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ANALYSIS OF EMPLOYMENT CHANGES OVER TIME IN THE U.S. MOTOR VEHICLE INDUSTRY

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ABSTRACT

Over the period from 1997 to 2014, U.S. employment in the combined motor vehicle industry declined from 932,265 to 719,983 employees. During this time, significant changes in trade and non-trade factors occurred that have likely impacted employment, such as the value and composition of U.S. imports and exports and the intensified use of technology in manufacturing which increased labor productivity in some segments of the industry. This analysis decomposes the annual growth rates of employment in three separate segments of the combined motor vehicle industry into the contributions from international trade, labor productivity, and total U.S. consumption. Employment fell in both the motor vehicle and the parts manufacturing segments during this period. Labor productivity gains and increased imports both contributed to the employment declines, with labor productivity associated with a larger decline in employment. In both segments, higher domestic consumption played a larger role than increased exports in offsetting part of the employment declines. On the other hand, the vehicle body manufacturing segment posted an employment increase during this period. In this segment, employment gains from increased domestic consumption and exports offset the reductions in employment from gains in labor productivity.

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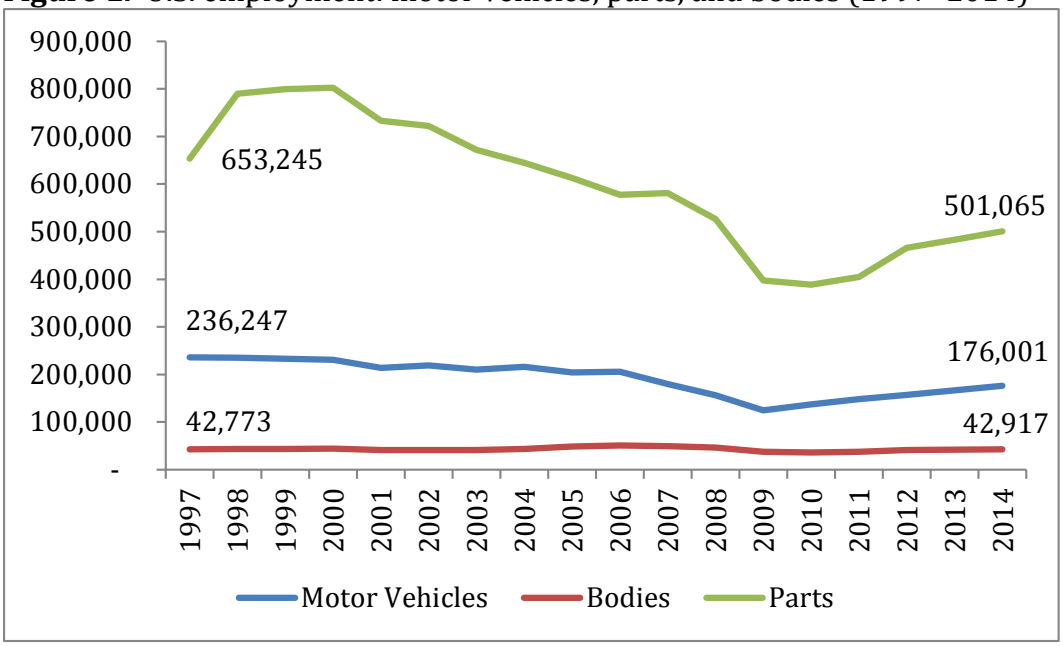
Introduction

The expansion in international trade in motor vehicles has coincided with persistent declines in U.S. employment in the combined industry. Between 1997 and 2014, total U.S. imports of motor vehicles, bodies, and parts increased a cumulative 128.3 percent ($169 billion), and U.S. exports increased a cumulative 111.0 percent ($69 billion).[1] During the same time, employment declined a cumulative 22.8 percent, from 932,265 to 719,983 employees (figure 1).

Figure 1. U.S. employment: motor vehicles, parts, and bodies (1997–2014)



Source: U.S. Census, ASM (accessed July 1, 2016). Corresponds to table A.1 in the appendix.

While part of the change in industry employment is likely tied to the growth of international trade, it also reflects improvements in labor productivity in the industry and in total consumption of motor vehicles in the U.S. market. This research note uses a growth accounting framework to quantify the relative contributions of changes in trade, technology, and total consumption – in some cases positive, in others negative – to the historical declines in industry employment. An increase in consumption in the United States due to an increase in aggregate demand increases labor demand and therefore employment in the U.S. industry. Likewise, an increase in U.S. exports due to an increase in foreign demand increases employment in the U.S. industry. On the other hand, an increase in imports due to a reduction in foreign costs of production generally reduces employment

[1] In this research note, the combined motor vehicles industry is defined as NAICS codes 3361, 336211, and 3363. For these years, the industry data are reported on a consistent NAICS basis.

in the U.S. industry. Finally, an increase in labor productivity in the United States could increase or reduce employment in the U.S. industry depending on the price sensitivity of the demand for the product.

Segments of the U.S. Motor Vehicle Industry

The manufacture of U.S. motor vehicles in the United States is reported in NAICS codes 3361, 336211, and 3363.[2] NAICS code 3361 (motor vehicle manufacturing) encompasses the manufacturing of passenger vehicles, heavy trucks, and buses. NAICS code 336211 covers the manufacturing of vehicle bodies. NAICS code 3363 (motor vehicle parts manufacturing) covers manufacturing of major motor vehicle systems, but may not include all of the indirect inputs such as steel. Table 1 reports the relative size of these three distinct segments and their engagement in international trade.

Table 1. Statistics for the U.S. Motor Vehicle Industry, by Segment in 2014

	NAICS 3361 Motor Vehicle Manufacturing	**NAICS 336211 Motor Vehicle Body Manufacturing**	**NAICS 3363 Motor Vehicle Parts Manufacturing**
Industry Employment (thousand)	176,001	42,917	501,065
Total Value of Shipments (million dollars)	307,269	13,225	244,688
Exports (million dollars)	72,797	452	53,180
Imports (million dollars)	190,764	784	106,487

Source: U.S. Census, ASM (accessed July 1, 2016); USITC DataWeb/USDOC (accessed July 1, 2016).

The data on the annual value of shipments and employment of the U.S. producers are from the Annual Survey of Manufactures and the Economic Census for 1997 through 2014. The data on the annual value of U.S. imports and exports are from the USITC's Trade Dataweb. They are the landed duty-paid value of U.S. imports for consumption and the free alongside ship value of U.S. domestic exports of these industries from 1997 to 2014.

[2] The six digit NAICS code 336211 Motor Vehicle Body Manufacturing is used instead of the four digit (3362), because the four digit category includes trailers that are produced with a separate supply chain that tends to have different suppliers.

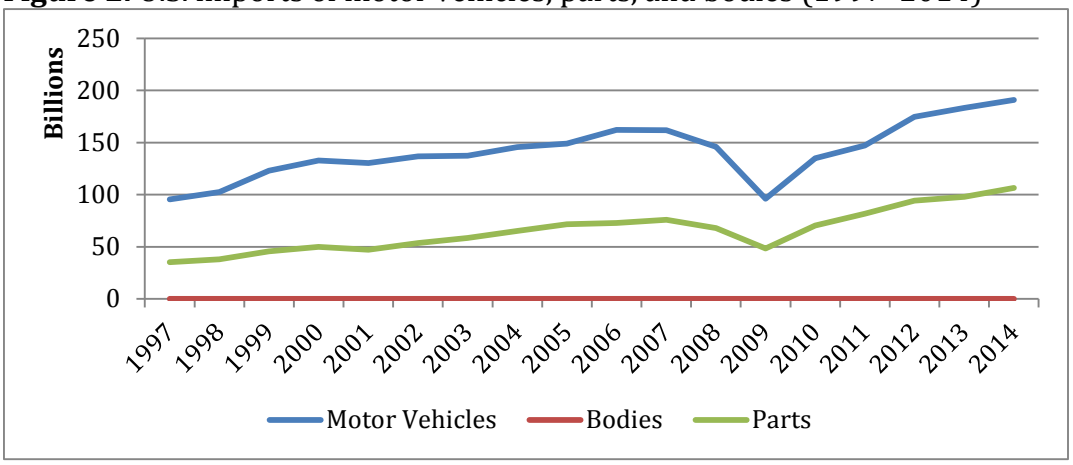
Evolution of the U.S. Motor Vehicle Industry

This section provides a short discussion of trends in each of the components of the employment analysis: imports, exports, labor productivity, and domestic consumption. Then the following section quantifies the contribution of these trends to changes in industry employment.

Imports

U.S. imports of vehicles, parts, and bodies all increased significantly during the 1997–2014 period. On a percentage basis U.S. parts imports increased the most (202 percent) to over $106 billion, while the $95 billion increase in the absolute value of vehicle imports to nearly $191 billion in 2014 was greater than the other two NAICS codes (figure 2). U.S. imports of bodies are relatively insignificant because bodies are typically produced at the assembly plant by the vehicle manufacturer and are thus unlikely to cross borders.[3]

Figure 2. U.S. imports of motor vehicles, parts, and bodies (1997–2014)



Source: USITC Dataweb (accessed July 12, 2016). Imports for consumption used. Corresponds to table A.2 in the appendix.

The four largest sources for U.S. imports of motor vehicles, parts, and bodies in 2014 were Mexico, Canada, China, and Japan. Canada and Mexico, along with the United States, are part of North America's integrated motor vehicle supply chain, with vehicles and parts traded freely between the three countries.[4] Mexico has become the leading supplier of parts and vehicles to the United States, rising from third largest in 1997. China is currently the third largest source of vehicle parts to the

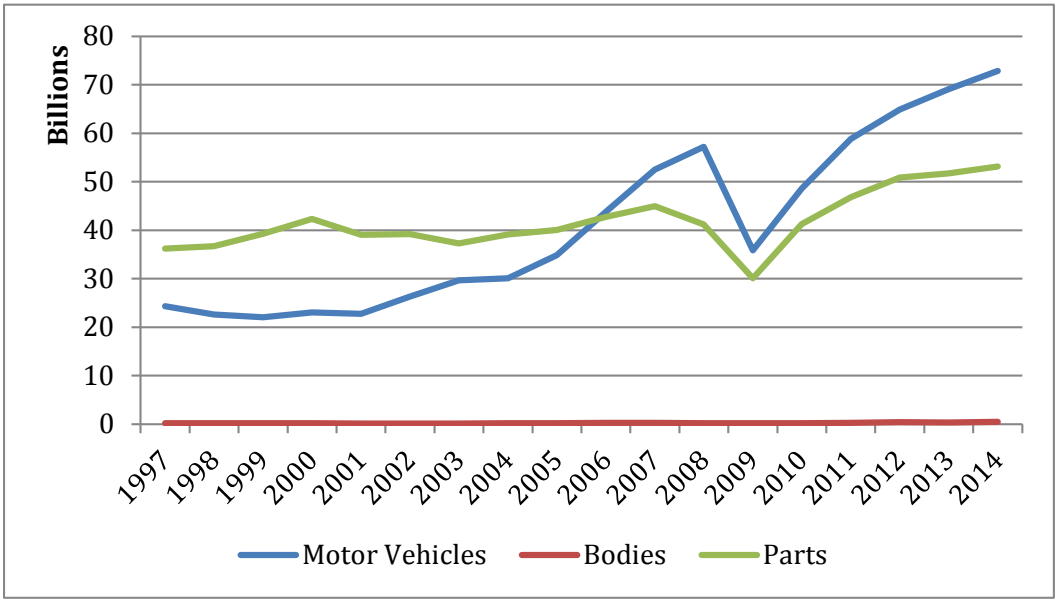
[3] Klier and Rubenstein, Who Really Made Your Car? 2008, 85–86.
[4] USITC, Economic Impact of Trade Agreements, 180; Coffin, Passenger Vehicle Industry and Trade Summary, May 2013, 53.

United States, supplying over $12 billion in 2014, compared to $300 million in 1997.[5] Japan is also a significant supplier of vehicles and parts to the United States. However, Japanese companies have invested heavily in Mexico and Canada in recent years, which have likely redirected supply to the United States to come from those countries rather than directly from Japan.[6]

Exports

U.S. exports of motor vehicles, parts, and bodies have increased significantly, from less than $61 billion in 1997 to more than $126 billion in 2014. U.S. exports of motor vehicles increased the most, growing from $24 billion in 1997 to $73 billion in 2014 (figure 3).

Figure 3. U.S. exports of motor vehicles, parts, and bodies (1997–2014)



Source: USITC Dataweb (accessed July 12, 2016). Domestic exports used. Corresponds to table A.3 in the appendix.

The four largest destinations for exports of products of vehicles, parts, and bodies in 2014 were Canada, Mexico, China, and Germany. Due to the integration of the North American supply chain discussed above, Canada and Mexico are also top destinations for U.S. exports. Canada is the leading U.S. market for these exports of all three categories, whereas Mexico is one of the top four destinations for all three categories. China, the world's largest single-country vehicle market, is a major destination for U.S. vehicles and part exports, ranking as the second largest market for U.S. motor vehicle exports, and third largest for motor vehicle parts exports. Germany is the third

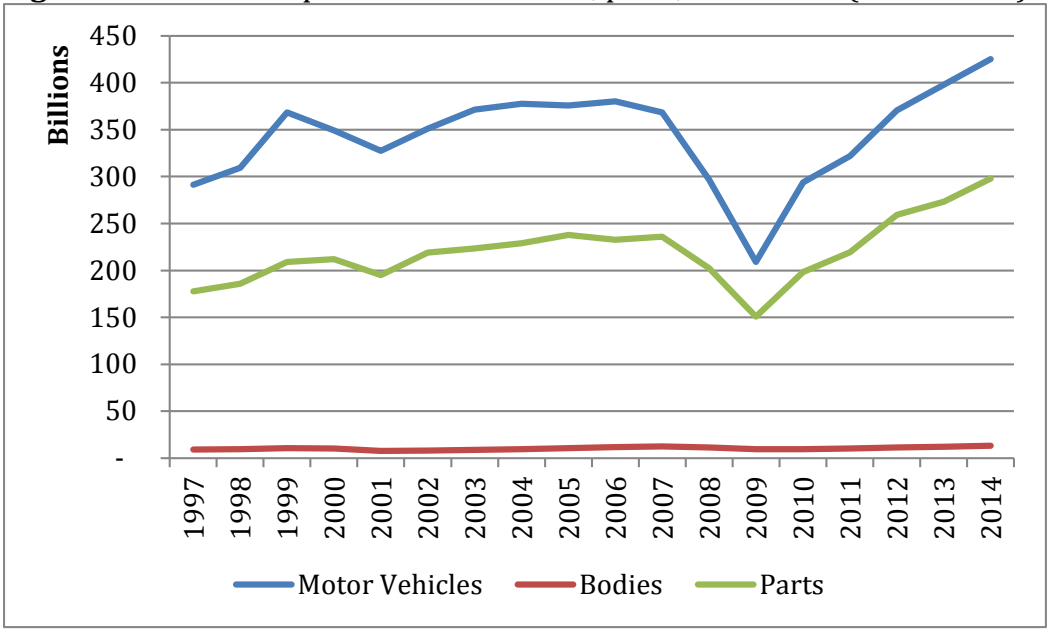
[5] USITC, Dataweb (accessed July 12, 2016).
[6] Coffin, Passenger Vehicle Industry and Trade Summary, 2013, 11.

largest U.S. market for motor vehicle exports, but U.S. exports of motor vehicle bodies and parts to Germany total less than $1 billion.

Consumption

Consumption of goods in this industry is primarily driven by macroeconomic trends. When the economy is growing, consumers purchase vehicles. When consumers purchase vehicles, manufacturers purchase parts. When consumers stop purchasing vehicles, manufacturers stop purchasing parts, as occurred during the economic downturn (figure 4).

Figure 4. U.S. consumption: motor vehicles, parts, and bodies (1997–2014)



Source: U.S. Census, ASM and U.S. International Trade Commission Dataweb (accessed July 1, 2016). Note: Total consumption is measured as total shipments of the U.S. industry minus U.S. exports plus U.S. imports. Corresponds to table A.4 in the appendix.

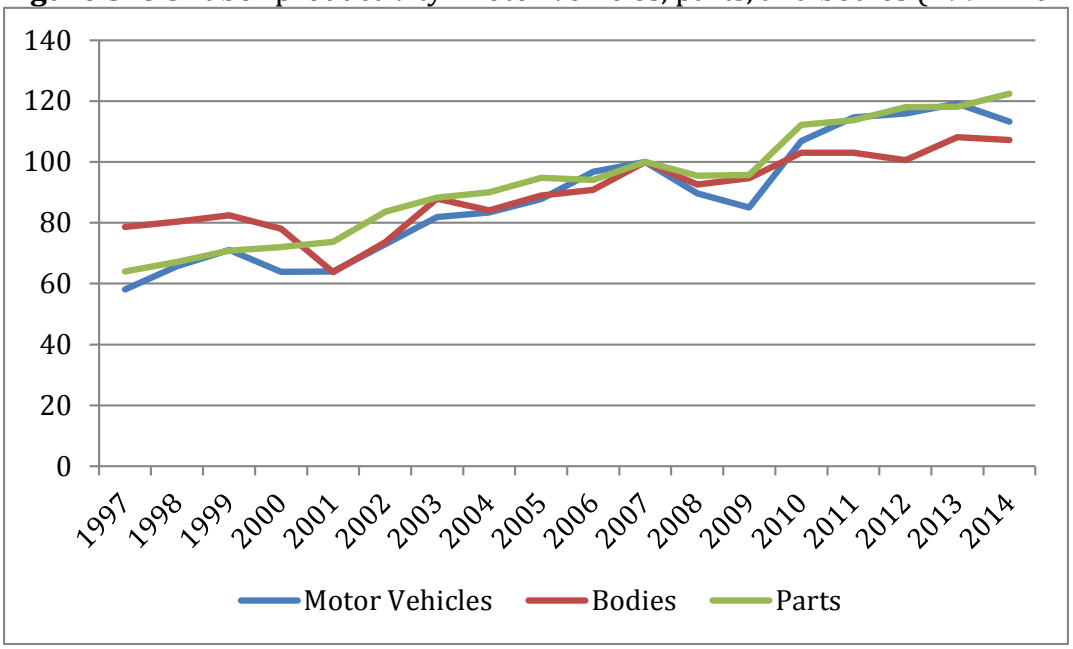
Productivity

During the 1997–2014 period, labor productivity in all three industry segments increased (figure 5). Several factors have likely contributed to these improvements in productivity. First, there has been a rise in the use of technology––including robotics, automation, and digital technologies–– in the production of vehicles and parts. The motor vehicle industry is the top purchaser of industrial robots, and installations of industrial robots increased significantly between 2010 and 2014.[7]

[7] International Federation of Robotics, "Industrial Robot Statistics," 2015. http://www.ifr.org/industrial-robots/statistics/.

Further, many vehicle manufacturers upgraded assembly plants to be more flexible, allowing different vehicle models to be produced on the same assembly line.[8] This flexibility reduces the need for different plants for each specific model and helps manufacturers to redistribute assembly based on demand. Also, upgraded plants operating at higher production capacities were likely one of the factors in increased productivity. Finally, the closure of older plants reduced overall production capacity, but likely contributed to capacity utilization rising to 77 percent for all motor vehicle and parts manufacturing in 2014, a level not seen since the first quarter of 2005.[9] Productivity in the remaining plants was likely higher than those that were closed during the economic downturn.

Figure 5. U.S. labor productivity: motor vehicles, parts, and bodies (1997–2014)



Source: U.S. Bureau of Labor Statistics, Labor Productivity and Costs Database. Corresponds to table A.5 in the appendix.

Framework for Analyzing the Changes in Industry Employment

We model the average annual percent changes in industry employment as a combination of the percent changes in several components – (1) labor productivity, (2) total U.S. consumption of the products of the industry, (3) U.S. exports of the products of the industry, and (4) the U.S. imports of these products – based on a mathematical accounting relationship between the industry variables.

[8] Coffin, Passenger Vehicle Industry and Trade Summary, 2013, 19.
[9] Federal Reserve, G.17 Industrial Product ion and Capacity Utilization, June 15, 2016. https://www.federalreserve.gov/releases/G17/default.htm.

The model quantifies the contributions of the components to the whole, based on the growth rates of the components and their initial size relative to total industry shipments.

Equation (1) defines the value of output per worker in segment j in year t:

$$P_{jt}\ L_{jt} = \frac{X_{jt} + C_{jt} - M_{jt}}{E_{jt}} \tag{1}$$

L_{jt} is labor productivity, defined as physical output per worker, and P_{jt} is the price of the product. The numerator on the right-hand side of equation (1), U.S. exports X_{jt} plus total U.S. consumption C_{jt} minus U.S. imports M_{jt}, is equal to total shipments of the segment. E_{jt} is employment in the segment. Equation (1) implicitly defines the price index P_{jt} as a function of the other variables.

Equation (2) is an expression for employment in segment j based on equation (1).

$$E_{jt} = \frac{1}{L_{jt}} \left(\frac{X_{jt}}{P_{jt}} + \frac{C_{jt}}{P_{jt}} - \frac{M_{jt}}{P_{jt}} \right) \tag{2}$$

Equation (3) relates the percent changes in industry employment to the percent changes in the price-deflated values of the other variables, based on a log-linearization of equation (2).

$$\hat{E}_{jt} \cong \left(\frac{X_{j,t-1}}{V_{j,t-1}} \right) \hat{X}_{jt} - \left(\frac{M_{j,t-1}}{V_{j,t-1}} \right) \hat{M}_{jt} + \left(\frac{C_{j,t-1}}{V_{j,t-1}} \right) \hat{C}_{jt} - \hat{L}_{jt} \tag{3}$$

where $V_{j,t-1} = X_{j,t-1} + C_{j,t-1} - M_{j,t-1}$ is the value of domestic shipments of segment j in year $t-1$. $\hat{E}_{jt}$ represents the percent change in employment in segment j from year $t-1$ to year t, $\frac{E_{jt} - E_{j,t-1}}{E_{j,t-1}}$. $\hat{X}_{jt}$, $\hat{M}_{jt}$, $\hat{C}_{jt}$, and $\hat{L}_{jt}$ represent the percent changes in the other variables from year $t-1$ to year t. The sum of the components on the right-hand side of equation (3) is approximately equal to the percent changes on the left-hand side of equation (3).[10]

Equation (3) is a decomposition of employment changes into changes in the component factors, and in this sense it is a quantification of the *contribution* of each factor. However, it is not an analysis of

[10] There is a linear approximation error when the formula in equation (3) is applied to the data, since equation (2) is not log-linear.

causation or a prediction of future effects.[11] The interpretation of the measured contribution of each factor is that it indicates how much employment would change if all other factors remained fixed, while the factor of interest changed by the historical amount.

Estimated Contributions to Changes in Industry Employment

Table 2 reports the contribution of each of the factors to the year-to-year percent changes in employment in the three segments of the combined U.S. motor vehicle industry. For each of the contributing factors, the table reports the percentage change in employment due to the factor, rather than the percentage change in the factor.

Table 2. Analysis of Average Annual Growth Rates, 1997-2014

	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
U.S. Industry Employment	**-1.4**	**0.3**	**-1.1**
Contributing Factors			
U.S. Exports	1.2	0.0	0.7
U.S. Imports	-2.9	0.0	-2.2
Total U.S. Consumption	4.9	2.5	4.2
U.S. Labor Productivity	-4.4	-2.2	-4.0

Source: USITC calculations. The linear approximation error in these calculations is discussed in note 10.

Overall, there was a decline in employment in the motor vehicle and parts segments and a slight increase in employment in motor vehicle body manufacturing. In all three segments, there were negative contributions to employment associated with increases in labor productivity and imports, and there were positive contributions to employment associated with increases in exports and total consumption in the U.S. market.

According to Table 2, employment in the U.S. motor vehicle manufacturing segment (NAICS 3361) declined by 1.4 percent per year, on average, between 1997 and 2014. The increase in labor productivity would have resulted in a 4.4 percent average reduction in employment if all of the other factors had remained constant, while the increase in U.S. imports would have reduced employment by 2.9 percent. The negative employment effects of these two factors were partly

[11] In general, the effect of a change in imports on U.S. employment will depend on the underlying source or cause of that change. If the increase in U.S. imports is due to a reduction in foreign production costs, then the increase in imports will be associated with a reduction in U.S. employment. However, if the increase in U.S. imports is due to an increase in U.S. aggregate demand, then it will be associated with an increase in U.S. employment.

offset by a significant increase in total U.S. consumption and a smaller increase in U.S. exports, for a net 1.4 percent reduction in employment.

On the other hand, employment in the U.S. motor vehicle body manufacturing segment (NAICS 336211) increased by 0.3 percent per year on average. The increase in labor productivity would have resulted in a 2.2 percent average reduction in employment if all of the other factors had remained constant. The increase in total U.S. consumption would have resulted in a 2.5 percent average increase in employment per year more than offsetting the negative effect of the increase in labor productivity, resulting in a net 0.3 percent increase in employment. U.S. imports and exports had a less significant impact on employment.

Finally, employment in the U.S. motor vehicle parts manufacturing segment (NAICS 3363) declined by 1.1 percent per year on average. The increase in labor productivity would have resulted in a 4.0 percent average reduction in employment if all of the other factors had remained constant, and the increase in imports would have reduced employment by an additional 2.2 percent. These two factors were partly offset by the increase in total U.S. consumption and the increase in exports, for a net 1.1 percent reduction in employment.

Conclusions

The employment changes in the U.S. motor vehicle industry between 1997 and 2014 reflect several trade and non-trade factors: there were negative contributions from increases in labor productivity and imports and positive contributions from increases in total consumption and exports. The growth accounting framework in this research note provides a simple method for quantifying the relative contributions of these factors using available industry data.[12]

When we split the motor vehicle manufacturing industries into three segments, we find that the relative contributions of the trade and non-trade factors are quite different, and this is ultimately reflected in the different historical changes in employment levels in the segments. While labor productivity and imports contributed to employment declines in motor vehicle and parts manufacturing, there were larger impacts from changes in labor productivity. This is notable since China's accession to the WTO as well as NAFTA and additional U.S. trade agreements were implemented over the time period, which likely accelerated the growth of U.S. imports and exports

[12] It would be straightforward to replicate this analysis for any of the U.S. manufacturing industries in the *Annual Survey of Manufactures*.

in these industries. However, trade appeared to play a less significant role in employment declines than the increased use of technology and other factors that increased labor productivity. In all three industries, increased domestic consumption played a larger role than exports in offsetting (partially in motor vehicle and parts manufacturing and completely in body manufacturing) employment reductions that are associated with increases in labor productivity and imports.

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Appendix Tables

Table A1. Data for Figure 1

Year	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
1997	236,247	42,773	653,245
1998	234,960	43,306	789,565
1999	233,053	43,170	799,174
2000	230,544	43,844	802,575
2001	213,761	41,254	732,704
2002	219,243	41,450	721,655
2003	210,387	40,874	671,990
2004	215,852	43,779	644,848
2005	204,065	48,342	612,872
2006	205,843	50,906	577,729
2007	179,885	49,165	580,845
2008	156,251	46,002	526,672
2009	124,792	37,561	397,277
2010	137,284	35,891	388,920
2011	148,009	37,665	404,636
2012	157,217	41,176	466,061
2013	166,608	41,881	483,131
2014	176,001	42,917	501,065

Source: U.S. Census, ASM (accessed July 1, 2016).

Table A2. Data for Figure 2

Year	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
1997	95,437,769,729	343,174	35,276,945,010
1998	102,498,662,613	366,237	37,899,879,496
1999	122,925,815,555	322,635	45,603,846,842
2000	132,814,615,371	414,446	50,000,082,551
2001	130,431,903,687	447,466	47,098,009,374
2002	136,633,879,892	403,039	53,700,221,933
2003	137,410,172,910	509,193	58,505,349,398
2004	145,690,283,994	626,834	65,292,234,447
2005	148,887,041,680	921,513	71,603,562,761
2006	162,140,539,954	1,019,701	72,955,491,912
2007	161,958,491,954	997,625	75,860,098,408
2008	146,025,142,306	822,811	67,949,072,917
2009	96,179,426,186	592,151	48,470,496,097
2010	134,994,259,755	661,431	70,524,147,403
2011	147,092,793,536	743,762	81,607,164,827
2012	174,779,220,486	955,985	94,269,326,731
2013	183,259,646,796	754,065	97,936,887,818
2014	190,763,845,384	783,795	106,486,821,687

Source: USITC Dataweb (accessed July 12, 2016). Imports for consumption used.

Table A3. Data for Figure 3

Year	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
1997	24,290,051,624	174,959,105	36,230,121,080
1998	22,619,412,870	179,323,308	36,716,266,188
1999	22,063,782,982	212,026,205	39,279,833,905
2000	23,022,509,474	154,036,319	42,288,439,404
2001	22,776,851,427	136,410,773	39,076,167,258
2002	26,314,058,613	109,875,547	39,160,015,750
2003	29,658,892,594	117,550,769	37,281,356,161
2004	30,108,237,085	160,398,476	39,128,056,532
2005	34,851,026,092	197,413,451	40,011,521,051
2006	43,829,584,407	237,976,908	42,739,107,919
2007	52,469,265,443	276,249,943	44,984,131,886
2008	57,176,246,645	192,739,988	41,213,374,787
2009	35,856,069,710	157,655,516	30,074,176,845
2010	48,620,856,753	169,252,333	41,272,401,607
2011	58,806,191,210	235,503,464	46,812,312,596
2012	64,860,753,616	363,704,168	50,878,115,492
2013	69,082,592,413	360,700,398	51,735,753,594
2014	72,839,507,001	451,661,832	53,157,860,602

Source: USITC Dataweb (accessed July 12, 2016). Domestic exports used.

Table A4. Data for Figure 4

Year	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
1997	291,200,575,105	9,008,680,215	177,558,392,930
1998	309,203,915,743	9,696,170,914	185,659,644,308
1999	368,262,006,573	10,520,423,609	209,121,022,937
2000	349,265,461,897	10,335,162,410	212,047,729,147
2001	327,389,837,260	7,660,342,055	195,142,004,116
2002	351,019,116,279	8,019,082,163	219,059,371,183
2003	371,182,198,316	8,648,213,642	223,517,327,237
2004	377,482,850,909	9,437,590,436	228,806,123,915
2005	375,879,985,588	10,797,334,100	237,697,603,710
2006	380,171,013,547	11,855,509,724	232,515,347,993
2007	368,526,939,511	12,350,667,375	235,829,570,522
2008	296,927,924,661	11,274,819,071	202,349,665,130
2009	208,927,369,476	9,571,669,495	150,814,825,252
2010	293,804,962,002	9,637,047,179	198,470,063,796
2011	322,072,260,326	10,102,314,259	219,559,277,231
2012	370,434,487,870	11,439,853,281	259,114,462,239
2013	397,973,706,706	12,181,962,365	273,190,160,854
2014	425,235,208,535	13,225,048,133	297,994,413,573

Source: U.S. Census, ASM and U.S. International Trade Commission Dataweb (accessed July 1, 2016). Note: Total consumption is measured as total shipments of the U.S. industry minus U.S. exports plus U.S. imports.

Table A5. Data for Figure 5

Year	NAICS 3361 Motor Vehicle Manufacturing	NAICS 336211 Motor Vehicle Body Manufacturing	NAICS 3363 Motor Vehicle Parts Manufacturing
1997	58.112	78.671	63.985
1998	65.767	80.359	67.179
1999	71.129	82.514	70.861
2000	63.845	78.043	71.969
2001	63.958	63.702	73.772
2002	72.991	73.688	83.6
2003	81.872	87.959	88.213
2004	83.426	84.1	89.981
2005	87.809	88.915	94.765
2006	96.781	90.853	94.052
2007	100	100	100
2008	89.634	92.593	95.418
2009	85.019	94.633	95.736
2010	106.846	103.01	112.19
2011	114.587	103.016	113.679
2012	115.951	100.59	118.032
2013	119.192	108.096	118.078
2014	113.278	107.253	122.47

Source: U.S. Bureau of Labor Statistics, Labor Productivity and Costs Database.