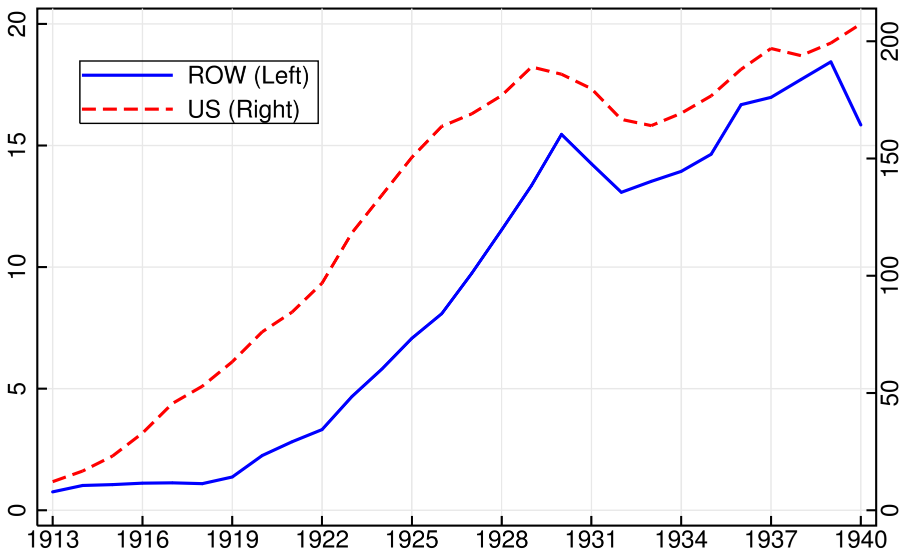
4. Annual depreciation rate is set at 20 percent.

3.2 Results

In order to gain an appreciation for the heterogeneity in the level and rate of diffusion of the automobile, we begin with a top-level comparison of registration data of the United States and an aggregate of US exports to 26 major destination markets (including the 23 countries mentioned earlier). At the turn of the 20th century (not shown), the number of vehicle registrations in the US were less than 1 per thousand population, but they rose at a phenomenal pace, to 100 in 1922 and crested at over 200 in 1940. Figure 3 clearly shows how exceptional the US was both in terms of its early adoption of the automobile and the terminal (1940) adoption level. In particular, note the need for two scales in the figure, US per capita registrations (measured on the right-hand-scale) are consistently 10 times higher than the top quartile of adopters abroad (measured on the left-hand-scale).

Turning to national level data for countries other than the US, Figure 4 shows

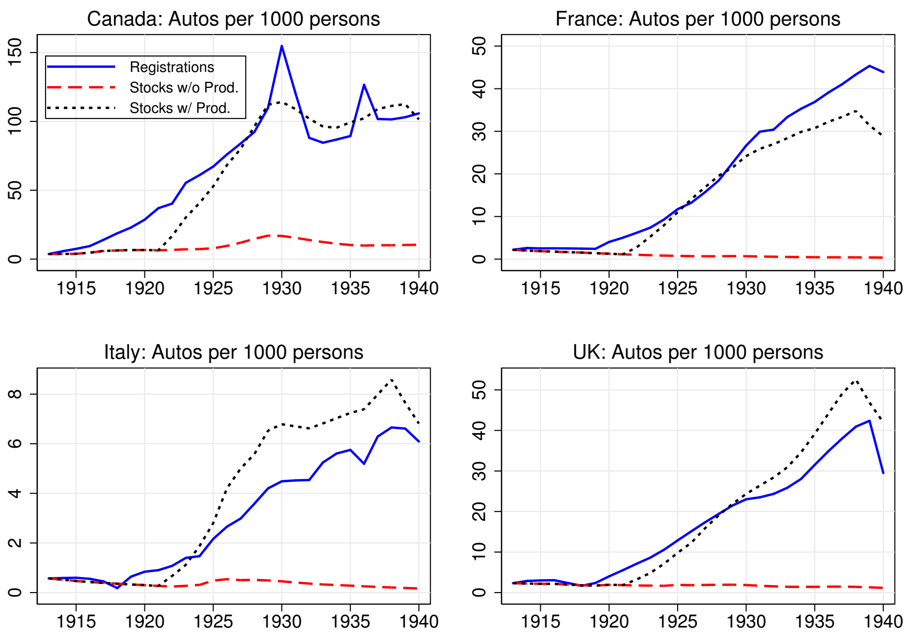
Figure 3: Automobile registration per 1,000 people (US vs ROW)



Note: Auto registration data from the CHAT database.

estimates of the stock of automobiles for Canada, France, Italy and the UK. The first observation to make is that while the volume of automobile production by these countries was dramatically lower than that of the United States, it was sufficient to supply most of domestic demand. This fact is readily evident in the enormous gulf between the black dashed lines and the red dashed lines, which represents the contribution of domestic production to the evolution of the stock. The fact that the two lines coincide before 1922 is an artifact of our lack of production data before that date. Comparing the registration-based estimate to the stock-flow estimate we see a very close correspondence. This is a reassuring cross-validation of measures given the concerns about measurement issues raised above. It also bodes well for reliance on export data to estimate foreign stocks in the larger sample where production data is difficult to come by or non-existent (possibly because there was no domestic

Figure 4: Automobile stock per 1,000 people (registration data vs our measure)

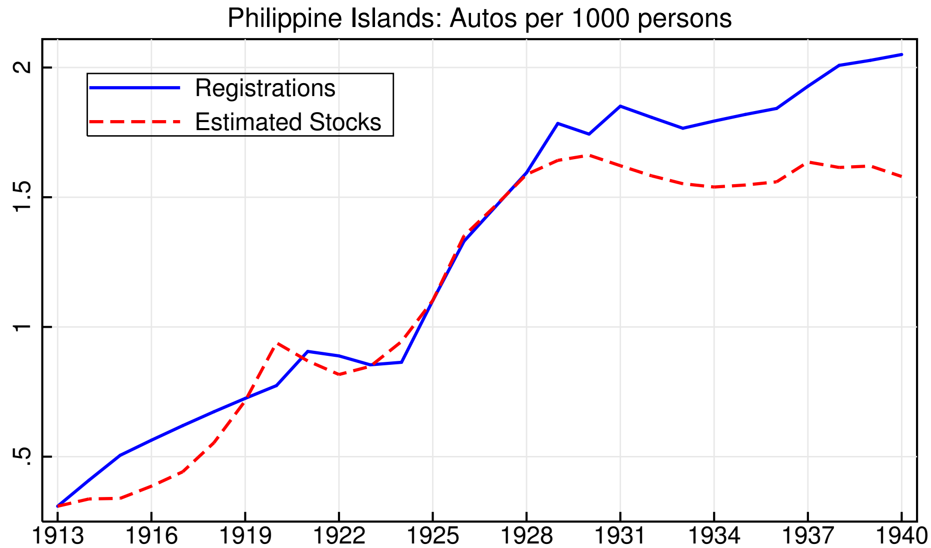


Note: Auto registration data from the CHAT database. Construction of automobile stock described in the main text.

production). Finally, it is worth noting that the notion registrations may under or over estimate the stock is not just a theoretical possibility, it is consistent with the fact that the stock-flow estimates (black dashed lines) are sometimes above and sometimes below the registration-based estimates (blue solid lines).

The utility of our US export archive to fill gaps in the data when automobile production is very limited (and/or the data is unavailable) is also supported by our results. The proximity of the registration-based estimates and the US export-based estimates is remarkable for the Philippine Islands (Figure 5) with the exception of the 1930s when the export-based data predicts a stagnation of diffusion while the registration data continues upward, though at a much slower pace than the previous

Figure 5: Automobile stock per 1,000 people (registration data vs our measure)



Note: Auto registration data from the CHAT database. Construction of automobile stock described in the main text.

decade.[13]

3.3 Reduced form quantity dynamics

A well-established empirical literature characterizes diffusion dynamics of products and technology using the following logistic function (Comin and Hobijn, 2010):

$$A_t = \frac{\alpha}{1 + \exp\left(-(\beta t - \tau)\right)} \ . \tag{2}$$

[13]In practice, it is difficult single out causes for the divergence for the reasons described in the methodology section. An aging fleet of cars later in the sample could account for the divergence since registrations fail to account for depreciation. However, Philippine production or re-exports from a third country could also account for the difference.

Table 1: Estimated Diffusion (logistic)

Measure	Long-run $\widehat{\alpha}$	Phase shift $\widehat{\tau}$	Diffusion rate $\widehat{\beta}$	R^2
Registrations	14.5	6.08	0.425	0.99
	(0.447)	(0.365)	(0.030)	
Stock-flow	16.9	4.49	0.316	0.99
	(0.605)	(0.307)	(0.029)	

Note: Estimation by NLS, all coefficients are significant at the 1% level.

Two key properties of this function are: i) $\lim_{t\to\infty} A_t = \alpha$; thus α is the predicted long-run level of adoption of the automobile; ii) and $t^* = \tau/\beta$ is the point at which the stock of automobiles is halfway to the long-run diffusion level (i.e., $A_{t^*} = \alpha/2$). It is also the inflection point on the logistic curve. Both of these properties and their estimated values will be important in our development of a structural diffusion curve below.

Table 1 reports estimates of (2) using the two alternative measures of the stock of automobiles (registrations and stock-flow measures) across 23 destination markets. The logistic function fits the stock of automobiles well and the estimated parameters are comparable across the two alternative measures. The long-run adoption levels are 14.5 automobiles per capita using the registration data compared to 16.9 automobiles per capita using the stock-flow model to estimate stocks. Notice that while the phase shift parameter and diffusion rate are numerically different estimates across the two cases, the point at which the diffusion process reaches the mid-point to the asymptotic steady-state is estimated to be 1927 in both cases.[14] It turns out that this inflection point matches that of the US, despite the much higher level of diffusion acheived.

[14] These values are computed as $1913 + \widehat{t^*} = 1913 + \widehat{\tau}/\widehat{\beta}$. Using the estimate using registration is 1913+6.08/0.425=1927.3 and from the production and export flow data is 1913+4.49/0.316=1927.2.

Table 2: Estimated Diffusion for Each Country (logistic)

Country	$\widehat{\alpha}$	$\widehat{\tau}$	$\widehat{\beta}$	R^2	Country	$\widehat{\alpha}$	$\widehat{\tau}$	$\widehat{\beta}$	R^2
Argentina	11.79	11.54	0.897	0.97	New Zealand	26.25	3.34	0.376	0.98
	(0.46)	(1.92)	(0.152)			(1.01)	(0.40)	(0.053)	
Australia	28.29	11.69	1.009	0.97	Norway	3.42	4.34	0.572	0.99
	(1.15)	(1.70)	(0.151)			(0.11)	(0.46)	(0.073)	
Brazil	1.93	10.43	0.833	0.97	Peru	1.65	3.39	0.281	0.98
	(0.08)	(2.33)	(0.185)			(0.09)	(0.35)	(0.036)	
Canada	114.10	8.11	0.623	1.00	Philippines	1.88	3.01	0.285	0.99
	(2.15)	(0.65)	(0.053)			(0.02)	(0.22)	(0.021)	
Chile	3.07	3.08	0.323	0.95	Portugal	1.00	5.41	0.400	0.99
	(0.17)	(0.66)	(0.073)			(0.02)	(0.76)	(0.060)	
Colombia	2.06	3.23	0.163	0.96	Spain	1.33	8.04	0.733	0.92
	(0.49)	(0.23)	(0.033)			(0.11)	(1.73)	(0.169)	
Denmark	12.05	14.06	1.037	0.98	Sweden	17.47	4.36	0.228	0.99
	(0.47)	(1.98)	(0.151)			(1.56)	(0.26)	(0.024)	
France	31.88	6.41	0.425	1.00	Switzerland	4.48	7.03	0.452	1.00
	(1.00)	(0.44)	(0.033)			(0.09)	(0.46)	(0.031)	
Greece	0.72	7.34	0.589	0.93	UK	52.96	5.37	0.285	0.99
	(0.05)	(2.33)	(0.200)			(4.71)	(0.37)	(0.030)	
Italy	7.66	8.05	0.570	0.99	Uruguay	14.19	5.25	0.525	0.95
	(0.22)	(0.51)	(0.040)			(0.90)	(0.88)	(0.094)	
Japan	2.40	4.67	0.177	0.98	Venezuela	6.41	3.90	0.235	0.99
	(1.14)	(0.23)	(0.029)			(0.43)	(0.25)	(0.024)	
Mexico	3.46	6.08	0.575	0.99	**Median**	4.48	5.41	0.452	0.98
	(0.090	(0.38)	(0.040)			(0.43)	(0.46)	(0.053)	

Note: Estimation by NLS. Standard errors in parentheses.

While the diffusion of the aggregate stock is interesting, our model will assume that decision-makers face different economic circumstances at the country-level and therefore choose both a different long-run number of automobiles and a different path toward that long-run target. Since the logistic function is highly non-linear, the parameters estimated from the aggregated data are likely to differ from those estimated for each country. Effectively this means that the estimates of Table 1 might be less suited for a structural interpretation.

This is born out by the results in Table 2, which present logistic estimates of automobile diffusion at the country level. Beginning with the diffusion speed parameters, $\widehat{\beta}$, range from a low of 0.177 in Japan.to a high of 1.037 in Denmark. The phase shift parameters differ substantially as well, but are not in comparable units when

Table 3: Estimated Inflection Points and Long-run Adoption Levels

Country	Inflection Year	Long-run Adoption Level
Norway	1921	3
New Zealand	1922	26
Chile, Uruguay	1923	3, 14
Mexico, Philippines, Spain	1924	4, 2, 1
Australia, Greece, Peru	1925	28, 1, 2
Argentina, Brazil, Canada	1926	12, 2, 114
Denmark, Italy, Portugal	1927	12, 8, 1
France	1928	32
Switzerland	1929	5
Venezuela	1930	6
Sweden, United Kingdom	1932	18, 53
Colombia	1933	2
Japan	1939	2
United States	**1927**	200+
Median	**1926**	4.5

Note:

the slope parameters also differ. Turning to the medians, which would be a point of comparison to the aggregate estimates in a linear model, the speed of diffusion and lag parameters are roughly comparable to the aggregate ones. In contrast, the median estimated long-run adoption level in the cross-section is dramatically lower than that of the aggregated data, 4.48 automobiles per thousand compared to 14.5 using registrations and 16.9 using the stock-flow data. The reason the aggregated data leads to a higher estimate is that the countries (Canada being the most dramatic) with a higher long-run adoption level get more weight in the aggregate (they also account for a disproportionate share of US exports). These results show the utility of using the disaggregated data.

Table 3 reports the long-run diffusion levels ($\widehat{\alpha}$), and the inflection points in the estimated diffusion curves. Converting these parameters to the inflection points at which countries are half-way to their long-run level of adoption (i.e., the inflection point year is $1913 + \widehat{\tau}/\widehat{\beta}$) returns the year 1939 for Japan and 1927 for Denmark. By way of comparison, the inflection year for the United States is 1927. Interestingly, the median inflection year is 1926, one year earlier than the United States. While the inflection points are similar across countries, the estimated long-run levels of automobile diffusion are not, ranging from a paltry 0.72 automobiles per 1,000 in Greece to a high of 114 automobiles per 1,000 in Canada. It is also worth noting that the adoption levels are highly right-skewed.

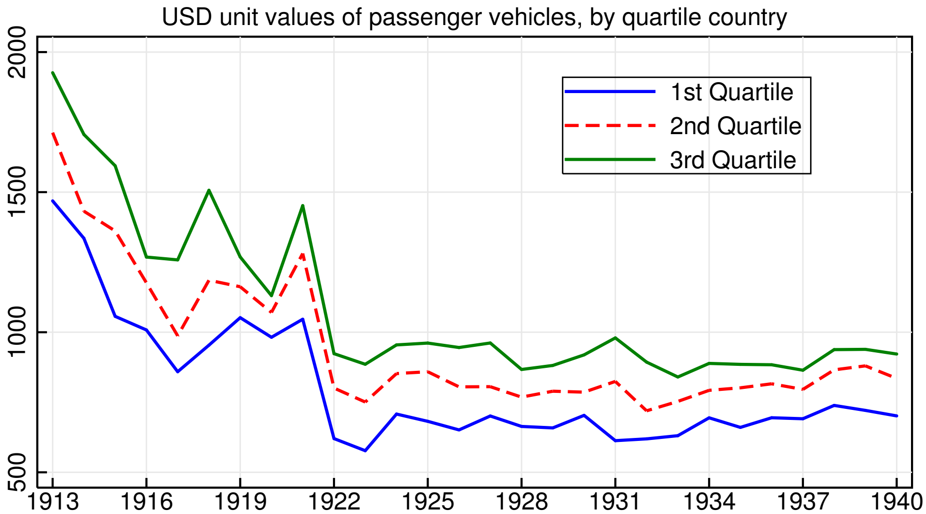
To summarize, the quantity data show simlar dynamic patterns of diffusion in terms of the rate of diffusion and the inflection point, but vastly different long-run levels of adoption. The main goal of our work is to explain the common and country-specific patterns of automobile diffusion as they relate to international wealth differences and the observed patterns of automobile export prices, to which we now turn our attention.

4 Price dynamics

Recall that the original source data report the US dollar value and number of units of passenger vehicles annually from 1913 to 1940 to more than 100 destination countries from the FCNUS. From these data, export unit values (i.e., average export prices) are computed by dividing the US dollar value of exports of passenger vehicles to country j ($V^A_{j,t}$) by the number of passenger vehicles exported to that same destination, ($X^A_{j,t}$):

$$P^A_{j,t} = \frac{V^A_{j,t}}{X^A_{j,t}} \ .$$

Figure 6: Automobile stock per 1,000 people (registration data vs our measure)



To eliminate inflationary trends, we take each of these nominal US dollar prices and divide them by the US CPI $P_{US,t}$:

$$Q^A_{j,t} = \frac{P^A_{j,t}}{P_{US,t}} \ .$$

The CPI is normalized to 1.0 in 1930 so that the raw nominal USD unit values equal their deflated counterparts in that year. Figure 6 plots the median and the first and third quartiles of the cross-destination price distribution of these relative prices.

The most striking feature of the price distribution is the very sharp relative price decline close to the start of the sample (during World War I). Noting that Henry Ford introduced a full assembly-line production of the Model T chassis in 1914, reducing the hours required for production from 12.5 to 1.5, a factor of more than 8 (Baldwin et al., 1987), it seems reasonable to assume that these dramatic efficiency gains were important in driving down the relative price of automobiles during these early years. A second sharp drop in relative price occurs from 1921 to1922. At first, it seems tempting to attribute this to the collapse in exports immediately following the war (see Figure 2). However, looking at the full interwar series, it is obvious that this relative price decline is a permanent feature and the relative price declines in the first half of the sample are plausibly due to ongoing efficiency gains and technological diffusion.

One might also be concerned that the product mix of exports may have changed over this early period, as Ford and GM (who consistently held between a 60% and 70% share of US production between 1929 and 1935) introduced new models. Ford changed the Model T (first introduced in 1908) four times between 1914 and 1927 and then introduced the Model A in 1928.[15] The models and date ranges of production were: the T1 (1909-1914), the T2 (1915-1916), the T3 (1917-1923), the T4 (1923-1925) and the T5 (1926-27). Since the price movements do not show an obvious correlation with model introduction dates by one of the dominant producers, it seems implausible that the declining relative price from the start of the sample through 1922 is due to product introductions. Thus, our interpretation will be that prices are fallen as process and product innovation lower the cost of producing the passenger automobile.

Turning to the cross-sectional variance, the prices range from a low of $539 in Brazil to a high of $965 in Spain (in 1929). Over the entire sample period, the inter-quartile range averages 30% of the median price. The maximum inter-quartile dispersion is 47% (in 1918) and the minimum is 14% (in 1920). What is particularly

[15] We emphasize the Ford Motor Company as the dominant producer, but GM was a close second. Ford seems to have dominated the export market due to its strategy of producing affordable models. By 1920 it is estimated that half of the stock of automobiles in the world were Model Ts. In 1929, Ford production peaked at 1.7 million units, more than a 100-fold increase from 1907.

important for the secular diffusion curve are the persistent differences in prices across destination markets.

4.1 Reduced form price dynamics

The relative price distribution appears to follow a downward secular trend to a stationary level. To characterize common and country-specific components of these secular trends, the following equation is estimated for each country:

$$Q^A_{j,t} = (\overline{Q}\exp(-\delta_j t) + \underline{Q})\mu_j + \epsilon_{j,t} \ . \tag{3}$$

Notice there is a permanent markup (μ_j) which shifts the initial and asymptotic price by the same proportion, a potentially different rate of change decline in the relative price (δ_j) and an additive error term to capture time series variation around the secular trend plus measurement error.

The estimated bounds on the price path from the pooled data are estimated to be \$1,000 at the start of the sample and \$500 at the end of sample. As evident in Table 4, most of the slope parameters (δ_j) are between 0.1 and 0.3. The estimated markups vary dramatically from a trivial 1% in Australia, Norway, Peru, Sweden and the UK, to more than 50% in Austria, Colombia, Finland, France, and Spain.

In the next section we elaborate an Armington model of diffusion whereby the cross-sectional and time series properties of relative quantities are endogenously determined as a function of the relative prices using a standard Euler equation.

Table 4: Reduced Form Price Dynamics

Country	$\widehat{\mu}_j$	$\widehat{\delta}_j$	Country	$\widehat{\mu}_j$	$\widehat{\delta}_j$
Argentina	1.04	0.2	Mexico	1.39	0.3
Australia	1.01	0.2	Netherlands	1.08	0.1
Austria	1.59	2.2	New Zealand	1.10	0.2
Belgium	1.07	0.2	Norway	1.01	0.1
Brazil	1.20	0.4	Peru	1.01	0.1
Canada	1.39	0.3	Philippines	1.33	0.3
Chile	1.48	0.5	Portugal	1.11	0.1
Colombia	1.53	0.6	Spain	1.77	2.7
Denmark	1.02	0.2	Sweden	1.01	0.1
Finland	1.51	0.8	Switzerland	1.05	0.1
France	1.97	3.3	UK	1.01	0.1
Germany	1.19	0.1	Uruguay	1.19	0.4
Greece	1.07	0.1	Venezuela	1.30	0.5
Italy	1.47	1.0	Mean		
Japan	1.14	0.2	Median		

Note: The price dynamics regression is based on equation (3).

5 Armington model of automobile diffusion

We model the diffusion of the automobile as a shift in consumer demand from an old vintage of a product to a new one, each of which provides personal transportation services. For concreteness the old vintage is powered literally by horse-power and the new vintage is powered by a combustible engine.[16] Less abstractly, each vintage could be a composite of product varieties where horse-drawn carriages come in varieties produced by companies like Wilson and Studebaker and the combustion engine vehicle product lines are rolled out by Ford, GM and Chrysler. The data demands of such an investigation are well beyond the scope of this paper and unlikely to alter the main thrust of our narrative about the international diffusion of US passenger automobiles. Later in the paper consider of the composition of domestic production and imports

[16]Steam engines pre-date the combustion engine and electric engines were also introduced, but neither is a significant market share in our period of study.

in the domestic consumption bundle is discussed for the few countries that have significant domestic production. For now the reader should think of these products as part of the aggregate in the new vintage with prices also driven by the dominant US suppliers through export unit values and mitigated by protectionist measured placed on imports.

Turning to specifics, the choice between the two modes of transportation in destination j is governed by a standard Armington aggregator with elasticity of substitution denoted by σ:

$$G_j(A_{j,t}, H_{j,t}) = [\theta_j^{\frac{1}{\sigma}}(A_{j,t})^{\frac{\sigma-1}{\sigma}} + (1-\theta_j)^{\frac{1}{\sigma}}(H_{j,t})^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \ .$$

Here the standard approach to modeling the utility flow of durables is to assume proportionality of transportation services to the existing outstanding stock. Under this interpretation, the objects in the aggregator are the outstanding stocks of automobiles ($A_{j,t}$) and horses and buggies ($H_{j,t}$), respectively.

Combined with the assumption of costless stock adjustment, the Euler equations linking stocks to market prices are:

$$\begin{aligned} D_1 G_j(A_{j,t}, H_{j,t}) &= G_j^{\frac{1}{\sigma}} \theta_j^{\frac{1}{\sigma}} (A_{j,t})^{-\frac{1}{\sigma}} = P_{j,t}^A \\ D_2 G_j(A_{j,t}, H_{j,t}) &= G^{\frac{1}{\sigma}} (1-\theta_j)^{\frac{1}{\sigma}} (H_{j,t})^{-\frac{1}{\sigma}} = P_{j,t}^H \ . \end{aligned}$$

In terms of the more familiar relative quantity demanded as a function of relative price, we have:

$$\frac{A_{j,t}}{H_{j,t}} = \frac{\theta_j}{(1-\theta_j)} \left\{ \frac{P_{j,t}^H}{P_{j,t}^A} \right\}^{\sigma} \ .$$

A few lines of algebra are need to show that this expression may be used to formulate a diffusion process bounded bounded between 0 and 1,

$$\omega_{j,t} = \frac{A_{j,t}}{H_{j,t} + A_{j,t}} = \frac{\frac{A_{j,t}}{H_{j,t}}}{1 + \frac{A_{j,t}}{H_{j,t}}} = \frac{\frac{\theta}{(1-\theta)} \left\{ \frac{P^H_{j,t}}{P^A_{j,t}} \right\}^\sigma}{1 + \frac{\theta}{(1-\theta)} \left\{ \frac{P^H_{j,t}}{P^A_{j,t}} \right\}^\sigma} .$$

Here the limit points are asymptotes which are reached only for dramatic shifts in the relative price of the old vintage relative to the new one.

A more transparent way of exploring the observable implications of this equation with an aim to estimation is to isolate the relative price in the denominator. Dividing through by the numerator and defining the relative prices as $Q_{j,t} = P^A_{j,t}/P^H_{j,t}$ and the home bias term as $\Psi_j = (1 - \theta_j)/\theta_j$, we have:

$$\omega_{j,t} = \frac{1}{1 + \Psi_j Q^\sigma_{j,t}} .$$

To get a sense of how this generates the type of diffusion curve often found in the literature on technological or product innovation, take the simplest possible case in which the pass-through of US factory gate prices to destination j is complete, assume the absence of tariffs and transportation costs and no 'taste bias,' ($\Psi_j = 1$). Furthermore, to focus on the secular decline of prices, let the relative price follow a declining exponential at rate β from some initially high value, $\overline{Q}$ to a floor of $\underline{Q}$

$$Q_t = \overline{Q} \exp(-\beta t) + \underline{Q}$$

and we have

$$\omega_t = \frac{1}{1 + \Psi(\overline{Q} \exp(-\beta t) + \underline{Q})^\sigma} .$$

6 Estimation

The estimation proceeds by using the implied ratio of old and new vintages of the model. We proceed in a number of steps.

We begin by defining the fitted diffusion curve. For country j, define the predicted share of transportation services coming from the automobile as:

$$\widehat{\omega}_{j,t} = \frac{\widehat{A}_{j,t}}{\widehat{\alpha}_{j,t}}$$

where $\widehat{A}_{j,t}$ is the fitted value of the automobile stock from the reduced form diffusion estimation and $\widehat{\alpha}_{j,t}$ is the predicted long-run level of diffusion. Essentially, this transformation maps the raw counts of automobiles to fractions between 0 and 1.

The Armington model with a prediction error added gives us:

$$\widehat{\omega}_{j,t} = \frac{1}{1 + \Psi_j \widehat{Q}_{j,t}^{\sigma}} + \vartheta_{j,t} \ .$$

where $\widehat{Q}_{j,t}$ is the fitted automobile relative price for destination j from the reduced form estimation using prices alone.

In order to estimate the elasticity and taste bias parameter, the regressand is transformed to yield the following estimable equation:

$$\log\left(\frac{1 - \widehat{\omega}_{j,t}}{\widehat{\omega}_{j,t}}\right) = \log \Psi_j + \sigma \log(\widehat{Q}_{j,t}) + \epsilon_{j,t} \tag{4}$$

Table 5 reports the results. The elasticity is consistently in the neighborhood of 14 with a low standard error.

Markups by destination. In order to set the absolute relative prices in relation to US factory gate prices factory-gate unit values and export unit values are compared.

Table 5: Armington Elasticity Estimates

Country	σ	$se(\sigma)$	T	R^2	Country	σ	$se(\sigma)$	T	R^2
Argentina	23.1	2.56	28	0.78	Mexico	8.7	1.58	28	0.46
Australia	19.8	0.86	28	0.97	Netherlands	12.3	0.96	28	0.89
Austria	-14.2	1.34	28	0.85	New Zealand	10.0	0.90	28	0.85
Belgium	11.6	1.02	28	0.86	Norway	20.3	1.44	28	0.91
Brazil	21.4	3.75	28	0.52	Peru	10.6	0.63	28	0.94
Canada	8.0	1.30	28	0.57	Philippines	6.8	0.95	28	0.66
Chile	6.3	1.58	28	0.22	Portugal	12.1	0.68	28	0.94
Colombia	5.6	1.13	28	0.45	Spain	48.6	4.16	28	0.88
Denmark	22.5	0.62	28	0.99	Sweden	6.1	0.14	28	0.99
Finland	37.1	9.46	27	0.26	Switzerland	10.1	0.28	28	0.99
France	17.3	0.15	28	1.00	UK	10.4	0.56	28	0.95
Germany	64.6	1.98	25	0.99	Uruguay	9.4	2.11	28	0.34
Greece	21.2	1.95	28	0.85	Venezuela	6.3	1.37	28	0.39
Italy	76.0	9.85	20	0.80	Mean				
Japan	5.2	0.57	28	0.77	Median				

Note: The regression equation is (4).

Table 6 reports the average prices of closed two and four door sedans across the three largest producers, GM, Ford and Chrysler in 1929, 1931, 1933 and 1935 (each year for which we have manufacturing Census data). With the exception of Chrysler in 1929, the prices are very comparable across manufacturers when similar models are used in the comparisons.

The physical production shares correlate negative with price levels across producers. GM has the highest market share and lowest average prices, while Chrysler has the lowest market share and highest average prices. Chrysler's major price reduction between 1929 and 1931 increases its market share when the comparisons are restricted to the Big Three (the shares in the table are restricted to this segment of the market), but wider comparison (not shown) are also significant.

Since our export data does not distinguish passenger vehicles by type, we aggregate the Big Three prices into an aggregate price index using their physical production

Table 6: Comparison of US factory and export unit values

	1929	1931	1933	1935
Export unit values	692	618	487	525
Markup (sedan, closed 4 door)	1.23	1.19	1.04	0.98
Markup (sedan, closed 2 door)	1.43	1.43	1.16	1.12
Production shares				
GM	0.51	0.52	0.50	0.44
Ford	0.38	0.34	0.27	0.31
Chrysler	0.11	0.14	0.23	0.25
Price of closed 4 door sedans				
GM	509	490	429	514
Ford	579	541	526	556
Chrysler	749	585	479	547
Price of closed 2 door sedans				
GM	446	414	389	446
Ford	475	452	456	481
Chrysler	672	459	438	498

Note: Authors' calculations from export unit values and Census of Manufacturing factory gate unit values.

shares. We still separate out the two and four door closed sedans in order to put bounds on the markups. Starting with the closed, 4 door sedans, markups start at 23% in 1929 and fall to basically zero. These markups are considered to be lower bounds because the larger vehicles are the more expensive ones. The closed, 2 door sedans have markups of 43% in 1929 and fall toward 12% in 1935. The declines in markups are certainly consistent with the time period covered by the data as the Great Contraction place extreme pressure on automobile sales and profit margins both at home and abroad.

7 Conclusion

This paper has attempted to explain the global diffusion of the automobile from its infancy at the turn of the 20th century to the eve of World War II. After showing how a two vintage CES aggregator produces a simple logistic model of diffusion as a function of the relative price of the two vintages, we use the model to simulate the path of automobile stocks across countries as a function of the pass-through of US unit values of exports into destination countries. The model also allows for the long-run differences in adoption that is strongly positively correlated with real income. Using a novel panel archive of US automobile exports and their unit values across 23 countries over the period 1913 to 1940, we find that this simple model tracks the broad contours of the global diffusion of the automobile. In future work we hope to decompose the relative price dynamics into the role of US factory gate prices, markups and the role of exchange rate and commercial policy. The other extension will be to consider the change in wealth expectations following the stock market crash and banking crises in generating the bust cycle in the early 1930s.

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8 Data Appendix

There are three distinct sets of data used in our analysis. The trade data come from the US Foreign Trade and Navigation of the United States, an annual serial volume that records line item imports and exports. From this volume we collected export quantities and value exported by destination market. The macroeconomic data consists of GDP, aggregate consumption, exchange rates and price indices. The manufacturing units values and other automobile production data are from the Census of US Manufacturers. We provide some details on each source below.

8.1 Trade Data

The automobile export panel spans the period 1913 to 1940 and records the value and number of passenger vehicles exported to as many as 171 destination countries. While the source does not disaggregate by make and model, it does break the passenger vehicle exports into price ranges. Thus, we have some confidence that unit values, computed as the ratio of value to quantity exported is a reasonably accurate estimate of destination unit prices of comparable passenger vehicles. The data appendix describes the original source data and how the panels used in subsequent analysis were constructed. Canada is the top export destination with about 42,000 units in 1929 valued at almost 34 million USD ($809 per vehicle). As surprising as it may seem for a small country to be such an important destination for US exports it is not alone: the five next largest destination markets are Australia, Argentina, Brazil and Mexico. The United Kingdom is the top destination among the largest industrialized nations, but despite being almost 10 times the size of Mexico, it accounts for a smaller export volume.

8.2 Macroeconomic Data

The passenger vehicle data are supplemented with the annual per capita GDP and population data complied by Angus Maddison. The per capita income data are presented in common base period units (1990 International Geary-Khamis dollars). In order to have a consistency between the trade data and the income data, we normalize the unit prices and values of US automobile exports by the US CPI obtained from the Bureau of Labor Statistics.

9 Historical Appendix

The Ford Motor Company was established in 1903 and plays a central role in the domestic growth and globalization of this budding industry. The industry had humble beginnings competing with the horse and carriage for short-haul trips by passengers and with limited cargo. Production numbers of the horse and carriage are difficult to come by, but the number of carriage companies operating in the United States fell from about 4,600 in 1914 to 150 in 1925 and then to less than 90 by 1929. Keeping in mind that aggregate real output grew quickly during this period, the decline is remarkable and it seems reasonable to attribute it to the rapid diffusion of the automobile as a replacement for the horse and carriage.

In 1907, Ford production had reached a meagre 14,887 units and the next largest manufacturer, Buick, produced just 4,641. While Ford's factories were initially assembly plants with chassis and running gears supplied from the Dodge brothers and bodies from the C.R. Wilson Carriage Company, by 1907 Ford was making almost all major components (except tires which were supplied by Firestone). In other words, Ford decided to *in-source* his inputs. This decision gave Ford more control over the development in his production process and was likely instrumental in facilitating a number of complementary technological changes that propelled Ford and the US automobile industry to world-wide dominance.

The rapid expansion specific to the Ford Company was in part due to Ford's insistence that the company focus on a four cylinder model with very little in the way of product variety, lending the process to assembly line production. Ford believed this would lead both to greater production efficiency and a mass market. His insistence on this focus and the desire of partners to move into the six cylinder market, lead to the dissolution of earlier (i.e., pre-1903) partnerships. Ford dropped the six cylinder model in 1907 and would not produce another one until 1941 (except through the acquisition of Lincoln in 1922). In October of 1907, Ford introduced the famous Model T and it would dominate his production plans and world markets for the next two decades.

In 1914 Henry Ford introduced a full assembly-line production of the Model T chassis, reducing the hours required for production from 12.5 to 1.5, a factor of more than 8 (Baldwin et al (1997)). This was a timely decision on the eve of World War I, placing the company in a position to satisfy war-time production demands along with the capacity to supply vehicles to the increasingly prosperous citizenry in the United States as Europe struggled to recover from the devastation of the war. Foreign producers are much more modest in production scale compared to Ford, which thus created a large world market into which Ford quickly expanded as one of the first truly multinational US companies. By 1920 it is estimated that half of the stock of automobiles in the world were Model Ts. By 1929, Ford production peaked at 1.7 million units, more than 100-fold increase from 1907. And then, of course, the industry would come to be dominated by the veracity of Great Depression.[17]

[17] It is surprising that the macroeconomics literature has not paid more attention to this industry. Check for references beyond the broad-brushed durable goods story (which were probably much less concentrated in production).

According to Wikipedia (https://en.wikipedia.org/wiki/Ford_Model_T), the Ford model runs and descriptions of products are as follows:

Model T1 (1909–1941) Characterized by a nearly straight, five-sided hood, with a flat top containing a center hinge and two side sloping sections containing the folding hinges. The firewall was flat from the windshield down with no distinct cowl.

Model T2 (1915–1916) The hood design was nearly the same five sided design with the only obvious change being the addition of louvers to the vertical sides. There was a significant change to the cowl area with the windshield relocated significantly behind the firewall and joined with a compound contoured cowl panel.

Model T3 (1917–1923) The hood design was changed to a tapered design with a curved top. the folding hinges were now located at the joint between the flat sides and the curved top. This is sometime referred to as the low hood to distinguish if from the later hoods. The back edge of the hood now met the front edge of the cowl panel so that no part of the flat firewall was visible outside of the hood. This design was used the longest and during the highest production years accounting for about half of the total number of Model T's built.

Model T4 (1923–1925) This change was made during the 1923 calendar year so models built earlier in the year have the older design while later vehicles have the newer design. The taper of the hood was increased and the rear section at the firewall is about an inch taller and several inches wider than the previous design. While this is a relatively minor change, the parts between the third and fourth generation are not interchangeable.

Model T5 (1926–1927) This design change made the greatest difference in the appearance of the car. The hood was again enlarged with the cowl panel no longer a compound curve and blended much more with the line of the hood. The distance between the firewall and the windshield was also increased significantly. This style is sometimes referred to as the high hood.

France, the world's second largest producer, turned out a mere 40,000 automobiles. While we thought this could be a misleading comparison point given that France was recovering from World War I, according to Wikipedia, even by 1950, France was producing 357,000 vehicles. United Kingdom production was probably even lower: production levels of 1920, 70,000, 237,000 and 134,000 by decade from 1920 to 1940.

According to Wikipedia, American economist Robert A. Brady extensively documented the rationalization movement that shaped German industry in the 1920s, and although his general model of the movement applied to the automotive industry, the sector was in poor health in the later years of the Weimar Republic. Germany's slow development of the industry left the market open for major American auto manufacturers such as General Motors who took over German company Opel in 1929, and the Ford Motor Company which maintained the successful German subsidiary Ford-Werke, beginning in 1925. The collapse of the global economy during the Great Depression in the early 1930s plunged Germany's auto industry into a severe crisis. While eighty-six auto companies had existed in Germany during the 1920s, barely twelve survived the depression, including Daimler-Benz, Opel and Ford's factory in Cologne. In addition, four of the country's major car manufacturers —Horch, Dampf Kraft Wagen (DKW), Wanderer and Audi — formed a joint venture known as the Auto Union in 1932, which was to play a leading role in Germany's comeback from the depression. The turnabout for the German motor industry came about in the mid 1930s following the election of the Nazi Party to power. The Nazis instituted a policy known as Motorisierung (de) ("motorization"), a transport policy which Adolf Hitler himself considered a key element of attempts to legitimize the Nazi government by raising the people's standard of living. In addition to development and extensions of major highway schemes (which saw the completion of the first Autobahn in 1935), the Volkswagen project was also conceived to design and construct a robust but inexpensive "people's car", the product of which was the Volkswagen Beetle, launched in 1937. A new city (known as Wolfsburg from 1945) was developed around the factory to house its huge workforce.

Table 7. Key dates related to nominal exchange rate arrangements

Country	Date of suspension of Gold Standard	Exchange Controls	Depreciation or Devaluation
Belgium	March, 1935	March, 1935	March, 1935
Denmark	November, 1931	November, 1931	November, 1931
Finland	December, 1931	–	October, 1931
France	–	–	September, 1936
Germany	–	July, 1931	–
Italy	–	May, 1934	March, 1934
Netherlands	September, 1936	–	September, 1936
Norway, Sweden, UK	September, 1931	–	September,1931

Notes: Table is reproduced from Eichengreen and Sachs (1985)