Looking into the Consumption Black Box:
Evidence from Scanner Data

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University of Mannheim

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Keywords: consumption polarization, data sparsity, NielsenIQ
Disclaimer

The researchers' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researcher and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.
### Motto of the Project

“There is no accounting for tastes”

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“There is no accounting for tastes”
Big Picture: Short Story of Non-Durable Consumption in Macroeconomics

Motto of the Project

“There is no accounting for tastes”

◊ Neoclassical model with representative agent

(Ramsey, EJ 1928; Cass, REStud 1965; Koopmans, 1965; Brock&Mirman, JET 1972; Kydland&Prescott, Ecta 1982)

- Early macroeconomic models considered a single representative agent.
- Consumption was aggregated into a single product for tractability.
- This approach ignored individual differences in consumption patterns.

◊ Models of Inequalities w/Heterogeneous Households

(Aiyagari, QJE 1994, JPE 1995; Huggett, JEDC 1993)

- Aimed to capture state-based consumption disparities.
- Generated differences in quantities consumed across households.
- Still focused on a single type of product.

◊ Models of Heterogeneous Goods (+Heterogeneity in Choices)

(Handbury, Ecta 2021; Michelacci-Paciello-Pozzi, REStud 2022; Faber&Fally, REStud 2022; Neiman&Vavra, AEJ:Macro 2023)

- Recognize that households may consume different varieties of products due to:
  - either (i) latent heterogeneity or (ii) (intratemporal) non-homothetic preferences.
- Differences in preferences lead to diverse consumption baskets.
- Aim to provide more realistic representation of actual consumption behavior.
Motivation and Why is It Important?

Research Questions

1. Do different groups of consumers buy different products?
2. How persistent are the individual choices over time?
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- **Importance for Macroeconomic/Industrial-Organization Perspectives:**
  - Direct implications for the ease or difficulty of price discrimination by retailers.
  - Influences the market power of retailers.
  - The level of heterogeneity in consumption bundles affects the magnitude of consumption externalities.
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While there is a rich empirical literature documenting inequality in consumption expenditures, there are still not many studies systematically analyzing the composition of consumption bundles across different groups of consumers.
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- While there is a rich empirical literature documenting inequality in consumption expenditures, there are still not many studies systematically analyzing the composition of consumption bundles across different groups of consumers.

- **Challenges:**
  - *How to measure group differences in (overwhelmingly) high-dimensional choices?*
  - *Potentially severe small-sample bias (yet to be discussed).*
Heterogeneous preferences:  
Neiman & Vavra (AEJ: Macro, 2023), Handburry (Ecta, 2021), 
Michelacci, Paciello, and Pozzi (REStud, 2022), Faber & Fally (REStud, 2022)

Polarization in Economics:  
Bertrand & Kamenica (AEJ: Applied, 2023), Alesina, Tabellini, and Trebbi (BP:EA 2017), 
Desmet & Wacziarg (EJ, 2021), Boar & Giannone (2023)

Big data with small sample bias:  
Gentzkow, Shapiro, and Taddy (Ecta, 2019), Armenter & Koren (AER, 2014), 
Conlon, Mortimer, and Sarkis (2023)

Confronting the mainstream models:  
Armenter & Koren (AER, 2014), Menzio (202*)

Defending the mainstream models: Becker (JPE, 1962)
Preview of the Results

◇ **Indistinguishable Consumption Choices:**
  - Consumption choices are practically indistinguishable between rich and poor households.
  - On average, the way one dollar is spent does not allow identification of whether the consumer is rich or poor.
  - This suggests that non-durable consumption is not polarized at all, contrary to common preconceptions.

◇ **Unstable Individual Consumption Choices:**
  - Individual consumption choices are very unstable.
  - On average, only 40% of products purchased in one year are bought again in the next year.

◇ **Parsimonious Model of Consumption:**
  - All products are perfect substitutes (per price); the composition of baskets is the result of random sampling.
Data: NielsenIQ Consumer Panel

- Data on Consumer Expenditures are taken from the Kilts-NielsenIQ Consumer Panel
- 40,000-60,000 households per year from 2004-2018 with socio-economic characteristics
- 1.5 million unique products including groceries, drug products, small appliances, and electronics
- Scanner data, so measurement error is expected to be rather low
  - Data is collected either with a separate scanner or an app by scanning the bar codes of the bought items
- Projection weights to be representative for the US economy
### Research Questions

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Consumption Polarization
Challenge 1: *How to measure group differences in high-dimensional choices?*

- Measuring inequality is dramatically simpler: Gini coefficient, Lorenz curve, etc.
- Measuring polarization is challenging due to high-dimensional data.
  
  (800,000 unique products per year)
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Using the methodology by Gentzkow, Shapiro, and Taddy (Ecta, 2019)

General Idea (adapted to Consumption Choices)

1. Randomly select $1 spent in the Nielsen universe.
2. Learn how this $1 is spent.
3. Predict the household’s group membership based on purchased products.
4. Polarization = expected predictive power.
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**Interpretation:**

- Values between 0.5 and 1.0.
- 1.0: Perfect prediction of group membership from products (*Full polarization*).
- 0.5: No predictive power from products (*No polarization*).
Challenge 2: Potentially severe small-sample bias.

- We have ≈ 800,000 unique products each year and only ≈ 50,000 households.
- Many products may be bought by only a few households, leading to severe small-sample bias in estimating the probability of buying a product.
- Why? In extreme cases, if a product is bought by only one household, the predictive power of this purchase is 100%.
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- We do not know whether purchases of products that are bought by only a few households are systematically purchased only by those households or if it is a random event.
Gentzkow et al. (Ecta, 2019) face data sparsity in congressional speech data. To overcome small sample bias, they propose studying polarization of the data generating processes estimated using a penalized estimator.
Consumption Polarization (cont’d)

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◊ In our application, let $c_{i,t}$ be a vector of all goods consumed by household $i$ in year $t$:

$$c_{i,t} \sim MN(m_{i,t}, q_{i,t}^{l_i,t}(x_{i,t}))$$

◊ $m_{i,t}$ is household $i$’s budget at time $t$, $l_{i,t}$ is the consumption group, $x_{i,t}$ is a vector of household characteristics, and $q_{i,t}^{l_i,t}(x_{i,t})$ is a vector of choice probabilities:

$$q_{i,t}^{l_i,t}(x_{i,t}) = \frac{e^{u_{i,j,t}}}{\sum_k e^{u_{i,k,t}}}$$

$$u_{i,j,t} = \alpha_{j,t} + x_{i,t}'\gamma_{j,t} + \varphi_{j,t} \cdot 1 \{l_{i,t} = H\}$$

◊ Parameter $\varphi_{j,t}$ is subject to regularization using the LASSO penalty.

Between-group differences caused by noise are shrunk to zero.

◊ How is it possible to estimate a multinomial logit with 800,000 (sic!) categories?

Distributed Poisson approximation by Taddy (AoAS, 2013).
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Distributed Poisson approximation by Taddy (AoAS, 2013).
Result 1

The polarization is extremely low. The choices made by high- and low-consumption households have almost no predictive power.
Main Questions

Research Questions

1. Do different groups of consumers buy different products?
2. How persistent are the individual choices over time?
3. What are implications for structural models of the answers to Questions 1 and 2?
Persistence in Composition of Baskets
We measure the persistence within the consumption basket of a household by computing the share of expenditures within a year spend on products already bought in the previous year.

Formally, we compute:

$$O_i^E = \frac{\sum_{j \in (U_{i,t-1} \cap U_{i,t})} e_{i,t}(j)}{\sum_{j \in U_{i,t}} e_{i,t}(j)}$$

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As a first step, we compute average persistence for each year.

To ensure that results are not driven by product exits and entries, we recompute persistence by using only expenditures on products that are available within the US in both years as a robustness check.
Result 2a
At the barcode level average persistence is quite low within the US. This result is robust to controlling for product entry and exit.
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- There also is on average no difference of economic significance between households that experience income changes and households that do not by income changes.
Results: Average Persistence [UPC level]

Result 2a
At the barcode level average persistence is quite low within the US. This result is robust to controlling for product entry and exit.

- There also is on average no difference of economic significance between households that experience income changes and households that do not.
- Importantly, products that leave the basket are not more expensive than those that stay in the basket (therefore, cannot be rationalized by price search models).
Results: Average Persistence [Product-module level]

Result 2b
Persistence is much higher on the module level.

- We can interpret the difference between the barcode and the module level as households having relatively stable preferences for the kinds of products they like to consume. But when it comes to the specific product itself choices are much less persistent.
### Question

We have seen that persistence is quite low on average. But is there some heterogeneity between households?

<table>
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| ⋄ There is substantial heterogeneity in persistence. More than 50% of aggregate non-durable consumption are accounted for by households with a persistence of less than 50%.
| ⋄ Heterogeneity in persistence is latent and not associated with any observable characteristics. |
Heterogeneity in Persistence

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The composition of consumption bundles is not influenced by income level. The choices made by high- and low-consumption households have almost no predictive power. This suggests that in contrast to models with intratemporal non-homothetic preferences, consumers’ choices are not income-dependent.

In models with (latent) heterogeneous preferences, the very low stability of consumption baskets over time can be generated only when households would experience significant preference shocks in each period.
- The composition of consumption bundles is not influenced by income level. The choices made by high- and low-consumption households have almost no predictive power. This suggests that in contrast to models w/intratemporal non-homothetic preferences, consumers’ choices are not income-dependent.

- In models with (latent) heterogeneous preferences, the very low stability of consumption baskets over time can be generated only when households would experience significant preference shocks in each period.

- These findings motivate a thought experiment: a model where differences in consumption bundles are driven by factors other than heterogeneous preferences. Instead, simple information frictions are considered, where households need to find goods before consumption. Consequently, different baskets result from different realizations of randomness rather than from choices driven by different preferences.
Shopping Spree of Beckerian Consumers
Extreme example of a *shopping spree*

I Gave People $1,000,000 But ONLY 1 Minute To Spend It!
209M views • 3 years ago

MrBeast


5:16 Je veux remercier M. Jimmy, Mr Beast et tout le monde. Ça rendra la vie bien plus

CC
Shopping Spree Model

- Each household $i$ has its own budget $m_{i,t}$ and nothing can be saved for the future.
- No information about products: to buy a product, they need to find it.
- There is no order in preferences; households randomly draw products during each purchase.
- Goal of each household: to spend as much as possible.

$^1e_j$ is a vector with 1 at the $j$-th position and 0 elsewhere.
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### Decision Problem of the Consumer

0. The consumer’s consumption $c_{i,t}$ is a zero vector at the beginning of the period.

1. The consumer randomly draws product $j$ from the set of all products. The probability of drawing product $j$ is product-specific and common across all consumers. The number of purchased products, $n_j$, is drawn from a product-specific Poisson distribution.

2. Update $c_{i,t} \leftarrow c_{i,t} + e_j n_j$.

3. If the budget constraint for the new bundle is not violated ($p'_{i,t} c_{i,t} < m_{i,t}$), go to **Step 1**. Otherwise, **Stop**.

---

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CDF of the top individual products
Average Spendings on Different Ranked Items

![Graph showing average spendings on different ranked items. The x-axis represents the number of products purchased, ranging from 1 to 20. The y-axis represents the share, ranging from 0 to 1. Lines indicate different ranks (1, 2, 5) and sources (data, model).]
Category Spendings on Different Ranked Items

(a) Seafood Canned

(b) Cereal

(c) Yogurt

(d) Pet Food
Despite its extreme simplicity, the model is able to capture the main cross-sectional features of the data.

Ad-hoc dynamics introduced by repeating the same problem over and over again would generate persistence much lower than observed in the data.

However, if we introduce a small amount of persistence in the model, we can generate a very interesting result. Namely, we assume that each product purchased in the previous period is purchased again with probability $\rho = 0.4$. This can be interpreted as either (i) a smaller level of frictions for products purchased in the past or as (ii) a form of breadth of variety à la Menzio (Ecta, 2023).
Despite the fact that the model is calibrated to capture only the average dynamics of the data, it is able to capture the heterogeneity in persistence of consumption bundles. The reason for this is that documented extreme values of persistence are driven by households with a relatively fewer number of transactions.
Purpose: Highlight that empirical patterns typically modeled with heterogeneous preferences can also be generated by very different models. The exercise is analogous to:

- “Balls-and-bins” model (Armenter & Koren, AER 2014) in the context of gravity models of international trade.
- Price search (Menzio, 202*) in the context of the Dixit-Stiglitz monopolistic competition model.
- Irrational consumers (Becker, JPE 1962) in the context of the utility-maximization theory.

The proposed model, though simple, captures main features of the data very well. Unlike models of heterogeneous choices, it relies on randomness, treating consumers as “zero-intelligence” agents with perfect substitutes.
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Policy implications differ significantly from heterogeneous preference models. Policies beneficial through the substitution effect of individual choices would not be beneficial in this model. For example, increasing product variety would be welfare decreasing in our setup, in contrast to being welfare increasing in a heterogeneous-preference framework by Neiman&Vavra (AEJ:Macro, 2023).
Concluding Thoughts

- Using scanner data, we document that consumption choices made by rich and poor households are surprisingly similar. Information on what product was purchased does not allow us to identify the group of households.
  - **New empirical challenge for** models with intratemporal non-homothetic preferences.

- Individual consumption choices are very unstable. A product purchased in one year will be purchased again with a probability of 0.4 in the next year.
  - **New empirical challenge for** models with latent heterogeneous preferences.

- We propose a new model where differences in consumption baskets are a result of randomness. This model fits the data quite well.

- The paper strikes a cautious note on policy implications drawn from models with heterogeneous choices on goods.
Thank you for your attention and have a nice lunch!
Gentzkow, Shapiro, and Taddy (Ecta, 2019) discuss a bias in their study on the polarization of US politics using congressional speech data. Developed a model of a speech-generating process. Analyzed the bias formally and introduced estimators to overcome finite-sample bias. Their methods help recover a more accurate estimate of polarization. Their methodology is well suited for studying consumption polarization because the structure of speech data is very similar to scanner data.
“Let’s look at how different the choices of two different groups are in that high-dimensional space (...). It could be which UPCs did they buy in the supermarket.”
<table>
<thead>
<tr>
<th>Quantile</th>
<th>Size</th>
<th>Male Age</th>
<th>Female Age</th>
<th>Race</th>
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<tbody>
<tr>
<td>1st</td>
<td>2.16</td>
<td>4.38</td>
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Persistence and Income Change

Persistence in Consumption Expenditures

Date

Persistence

Color
- Income Change
- No Income Change

Zooming into the Heterogeneity

**Question**

Can we attribute the heterogeneity to observable characteristics of the households?
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- We employ a random forest algorithm to find the household characteristics that are most important to explain differences within persistence.
- We can then use accumulated local effects to see the size and direction of the influence of individual characteristics.
  - Identifies the effect of singular variables while holding all else constant.

Alternatively: Subgroup analysis.
Variable Importance
Effect of Male Head Age on Persistence

Effect of Female Head Age on Persistence
Effect Race

Effect of Asian on Persistence

Effect of Afro-American on Persistence
Results: Persistence Summary

- We have seen that households are **on average** highly impersistent with their consumption choices.
- More than 50% of aggregate non-durable consumption is accounted for by households with a persistence of less than 50%.
- **But** there is substantial heterogeneity within persistence.
- Most of the heterogeneity is latent and only some can be explained by household characteristics.