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Energy and Resources Group
University of California at Berkeley
USA

for her Paper entitled:

“Shop ‘Till We Drop: A Historical and Policy Analysis of Retail Goods Movement in the US”
Shop ’Till We Drop: A Historical and Policy Analysis of Retail Goods Movement in the U.S.

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ABSTRACT

The movement of retail goods is central to modern economies and is a significant – but understudied – fraction of our overall energy footprint. Thus, we propose a new category for energy analysis called Retail Goods Movement (RGM) that draws its boundaries around the portion of freight dedicated to retail goods and the portion of driving dedicated to shopping. Historically, the components of RGM have not enjoyed policy priority. However, the net payoff from energy research and policy directed at RGM may now be high enough relative to other options to deserve increased investment. We combine a quantitative decomposition of the dynamics of RGM energy use with a qualitative discussion of what trends could have contributed to them. The RGM sector’s energy use grew from 1.3EJ (2.8% U.S.) in 1969 to 7.0 EJ (6.6% U.S.) in 2009. The major drivers were increases in: population, freight tonnage (before 1990), distance freighted per tonne and driven per shopping trip (after 1990), and weekly shopping trips per household (before 1995). RGM energy intensity increased per capita (180%), per constant dollar GDP (60%) and per retail expenditure (140%). Finally, we describe policy recommendations that could become the basis of a sound RGM resource plan.
1. INTRODUCTION

The traditional division of the transportation sector into two subsectors – personal transport and freight transport – masks connections between the two. For examples of this division, see the chapter organization of the Transportation Energy Data Book (1), or recent research on the global climate impact of transportation (2). Yet, the same act of consumption increases the likelihood of both an individual round trip to the retail outlet and a chain of freight shipments to restore the inventory of the retail node (see Figure 1). As shown in Figure 2, we find it more revealing and useful to quantify this overlap between the two sectors, which we call “Retail Goods Movement” (RGM).

Figure 1: Flow of goods from point of manufacture/import to the consumer
Transportation (represented by arrows) occurs on the freight side and on the personal side of the retail outlet
In the past, the separate components of RGM have not enjoyed policy priority. U.S. transportation energy policy has historically focused on individual driving instead of freight (3). Now freight is the fastest growing category of energy use in the transportation sector, and is growing faster than most other energy using sectors in both absolute terms and intensity (4). Similarly, most transportation policy affecting personal transport has historically focused on commuting (3), but driving for commuting is shrinking as a percent of kilometers (km) driven in favor of other trip purposes such as shopping and social/recreational trips (5).

RGM energy use is increasing faster than even aviation: since 1969, RGM’s energy use has increased 440% compared to aviation’s 70%. Aviation energy use contributed 2.2% of US total energy use, while RGM accounted for 6.6% in 2009 (7). And yet, aviation’s energy and climate impact has received significant attention (6) (7).

As we show in this paper, The RGM sector’s energy use grew from 1.3EJ (2.8% U.S. total) in 1969 to 7.0 EJ (6.6% U.S. total) in 2009. These figures translate to just over 6% of the US total greenhouse gas emissions (8). In the decomposition analysis, we explore the factors which contributed quantitatively to that increase. Table 1 shows which of these factors were most responsible for the growth in RGM energy use. Table 2 shows our list of contextual explanations for the changes in the factors from Table 1.
Table 1: **Summary of the key contributors to the 440% increase in Retail Goods Movement energy use between the late 1960s and 2009, from 1.3 EJ to 6.9 EJ**

Overall, retail freight contributed ~70% of the increase in RGM energy use.

<table>
<thead>
<tr>
<th>Driving-for-shopping</th>
<th>Late 1960s to Late 1980s</th>
<th>1990 to 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>● Increase in population</td>
<td>● Increase in population</td>
</tr>
<tr>
<td></td>
<td>● Increase in weekly shopping trips</td>
<td>● Increased distance per shopping trip</td>
</tr>
<tr>
<td></td>
<td>*Mitigated by improved MPG resulting from CAFE legislation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Retail freight</th>
<th>Late 1960s to Late 1980s</th>
<th>1990 to 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>● Increased tonnage (per capita and per retail dollar)</td>
<td>● Increase in distance shipped per tonne</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Increase in energy intensity per tonne-km</td>
</tr>
</tbody>
</table>

Table 2: **Proposed explanations for changes in the key factors behind the increase in Retail Goods Movement energy use**

<table>
<thead>
<tr>
<th>Contributor to increase in RGM energy use from Table 1</th>
<th>Proposed explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>More frequent shopping trips per capita and per household, 1969-1995</td>
<td>● Expansion of the utility of shopping (shopping for fun, relaxation, exercise)</td>
</tr>
<tr>
<td></td>
<td>● Increase in women in the workplace and related fragmentation of household organization (41% of women worked in 1969, up to 59% in 1995)</td>
</tr>
<tr>
<td></td>
<td>● Move to fresher foods and more frequent grocery shopping (e.g. 27% increase in fresh fruit sales compared to 2% increase in preserved in the relevant time period)</td>
</tr>
<tr>
<td>Increase in kms / trip, 1990-2009</td>
<td>● Fewer retail stores density from ~9 per 1000 people to ~4 per 1000 people</td>
</tr>
<tr>
<td></td>
<td>● Segregation of residential and commercial areas</td>
</tr>
<tr>
<td>Increase in distance shipped / tonne, 1967-2007</td>
<td>● Deregulation driving down the costs of trucking a tonne-km from by 12-77% per tonne-km depending on truckload size.</td>
</tr>
<tr>
<td></td>
<td>● Increase in share of retail goods that are imported</td>
</tr>
<tr>
<td>Increase in energy intensity / tonne-km for retail freight, 1967-2007</td>
<td>● Deregulation driving down the cost of trucking compared to rail and barge leading to some modal shift</td>
</tr>
<tr>
<td></td>
<td>● Just-in-Time delivery trend favoring trucks over rail to barge</td>
</tr>
</tbody>
</table>

All these factors suggest that the net payoff from energy research and policy directed at RGM may deserve increased investment. In the following section we:

- Define and develop the new category of transportation services: “Retail Goods Movement” (RGM);
- Calculate the energy used for RGM, and to changes in that energy use for the past 40 years in the U.S.;
- Decompose those changes to reveal key factors behind the change;
- Trace the history of both qualitative and quantitative indicators that account for the changes observed in the factors; and
- Suggest policy approaches that can slow and reverse the increase in RGM energy use.
Energy-related policy that addresses the RGM will have features distinct from other transportation energy policy, and addressing RGM as one integrated sector will have priorities different from energy policy that addressed to each component separately.

2. EXISTING LITERATURE

This paper presents the first peer-revised historical statistical and policy consideration of the energy impact of RGM as a consolidated sector (retail freight and driving-for-shopping) in the U.S. Our work builds on existing literature that has addressed elements of RGM, or has developed the use of decomposition as a technique to understand energy changes over time.

2.1 Literature about driving-for-shopping

A detailed study of change in US driving behavior was done by Hu in 2004, which looked at change over time of certain driving habits from past editions of the National Household Travel Survey (9). We use the same source. However, whereas Hu only looked back to the 1995 study, we start in 1969. Hu did not explore the energy implications of the longitudinal behavioral changes, which is the focus of this paper.

A sizable body of literature has shown that proximity is not key determinant of retail store choice for consumers (10) (11). This literature challenges some traditional frameworks for retail placement, including central place theory which found a more clear relationship between proximity of consumer to the retail, and likelihood of purchase at that retailer (e.g. 12). It can also be seen as an extension of Alderson’s “dynamic” theories of heterogeneity and retailer differentiation (13). Modern researchers have begun to point out the energy implications of this: Handy et al found that residents of “new urban” communities with walkable shopping did not necessarily use the nearby stores, while Austin residents from other neighborhoods in turn drove from their neighborhoods to the “walkable” retail district. This led the authors to question the claim that mixed-use developments will necessarily reduce fuel use because of the complexity of shopping travel, a concern which in part motivated the research in this paper (14). In addition, Cervero found in 2006 that mixed job/residential development reduces vehicle-km travelled more than mixed retail/residential development (15).

2.2 Literature about retail-driven shifts in freight

Freight as an energy-using sector has a notably poor literature and policy history, as noted by the Transportation Research Board (3). Schipper et al. did the most comprehensive analysis of the drivers behind changes in freight energy use in the U.S. in 1992, updated in 2011. These studies did not remark on the role of retail goods compared to other goods.
2.3. Literature about the connection between driving-for-shopping and freight, including e-commerce

A foundational work on the energy implications of the linkage between driving for shopping and freight was by McKinnon and Woodburn in 1994. They remarked: “Retailers are in the unique position of being able to influence the levels of both lorry and car traffic… This suggests that, when assessing the environmental impact of retailing operations, it is important to regard the supply chain as extending as far as the customer’s home” (16).

Since then, the work that most directly relates to RGM addresses the energy implications of on-line shopping. However, while catalogue and on-line commerce has seen a tenfold increase since 1969, the same cannot be said for energy and environmental literature related to it. The new relevant studies tend to take the form of life-cycle assessments (LCAs) comparing the energy impact of delivering a product by going to the store, or by on-line shopping. Matthews et al. (2001) and Fichter (2002), reviewing impact assessments for books and groceries respectively, found that on-line shopping could reduce total transportation energy associated with the good by 0% (break even) to 35% (17) (18). McKinnon et al. found that savings could be as high as 95%, under the right conditions in the UK (19). These conditions include being sure that the delivered good is actually displacing a trip to the store and that the package is delivered on the first trip. However, in a case study on electronics, Weber pointed out that if e-commerce causes goods to fly on planes when they otherwise would not have, then it is the less environmentally friendly option (20). The “right” conditions noted by McKinnon and Fichter and “wrong” conditions noted by Weber inform our policy implications relating to e-commerce.

2.4 Literature about the use of decomposition as a technique for understanding the impact of factors on changing national-level energy use over time

Our approach builds on a body of literature that uses decomposition techniques such as the Kaya Identity to analyze changes in energy use in large sectors of national economies across time (21).

The Kaya Identity multiplies population, energy intensity, and activity (shown in the Kaya Identity as gross world product, and here as trips and shipments) to measure a composite measure of impact called F. Analysts can then index both F and its constituent components to show changes in F as well as to evaluate the relative importance of each component of F.

Log-Mean Divisia Index LMDI is similar approach to Kaya, but used when factors are additive to contain residuals, as our factors are in the combined RGM analysis (22). Our integration of decomposition with contextual historical data, cultural trends, and policy implications draws on Raupach et al. (15). Like Raupach, we use ratios to explain how components of the decomposition relate to each other. Unlike Raupach, we use ratios between the decomposition factors and economic markers such as GDP, cost of fuel, and expenditures for retail.

Some researchers have already applied this technique to transportation. Schipper published several studies which use decomposition to explore the increase in national transportation emissions in the U.S. and abroad, and to project energy use into the future (4) (23) (24).

Steenhof et al. (25) used the same decomposition technique to understand the increase in Canada’s emissions from freight and also project them into the future. Both Schipper et al. (in the US) and
Steenhof noted the modal shift to trucks was a key culprit on both sides of the border, and that freight’s share of both nations’ energy and emissions bill would continue to without policy and technical change. In addition to the shared methodologies, this study can be seen as a deeper investigation of one tranche of the freight sector called out by these earlier authors as an important focus for research.

3. METHODS AND DATA

We organize data from publically available data through the lens of “retail goods,” which has not been done before. We have extracted data from older data sets, and standardized this data across years so as to facilitate comparison. This data set is both novel and useful to other researchers and is available in the supporting materials section.

3.1 Driving-for-shopping

The impact of driving-for-shopping is measured by Joules (J) for driving-for-shopping, the product of Vehicle Kilometers Travelled for Shopping (VKTs) and energy intensity of each km. We decomposed VKTs into five factors (see Equation 1). We chose factors which were policy-relevant and available from the National Highway Travel Survey (NHTS) for the sake of data consistency (26).

\[
\text{VKT}_s = U \text{S}_{\text{pop}} \times (\frac{\text{people}}{\text{household}})^{-1} \times \text{person } \text{shopping trips } \text{in } \text{household} \times \text{person } \text{shopping trip } \text{in } \text{trip}
\]  

(1)

Next, we calculated the gallons of fuel burnt for driving-for-shopping by multiplying VKT, by the weighted average fuel efficiency of the on-road fleet in gallons per kilometer (GPK) in the appropriate year (27). The GPK figure used is a mileage-weighted average of passenger car (PC) and light trucks (LT) as shown in Equation 2. Equation 3 shows how the results of 1 and 2 are combined to get total energy use for driving-for-shopping (dfs) measured in Joules (J). We assume that all fuel was gasoline.

\[
\frac{\text{gallon}}{\text{km}} = (k\text{m}_{\text{PC}} \times \text{gallon}_{\text{PC}} + k\text{m}_{\text{LT}} \times \text{gallon}_{\text{LT}})/(k\text{m}_{\text{PC}} + k\text{m}_{\text{LT}})
\]  

(2)

\[
J_{\text{dfs}} = \frac{\text{gallon}}{\text{km}} \times \text{VKT}_s \times \frac{1}{\text{gallon}}
\]  

(3)

For the presentation of results, we indexed values to 1990 (for driving) or 1987 (for freight) because a) both sectors experienced significant shifts in around those times better demonstrated by the central index b) data was directed collected for 1990 for driving and 1987 for freight, and we believe it would be more accurate to use non-extrapolated data for the fulcrum.
Finally, we performed a literature review of historical, sociological, and business literature to look for qualitative information that could create an explanatory narrative around the most important ratios.

### 3.2 Retail Freight

We used analogous methods for freight analysis. Retail freight (RF) activity is measured in Vehicle Tonne Kilometers Travelled (VTKT_{RF}) shown in Equation 3 and energy use for retail freight (J_{RF}), shown in Equation 4.

\[ VTKT_{RF} = \frac{\text{avg} \ km \times \text{tonnes per trip}}{\text{year}} \]  
\[ J_{RF} = \sum_{i=1}^{I} \sum_{j=1}^{J} VTKT_{i,j} \ast \left( \frac{J}{VTKT} \right) \]

In Equation 4, J indicates units of Joules, “i” represents the mode of transportation (i = 1 means railroad, 1=2 means truck, etc.), “j” stands for class of retail freight (j=1 means textiles and leathers, etc.).

### 3.3 Combined RGM

Combining the two sets of data into one presents a few hurdles. First, the data sets do not draw data from the same years. We took a simple approach to this problem, extrapolated linear growth for each variable between each pair of contiguous years in the data set.

Because the RGM energy use was derived from additive factors, we used an LMDI decomposition (see methods). The effect “D” for a given variable is calculated as shown in Equation 5:

\[ Dx_{i} = \exp \left( \sum_{i} \frac{L(U_{i}^{T}, P_{i}^{0})}{L(U_{i}^{T}, P_{i}^{0})} \ln \left( \frac{\hat{x}_{i}}{x_{i}} \right) \right) \]

\( x_{i} \) is a variable (e.g. \( x_{1} \) equals US population), i is a sub-category (i = 1 is driving, i = 2 is freight), V is the output of total energy use, T = 0 is the base year, and T is the year in question.

\[ L(a,b) = (a-b)/(\ln a - \ln b) \]

### 3.4 Data

Our earliest driving data is from 1969, while our earliest freight data is from 1967. Therefore, all driving indices, and all combined RGM indices start at 1969, while the freight indices start in 1967. All dollars are measured in 2007 USD and inflated using the consumer price index (CPI),
except where explicitly noted. Table 3 summarizes the data sources, benefits, and detriments of the sources.

<table>
<thead>
<tr>
<th></th>
<th>Driving for Shopping</th>
<th>Retail Freight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data source</td>
<td>National Household Transportation Survey</td>
<td>Commodity Flow Survey</td>
</tr>
<tr>
<td>Benefits</td>
<td>Nationwide sample, relatively constant</td>
<td>Regular surveys, nationwide sample, use of NAICS codes</td>
</tr>
<tr>
<td></td>
<td>categorization and historical reach</td>
<td></td>
</tr>
<tr>
<td>Limitations</td>
<td>Slight shifts in categorization, lack of</td>
<td>Shifts in NAICS codes, poor data</td>
</tr>
<tr>
<td></td>
<td>statistical markers in earlier sets (such</td>
<td>formatting/availability for early years,</td>
</tr>
<tr>
<td></td>
<td>as sample size), sporadic sampling gaps</td>
<td>no explicit tracking of empty</td>
</tr>
<tr>
<td></td>
<td>(five or more years) and poor data</td>
<td>backhauls.</td>
</tr>
<tr>
<td></td>
<td>formatting and usability for earlier years.</td>
<td></td>
</tr>
</tbody>
</table>

Most data related to driving-for-shopping section comes from the National Household Travel Survey (NHTS) and preceding surveys (5). Historical data about the average kilometers per gallon of vehicles and energy content of fuel was available from the Transportation Energy Data Book series (28), Annual Energy Reviews (29), and the Environmental Protection Agency (30).

Data for the freight analysis came from the Commodity Flow Survey (CFS) (31) and its earlier iterations (32). Using the two-digit codes from the Standard Industry Classification (SIC) and North American Industry Classification System (NAICS), we included and excluded categories of freighted goods based on whether or not those goods went to retail final destinations or not. To make this decision, we relied on descriptions of classifications in the CFS. Energy intensity data for freight modes in specific years was taken from appropriate editions of the Transportation Energy Data Book (1). More details can be found in the supporting material.

Our category for freight only includes freight that moves within the borders of the United States. Thus for imports, movements to the border of U.S. and movement within the country of production are excluded. Exploring these “imported” and “exported” freight emissions is beyond the scope of this paper, but will be integrated in the future, building on emerging research on this difficult-to-track topic. For example, Davis and Caldeira found that the transport emissions exported by the U.S. (fuel burned here for goods consumed elsewhere) about equals the transport emissions imported (transportation elsewhere for goods consumed here) (33). Yet Steenhof et al. found that one of the top causes of freight emissions increase in Canada was cross-border movement with the U.S. (25). We discuss the impact that rising imports have on domestic freight movements later in the paper.
4. RESULTS AND CONCLUSIONS

RGM sector’s energy use grew from 1.3EJ (2.8% U.S. total) in 1969 to 7.0EJ (6.6% U.S. total) in 2009. This 440% increase far exceeded the increase in all energy use in the U.S. (45% in the same time frame) and in the transportation sector (75%). Energy use for driving for shopping increased more sharply (160%) than all driving (45%), and energy use for retail freight increased faster (580%) than freight as a whole (120%) (27). Key contributors to the 440% increase are summarized in Table 1.

4.1 Contributors to Increase in RGM Energy Use

As shown in Tables 4 and 5, before 1990, increase in RGM energy use was driven mainly by population growth, increase in shopping trips per household, and increase in retail freight tonnage. After 1990, increase in RGM energy use was driven mainly by population growth, increase in shopping trip distances, and increase in distance travelled per tonne freight. As population growth is generally outside of the purview of transportation policy, we do not consider policy addressing population in our conclusions.

Table 4: Changes in five factors related to increase in energy use in driving to shop since 1969, indexed to 1990 = 1*

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq. 1</td>
<td>US Population</td>
<td>0.81</td>
<td>0.88</td>
<td>0.94</td>
<td>1.00</td>
<td>1.07</td>
<td>1.14</td>
<td>1.24</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>Households/Person</td>
<td>0.81</td>
<td>0.90</td>
<td>0.95</td>
<td>1.00</td>
<td>0.97</td>
<td>0.99</td>
<td>0.99</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>Person Trips/Household</td>
<td>0.67</td>
<td>0.85</td>
<td>0.94</td>
<td>1.00</td>
<td>1.23</td>
<td>1.12</td>
<td>0.97</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Vehicle Trips/Person Trip</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>1.00</td>
<td>0.94</td>
<td>0.95</td>
<td>0.99</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>Vehicle Kms per Trip</td>
<td>0.85</td>
<td>0.98</td>
<td>1.04</td>
<td>1.00</td>
<td>1.11</td>
<td>1.32</td>
<td>1.21</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>VKT for shopping</td>
<td>0.35</td>
<td>0.61</td>
<td>0.79</td>
<td>1.00</td>
<td>1.33</td>
<td>1.60</td>
<td>1.41</td>
<td>4.06</td>
</tr>
<tr>
<td>Eq. 2</td>
<td>VKT for shopping</td>
<td>0.35</td>
<td>0.61</td>
<td>0.79</td>
<td>1.00</td>
<td>1.33</td>
<td>1.60</td>
<td>1.41</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>Gallons per km</td>
<td>1.45</td>
<td>1.40</td>
<td>1.16</td>
<td>1.00</td>
<td>0.96</td>
<td>0.93</td>
<td>0.92</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Driving for shopping</td>
<td>0.50</td>
<td>0.85</td>
<td>0.92</td>
<td>1.00</td>
<td>1.29</td>
<td>1.49</td>
<td>1.30</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td>Driving for Shopping Energy Use, EJ</td>
<td>0.7</td>
<td>1.3</td>
<td>1.4</td>
<td>1.5</td>
<td>1.9</td>
<td>2.2</td>
<td>1.9</td>
<td></td>
</tr>
</tbody>
</table>

*A low value before 1990 means that this factor increased between that year and 1990. For example, the index value of person trips per household in 1969 is 0.67. This means that if all factors in Equation 1 had been held constant to 1990 values except person trips per household, then VKT for shopping would have increased 33% (1.00-0.67) between 1969 and 1990. If all values except vehicle km per trip had been held constant, VKT would have increased only 15%
(1.00-0.85). Thus, person trips per household had a larger effect on changes in VKT than km per trip. After 1990, the opposite is true: if only vehicle km/trip had changed, VKT would have increased 21% (1.21-1.00). Even though fuel economy improved 64% between 1969 and 2009, it was not enough to offset increases in other factors.

Sources: National Highway Travel Survey and predecessors, Energy Information Agency.

Table 5: Changes in factors contributing to retail freight energy use, indexed to 1987=1

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq. 3: Km/trip tonn</td>
<td>Data not available; must be inferred from comparing tonnnes and VTKT.</td>
<td>0.18</td>
<td>0.38</td>
<td>0.59</td>
<td>0.79</td>
<td>1.00</td>
<td>1.21</td>
<td>1.16</td>
<td>1.13</td>
<td>1.28</td>
<td>7.2</td>
</tr>
<tr>
<td>Eq. 4: VTKT</td>
<td></td>
<td>0.42</td>
<td>0.57</td>
<td>0.71</td>
<td>0.86</td>
<td>1.00</td>
<td>1.14</td>
<td>1.36</td>
<td>1.48</td>
<td>1.67</td>
<td>3.9</td>
</tr>
<tr>
<td>Eq. 4: Joules / km</td>
<td></td>
<td>0.42</td>
<td>0.57</td>
<td>0.71</td>
<td>0.86</td>
<td>1.00</td>
<td>1.14</td>
<td>1.36</td>
<td>1.48</td>
<td>1.67</td>
<td>3.9</td>
</tr>
<tr>
<td>Retail Freight</td>
<td></td>
<td>0.86</td>
<td>0.97</td>
<td>1.05</td>
<td>1.00</td>
<td>1.00</td>
<td>1.04</td>
<td>1.05</td>
<td>1.06</td>
<td>1.10</td>
<td>1.3</td>
</tr>
<tr>
<td>Retail Freight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.36</td>
<td>0.55</td>
<td>0.75</td>
<td>0.85</td>
<td>1.00</td>
<td>1.19</td>
</tr>
<tr>
<td>Energy Use (EJ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.43</td>
<td>1.57</td>
<td>1.85</td>
<td></td>
<td>5.1</td>
</tr>
</tbody>
</table>

See the caption for Table 4 for interpretation. The table shows that increase in tonnage was the main driver of change before 1987. After 1987, the sharp increase in tonne-kilometers travelled compared to tonnnes (1.67 compared to 1.28) indicates an increase in distance travelled per tonne. Energy per t- km increased relatively steadily between 1967 and 2009, but its contribution to increased energy use in retail freight was much less than the increase in vehicle tonne-km travelled (1.3 compared to 3.9).

Finally, as shown in Table 6 (which uses an LMDI decomposition instead of a Kaya to reduce residuals, see Methods section for details) retail freight accounted for 70% of the increase in total RGM energy use.
Table 6. **LMDI decomposition of RGM energy looking at only driving-for-shopping and freight, 1990 = 1**

Freight drove more of the total RGM energy use change between 1969 and 1990
(1-0.41 = 0.59 which is greater than 1-0.71 = 0.29).

<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D (driving)</td>
<td>0.71</td>
<td>0.94</td>
<td>0.99</td>
<td>1.11</td>
<td>1.10</td>
<td>1.52</td>
</tr>
<tr>
<td>D (freight)</td>
<td>0.41</td>
<td>0.72</td>
<td>0.95</td>
<td>1.13</td>
<td>1.37</td>
<td>3.53</td>
</tr>
<tr>
<td>Relative change in total RGM energy</td>
<td>0.29</td>
<td>0.68</td>
<td>0.94</td>
<td>1.25</td>
<td>1.51</td>
<td>5.39</td>
</tr>
</tbody>
</table>

In addition to finding an increase in absolute energy, we found that the transportation energy intensity of RGM has gone up on several variables between 1969 and 2009 as shown in Figure 3.

**Figure 3: Change in RGM energy intensity**

The increase in RGM energy per constant dollar GDP indicates that Americans used 60% more energy for RGM to create a constant dollar of GDP in 2009 than they did in 1969.

4.2. **Explanation of Results**

For each of the drivers named in Table 1, excluding increase in population, we performed further research, both within and beyond the previously-discussed data sets to determine the context of the change. This discussion is summarized in Table 2.

4.2.1. **Proposed Explanations for the Increase in Frequency of Shopping Trips 1969-1995**

Average annual shopping trips went from 134 per person (425 per household) in 1969 to 295 per person (725 per household) in 1995. The increase in shopping trips resulted in part from an overall increase in sheer consumption: Americans in 1969 spent USD 4 550 per capita on goods compared to USD 6 840 per capita in 1990 (34) [measured in 2007 USD (34)]. But the increase
in frequency of shopping trips outpaced increases in consumer spending: American consumers purchased USD 64 per trip in 2007 USD in 1969 compared to USD 35/trip in 1995 (~65% less per km driven to shop). Thus further investigation is needed to explain why Americans would go on so many more and cheaper shopping trips between 1969 and 1995.

First, since the late 1960s, many scholars have remarked that utility of shopping expanded from merely acquiring goods to include social, romantic, relaxation, and even exercise functions (35), (36), (37). This could be reflected in the increase in trips tagged as “shopping” in the statistics. Ideally, we could explore the sub-categories of shopping over time (window shopping, comparison shopping, food shopping, etc) to look for evidence of this expansion in our data. However, this richer data is not available from the earlier surveys, so we must rely on the assertions from the literature.

Second, in these decades American family life became more hectic, in part due to an increase of women in the workplace, rising from 41% of women in 1970 to 59% in 1995 (38). This, as remarked upon in relevant contemporary literature, fragmented housekeeping efficiency and increased the number of individuals tending to tasks like shopping (28) (40). Unfortunately, reports on the 1969 and 1977 NPTS did not break down trip purpose by gender of the driver. We do know that time of day for shopping did not shift during our time frame, but trips did shift across days of the week, with Sunday’s share going from 7.7% to 12.2% of the trips (taking most trips from Thursday and Friday’s share). This indicates a shift towards doing more business on Sundays, which some scholars have attributed to women working (41). Gershuny and Robinson’s in-depth re- analysis of time-use survey data from 1965-1985 provides more insight: women’s domestic work time did decrease significantly. But time for shopping only went up slightly both for women and (40). As we know that shopping trip numbers went up sharply in this period, we can conclude that the trips were much briefer. These factors together confirm the fragmentation of shopping, though don’t confirm or deny the working woman’s role in it.

Food is the single largest component in retail freight, with 44% of VTKT in 2007. Americans’ preference for fresh foods with a shorter home shelf-life rose between 1969 and 2009 (42). As an example, per capita consumption of fresh fruits rose 27% in this time, whereas canned and processed fruit rose only by 2%. Thus, increase in grocery shopping frequency to accommodate new trends in health could help explain the increase in trip frequency.

4.2.2 Explanation for Increase Distance per Shopping Trip, 1983-2009

The retail industry consolidated, from about nine stores per thousand residents in 1970 to less than four per thousand residents in 2009 (43). This phenomenon is known as the “Retail Revolution,” first named in the economic literature in 1981 (44). It began with the rise of the department store and concluded with the widespread presence of Big Box retail and suburban malls. Automobiles with cheap fuel and roadway use were implicit; they reduced the consumer’s cost of reaching a distant store. Thus, competition among stores increased, driving down margins and favoring stores with more customers (45). Fewer stores per capita meant that shoppers were less likely to be near a store containing the goods they want, and had to travel farther per shopping trip. Furthermore, expanding urban sprawl increased distances between retail and residential districts (46).
The household surveys (relying on 1990 as the starting year, as relevant information was not available from the 1983 survey) indicate that the increase was driven by an increased share of total trips over 21 miles, while trips less than six miles lost share. Trips between these distances maintained their share. This could also be explained by the rise of large destination retail (Costco, Home Depot) relatively far outside of cities.

4.2.3 Increase in retail freight tonnage, 1967-1987

Retail freight tonnage increased 82% between 1967 and 1987. There are two potential explanations: an increase in sheer consumption by Americans and an increase in the mass density (per dollar or cubic foot) of retail goods.

As remarked on above, Americans consumed USD 4100 per capita 1967 and USD 6400 in 1987, over a 55% increase. Combined with population rise, this led to an increase in total expenditures of 89% (34). This can directly explain the change in retail tonnage during these years.

The commodity surveys also contain information (limited in the earlier surveys) about the value of goods shipped, allowing us to explore mass density of goods. In 1993, each 2007 USD of retail goods weighted 0.59 kg. By 2007, this number had shrunk to 0.35 kg. This trend indicates that retail goods in fact have been getting less dense per dollar, giving further culpability to the increase in total shopping expenditures on RGM goods movement.

Note: the overall freight sector became more dense per dollar value in this time period, going from USD 931 dollars per ton in 1993 to USD 829 in 2007.

4.2.4 Increase in Retail Freight Average Trip Length, 1987-2007

We find two drivers for this change: first, deregulation of the trucking sector and second, increase in imported retail goods.

One of the most prominent effects of deregulation was a decrease in truckload (TL) prices (77%) and less than truckload (LTL) prices (12% to 35%) despite a large increase in diesel prices (47) (48). This incentivized goods movers to ship more on trucks than trains and barges and to ship longer distances on trucks (47).

While we do not include the distance shipped from foreign countries to the U.S. border in our statistics, we hypothesize that the increase in percent of imported retail goods could have driven up domestic shipping distances. Imports as a percent US GDP have risen from 11% in 1987 to 17% in 2009 (49). Imported goods “emerge” into the U.S. atports, which may be further from their final destination than were domestic production facilities of earlier decades. Forty percent of these goods imported to the Ports of Los Angeles and Long Beach are shipped east of the Rocky Mountains (50). No previous literature has explored this idea methodically, and it remains a topic for future research.

Some literature has argued that the rise of Just-in-Time (JIT) delivery decreased efficiency of freight, by reducing average payload through prioritization of timing over truck utilization thereby driving up total trip mileage (51). However, McKinnon also pointed out that for the UK
at least there was not overwhelming evidence that this reduction in utility due to JIT had, in
fact, occurred (52) and he and others have also noted that increased centralization from JIT can
offset the inefficiencies from potentially lower utilization factors (16) (53).

4.2.5 Increase in Retail Freight Energy Intensity per Tonne-Km

Retail freight energy intensity increased 30% between 1967 and 2007. Yet, each individual
mode of freight improved its average fuel efficiency in this time (I). Therefore, the increase in
energy intensity measured as joules per tonne-km must be result of a modal shift from rail and
barge (efficient modes) to trucks (inefficient mode). Indeed, trucks’ share as a percent of retail
goods tkm went from 28% in 1967 to 52% in 2007. Energy intensity for retail freight went up
much less sharply (30%) than energy intensity as freight which went up over 300% (4). This
indicates that the bulk and industrial freight sectors experienced a much stronger modal shift
than retail freight.

5. POLICY IMPLICATIONS

More efficient vehicle platforms, cleaner fuels, and mass transit for goods and people could let
us keep most of the benefits of mobility and regional/national/global trade, without all the
detriments (some detriments, like sprawl, would not be mitigated). Such technologies, and the
policies which support them, will reduce the energy impact of RGM just as they reduce the
impact of all transportation. However, because they are not unique to RGM, we do not call them
out in our concluding section. Similarly, several problems that increase the energy intensity of
transportation systems in general also plague RGM, especially the under-pricing of land, of the
use of automobile and trucking infrastructure, and of our own time. With that said, our top
unique RGM policy

5.1 The same trends affect both driving-for-shopping and retail freight, especially
trends related to retail stores, urban planning, and e-commerce. However, saving
energy on one side of RGM may cost energy on the other (see Figure 1). Thus,
policy that considers these two transportation sub-sectors as one integrated RGM
sector may be able to achieve more energy, time, and greenhouse gas savings than
policy that considers them apart.

For example, as mentioned above, the retail industry has consolidated notably in the last four
decades, from about nine stores per thousand residents to less than four. On the driving-for-
shopping side, this consolidation can and has raised energy use. On the freight side, however,
fewer and larger stores mean larger trucks can make deliveries with fewer trips, improving
efficiency per tonne-km. Thus, policy that seeks to support smaller local stores needs to
consider the both driving-to-shop and freighting implications of store location, clustering of
different types of stores, warehousing logistics, and size. Sponsoring consolidated warehousing
and delivery for local retailers, for example, may facilitate energy use reduction (and less
traffic) on both sides of Retail Goods Energy Movement.
Another prominent example is on-line shopping and delivery, which can eliminate much of the energy use associated with RGM, under the right circumstances (conditions like no missed delivery, low returns, full shopping trip displacement, and no additive air freight). Good policy can facilitate some (not all) of these circumstances. For example, policy can help reduced “missed deliveries” which can double truck mileage by encouraging business to allow employees to get personal packages at work, and by developing secure standard mailboxes designed for parcels. In addition, state and federal policy makers can work with major delivery-based retailers to reduce the use of aviation for delivered goods via pricing, customer notification and education, and smart predictive logistics and warehousing [see Zappo’s practices for an example (54)].

Increased delivery means increased reliance on smaller, parcel delivery trucks for last-mile coverage. These trucks are more amenable to certain types of fuel substitution, specifically electrification, than other, larger, freight vehicles.

5.2 **Compared to all other trip purposes (commuting, social visits, activities) people are less likely to use non-personal vehicle transit for shopping than any other purpose. This is understandable: carrying 20 pounds of groceries on the bus is not particularly pleasant. Thus, policy to encourage transit needs to take shopping-specific considerations into account.**

Examples of shopping transit policy include working with stores to provide same-day home delivery of goods selected in-store, and designing transit vehicles and routes to facilitate shopping. This approach can be targeted at retail good types which have not had great success as on-line goods, such as fresh food.

The strong trend of increased shopping trips per week and decreased expenditures per trip could offer some hope in this regard: if shopper move towards a model of very few purchases per trip, transit or walk/biking to-shop could become a more viable option, mimicking the old European practice of picking up just enough food for dinner on the walk home.

5.3 **Whereas a push to slow and reverse modal shift towards trucks (from rail and water) is a critical policy agenda item for freight overall, it should not be the focus for retail freight.**

Retail freight has experienced much less modal shift to trucks from more efficient modes in the past 40 years compared to freight overall. Because retail freight includes the “last mile” of freight (to the retail store), it’s much less conducive to being taken over by train/barge, and it has always had a much higher modal share for trucks than all freight. Policy oriented at truck-to-rail shift should disaggregate its efforts to focus on commodities conducive to this change. Policy oriented at reducing goods-movement energy should focus on the structural changes outlined in the other recommendations of this paper as well as trucking efficiency per tonne-km: drive train technology, platform fitness (better tires and aerodynamics), logistics improvement, and regulatory shifts such as allowing multiple trailers.
5.4 Change in the way travel survey data is collected to be more conducive to the RGM framework, as well as other commodity-specific transportation energy analyses and policy.

The set of unique policies aimed at reducing the energy impact of RGM is a form of commodity specific transportation energy reduction policy, which, several researchers have noted, is more effective than generic transportation policy (55). Better data collection can facilitate such policy for RGM and other commodities. In the household surveys, more differentiation in the household survey as to the type of shopping trip (window, food, luxury) and better compensation for failures in driver recall of their own driving behavior (56). Such data can be collected, using now-affordable tools, specifically mobile computing with GPS, and in fact some states and countries, including California, are exploring with such approaches now (57), (58), (59), (60). For freight, more detailed record keeping of shipped goods in the commodity flow surveys (such as origin and destination type by warehouse, production facility, retail outlet) is necessary to take full advantage of the potential energy reductions.

5.5 The trends that have led to the increase of energy use in RGM (some of which, such as women in the workforce and fresh food, have improved gender equality and health) do not derive from energy-related factors, such as energy price, energy conservation, or concern for the environmental impacts of fossil energy use. Therefore, the most effective policies to reverse these trends may not be explicitly driven by energy or climate agencies, but may instead relate to safety, quality of life (and quality of shopping experience), or local economic strength.

For example, policy to support more small, local grocery stores may be more successful if presented in a framework of increasing residential property values nearby (14), or in the context of reducing obesity in poorer communities (61). The transportation energy benefits, including RGM would be a happy side effect and perhaps would be more sustainable and scalable due to their association with more politically, financially and emotionally powerful causes.

Many of our policy suggestions reside in the sphere or local and even neighborhood or office policy (mailbox design, deliveries to work), and transgress the boundaries of transportation departments. This offers new opportunities to help reduce energy use and greenhouse gas emissions to policy actors who may find themselves frustrated at their lack of influence. Transportation energy research and policy must expand beyond driving for commuting if the U.S. is to achieve significant energy use reduction goals, and RGM is one example for a good target of such an expansion. Successful policy requires more rigorous and rich data collection, combined with incorporation of the social, psychological, and infrastructure factors that create transportation behavior.
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Associated Content

Supplemental material includes a more detailed description of the data included in and excluded from the analysis from the government databases cited throughout.
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