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The Extensive Margin of Aggregate Consumption Demand

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About half of the change in U.S. non-durable consumption expenditure is due to changes in the products entering households' consumption basket (the extensive margin). Changes in the basket are driven by fluctuations in the rate at which households add products; removals fluctuate little. These patterns reflect that, in response to income increases, households adopt consumer products already available in the market. Household adoption amplifies the effects of fiscal transfers on consumption by more than 30%. Cyclical household adoption of products also implies that inflation measures based on a representative household consuming all varieties available in the market underestimate true household-level inflation by as much as 1% per year over the Great Recession in the consumption categories covered by our data.

Key words: Nielsen, Love of Variety, Customers, Search

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1. INTRODUCTION

At least since Dixit and Stiglitz (1977), Krugman (1980), and Romer (1990), it is well known that the introduction of new product varieties in the market changes the consumption basket of households along the *extensive margin*, increasing welfare. In practice, an average household consumes just a tiny fraction of the varieties in the market and most changes in the consumption basket along the extensive margin are due to varieties already in the market.[1] The conventional

1. Under our preferred definition of variety in the Kilts–Nielsen Consumer Panel (The Nielsen Company a), in a typical year there are about 70,000 different varieties on sale in the market and a household consumes just half a percentage point of them. In a year, the expenditure of a household on varieties that she did not purchase in the previous year is 33%

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view, well formalized by Anderson *et al.* (1992), is that households consider for consumption *all* varieties in the market and the observed heterogeneity in consumption baskets is just noise, irrelevant for the aggregate implications of love-of-variety models and consistent with a representative household preferences.[2] In this article, we show that, in response to income shocks, households do persistently change their consumption basket: they start to buy varieties never purchased before even if they were available all along. Essentially, households search for the varieties they like to consume and, when income increases, they search more adopting consumer products in their basket. We show that this *search-for-love* formulation has novel implications for the macroeconomic effects of fiscal transfers and the measurement of household-level inflation.

We incorporate a random utility model of discrete product choice à la McFadden (1973, 1974) in a standard household dynamic optimization problem à la Ramsey (1928). As in the conventional view, the household has a set of varieties she considers for consumption (her "consideration set"); varieties in the set are subject to preference shocks, which induce noisy changes in the consumption basket; owing to the preference shocks, a larger set reduces the welfare-relevant household price index, which provides a micro-foundation for love of variety. Differently from the conventional view, the consideration set is endogenous and heterogeneous across households due to search-for-love: a household decides how many new varieties in the market to sample (adoption expenditure) and some of the newly sampled varieties are randomly brought into the consideration set.[3] In response to a transitory income shock, the household adopts more varieties: first, there is a *scale effect*, typical of love-of-variety models, which makes varieties more valuable when spending is higher; secondly, adoption is a form of investment which persistently reduces the welfare-relevant household price index and serves to *smooth consumption*.

Over time consumption expenditure can change along the intensive and the extensive margin. The extensive margin reflects *net* additions of varieties to the consumption basket, which is the difference between gross *additions* (expenditure on varieties not previously purchased) and *removals* of varieties (previous-period expenditure on varieties no longer purchased). Some gross additions are just noise due to preference shocks, others reflect household adoption of varieties continuously available in the market, the remaining ones are due to new varieties in the market. We calibrate the model by drawing detailed statistics from the Kilts–Nielsen Consumer Panel (The Nielsen Company a) and reproduce the level of net and gross additions in the data. The model matches fairly closely the effects of the federal government's Economic Stimulus Payment (ESP) to households in 2008, which we take as an example of a transitory income shock. As in Parker *et al.* (2013); Broda and Parker (2014), we compare households who receive the payment randomly over time and interpret the estimated responses as characterizing household behaviour in partial equilibrium (at constant aggregate supply of varieties). The marginal propensity to consume out of the ESP is the sum of a marginal propensity to consume along the intensive and one along the extensive margin, the latter the resultant of additions less removals. The extensive margin accounts for more than a third of the overall propensity, almost entirely driven by additions. Around a third of the increase in additions is due to varieties that the household had never purchased in the previous (four) years and will repurchase again at least once in the year after receipt of ESP. A model with an exogenous consideration set (determined just by the aggregate

of total expenditure. The expenditure on varieties new to the U.S. market is just around 1.3% of total expenditure (see also Table 4 in Broda and Weinstein 2010).

2. Formally, Anderson *et al.* (1992) show that the CES utility of the representative household is the expected utility of (ex ante identical) households facing a discrete choice problem over all varieties in the market subject to idiosyncratic preference shocks with an extreme value distribution of type I.

3. It is these differences in consideration sets for identical households (in terms of observable characteristics such as income, education or geographic location) that make the model different from other standard variety choice models, *e.g.*, Hottman *et al.* (2016).

supply of varieties), which we take as a formalization of the conventional view, fails to match this evidence.

We estimate the time series of adoption expenditure by full information methods using data on net additions and expenditure. We allow the return to adoption to vary over time, in order to control for changes in the number of varieties available in the market (Perla 2017), advertising by firms (Goeree 2008) or search intensity by households (Kaplan and Menzio 2016). In the data about half of the cyclical dynamics of aggregate consumption expenditure is accounted for by net additions, driven mostly by the pro-cyclicality of the rate at which households add new varieties, while removals are comparatively acyclical. The model fits well these cyclical patterns. Household adoption expenditure is pro-cyclical and two-and-a-half times as volatile as total expenditure.

We show that search-for-love has novel implications for the macroeconomic effects of fiscal transfers as well as for the measurement of household-level inflation. Since household adoption of varieties affects firm incentives to introduce new varieties in the market, we study the effects of fiscal transfers in general equilibrium after endogenizing the number of varieties in the market, as in Romer (1990) and Bilbiie *et al.* (2012). We consider an economy in a liquidity trap and measure the effects of fiscal transfers during the U.S. Great Recession and its recovery.[4] Fiscal transfers stimulate household expenditures and increase household incentives to adopt consumer products already available in the market. In our calibration, during the period 2010–19, fiscal transfers increase consumption by little less than a percentage point on average. Endogenous adoption matters for this sizable effect: relative to a model with exogenous adoption, it amplifies the effects of transfers on consumption and expenditure by 30–40%, depending on the exact share of aggregate consumption expenditures covered by our search-for-love mechanism. The reason for the amplification is 2-fold. One is due to *household-level inflation*: fiscal transfers stimulate adoption that pushes down the welfare relevant household price index today, generating expectations of higher future household-level inflation, which reduces the real interest rate and stimulates aggregate demand—an effect particularly valuable for an economy in a liquidity trap. The other is due to the *demand for innovation*: more household adoption pushes up the value of a new product, because new firms find easier to accumulate a customer base, causing a larger increase in innovation. Quantitatively, the two effects account roughly equally for the amplification of endogenous household adoption on aggregate consumption.

Search-for-love has also novel implications for the measurement of household-level inflation. Since household adoption of consumer products is pro-cyclical, measures of inflation based on a representative household who consumes all varieties available in the market tend to underestimate true household-level inflation in recessions. This bias applies to inflation measured with the Consumer Price Index (CPI) as well as to inflation measures that correct for love of variety, as in Feenstra (1994) or Redding and Weinstein (2019). Essentially, the inflation of the representative household depends (negatively) on the number of varieties available in the market, while true household-level inflation depends on the number of varieties in the household consideration set, which is a time varying subset of all varieties available in the market. Due to household adoption, the difference between the number of available varieties and the average number of varieties in the consideration set of an household increases in recessions, which makes representative household inflation underestimate true household-level inflation. We quantify the bias of CPI inflation (in the consumption categories covered by KNCP) and also relate household-level inflation in the model to the inflation implied by the CES unified price index (CUPI) of Redding and Weinstein (2019). CUPI is based on a representative household and extends the price index by Sato (1976) and Vartia (1976) to allow for love of variety, as in Feenstra (1994), as well as for time varying

4. Fiscal transfers represented almost 80% of the increase in government expenditure over the period (Oh and Reis 2012).

preference shocks, which in our model are endogenous due to household adoption. We find that at the trough of the Great Recession CPI and CUPI inflation underestimate yearly inflation by as much as 1%.[5]

Relation to the literature. Other authors have shown that household shopping behaviour responds to shocks by documenting changes in product quality Jaimovich *et al.* (2019); Argente and Lee (2021); Faber and Fally (2021) and in how intensively households search for lower prices on the products they usually purchase (Coibion *et al.* 2015; Campos and Reggio 2020). The focus on the extensive margin and household adoption of varieties *within* quality groups of products is novel. We also show that search intensity alone cannot explain the pro-cyclicality of gross additions and household adoption of varieties. A key distinction is that search is intensive in time, which is more abundant in recessions, whereas adoption entails the purchase of new products, a form of pro-cyclical investment.

Broda and Weinstein (2010) and Argente *et al.* (2018) document that the launch of new products is pro-cyclical. Here we show that household propensity to adopt new varieties matters for this cyclical pattern, since acquiring a stable customer base is a primary determinant of the profitability of a new product. Bilbiie *et al.* (2012) study how the introduction of new varieties in the market affects business cycles; (see Bilbiie *et al.* 2007, 2014; Chugh and Ghironi 2011) for an analysis of the implications for monetary and fiscal policy. Our focus on the household, which should invest actively in adopting new consumption varieties, is novel and complementary to theirs. Household adoption influences the aggregate demand for new products and amplifies the effects of shocks on firm innovation.

The thesis that household consideration set is only a subset of the products on the market is shared with Perla (2017), who studies the implications for firm growth and industry dynamics. Here we focus on the determinants of household adoption of new varieties, emphasizing the implications for inflation and business cycle analysis.

There is an abundant literature on measuring the marginal propensity to consume out of income shocks (Blundell *et al.* 2008; Broda and Parker 2014; Johnson *et al.* 2006; Parker *et al.* 2013) as well as on its theoretical determinants; see for example Kaplan and Violante (2014), Kueng (2018), and Campbell and Hercowitz (2019). We decompose the overall marginal propensity to consume into propensity along the intensive margin and propensity along the extensive margin, showing that the latter's response partly reflects the adoption of additional varieties.

Section 2 decomposes fluctuations in expenditure into the intensive and extensive margin. Section 3 studies the 2008 tax rebate. Section 4 presents the household model, Section 5 parameterizes it. Section 6 analyses the effects of the tax rebate shock and the business cycle properties of the model. Section 7 discusses implications of search-for-love. Section 8 concludes. The Appendix contains details on data and model.

2. DECOMPOSING HOUSEHOLD CONSUMPTION EXPENDITURE

We characterize how household consumption expenditure changes along the intensive and the extensive margin over time (Section 2.3) and in response to an income shock (Section 3). We

5. We also constructed a version of CUPI at the household-level, thereby removing the representative household assumption that the household consideration set comprises all varieties available in the market. The bias between true household-level inflation and CUPI at household level is positively correlated with adoption expenditure and reaches a maximum of 35 basis point per year. The bias mainly arises because adoption is an expenditure (a “cost") with only indirect effects on current consumption.

later use this evidence to identify and validate the model of Section 4. We first introduce some definitions, then discuss the data and finally present empirical results.

2.1. *Methodology*

The consumption expenditure of household $h \in \mathcal{H}$ at time t is equal to the sum of the expenditures on all varieties consumed

$$e_{ht} \equiv \sum_{\nu \in \mathcal{V}} e_{\nu ht}, \tag{1}$$

where $e_{h\nu t}$ denotes the expenditure of the household on variety $\nu \in \mathcal{V}$. Here, by convention, all expenditures are per household (total expenditure divided by the total number of households). $\mathcal{H}$ and $\mathcal{V}$ denote the set of all households and of all varieties in the economy at *some* time t, respectively. Given (1), aggregate expenditure per household is equal to

$$E_t = \sum_{h \in \mathcal{H}} e_{ht},$$

whose growth rate can be expressed as:

$$\frac{\Delta E_t}{E_{t-1}} \equiv \frac{E_t - E_{t-1}}{E_{t-1}} = \sum_{h \in \mathcal{H}} \frac{e_{ht} - e_{ht-1}}{e_{ht-1}} \times \frac{e_{ht-1}}{E_{t-1}}. \tag{2}$$

The overall change in household h's expenditure stems partly from changes in expenditure on products already purchased in the previous period—the *intensive margin*—and partly from net additions of products to the consumption basket—the *extensive margin*. Net additions are the difference between the household current expenditure on products newly added and previous-period expenditure on products now removed from the basket. In brief, we have that

$$\frac{e_{ht} - e_{ht-1}}{e_{ht-1}} = i_{ht} + a_{ht} - r_{ht}, \tag{3}$$

where

$$i_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht} - e_{\nu ht-1}}{e_{ht-1}} \times \mathbb{I}(e_{\nu ht-1} > 0) \times \mathbb{I}(e_{\nu ht} > 0) \tag{4}$$

$$a_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht}}{e_{ht-1}} \times \mathbb{I}(e_{\nu ht-1} = 0) \times \mathbb{I}(e_{\nu ht} > 0) \tag{5}$$

$$r_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht-1}}{e_{ht-1}} \times \mathbb{I}(e_{\nu ht-1} > 0) \times \mathbb{I}(e_{\nu ht} = 0) \tag{6}$$

with $\mathbb{I}(\cdot)$ denoting the indicator function. Changes in the expenditure of household h can be due to the intensive margin i_{ht} in (4), to (gross) additions of products to the basket a_{ht} in (5), or to removals from the basket r_{ht} in (6). Combining (2) with (3), we obtain

$$\frac{\Delta E_t}{E_{t-1}} = I_t + N_t, \tag{7}$$

where I_t and N_t denote the changes in aggregate expenditure due to the intensive margin and net additions, respectively. The contribution of the intensive margin is the weighted sum of the terms

i_{ht} in (4)

$$I_t = \sum_{h \in \mathcal{H}} i_{ht} \times \frac{e_{ht-1}}{E_{t-1}}, \tag{8}$$

while net additions are defined as

$$N_t = A_t - R_t, \tag{9}$$

which is the difference between the weighted sum of the expenditures on products added,

$$A_t = \sum_{h \in \mathcal{H}} a_{ht} \times \frac{e_{ht-1}}{E_{t-1}}, \tag{10}$$

and the weighted sum of previous-period expenditures on products now removed,

$$R_t = \sum_{h \in \mathcal{H}} r_{ht} \times \frac{e_{ht-1}}{E_{t-1}}. \tag{11}$$

2.2. *The data*

Our analysis relies on the Kilts–Nielsen Consumer Panel (The Nielsen Company a, henceforth KNCP). Here, we discuss the data briefly, leaving further details to Appendix A. KNCP is a rotating panel of an average of 60,000 households per year, with the median household remaining in the sample for three consecutive years. Households report the prices and quantities of all the products purchased in stores, using a scanning device provided by Nielsen.[6] The sample is representative of the U.S. population, and expenditures in KNCP track the corresponding categories in the Consumer Expenditure Survey (CEX) quite well. Products are identified by their Universal Product Code (UPC). Since versions of the same product packaged differently have a different UPC, identifying a variety with the UPC would force us to classify a change along the extensive margin also when the household still consumes exactly the same product. The University of Chicago has addressed this problem by grouping all UPCs with the same characterizing name or logo into a single *brand* variable. Examples of brands in the "Ice cream, Novelties" category are "Häagen Dazs" and "Häagen Dazs Extra." Of course, the same brand could be used for different products (Häagen Dazs could refer to ice cream as well as frozen desserts or yogurt). Nielsen groups the 1.4 million UPCs present in KNCP into 735 homogeneous product modules. Examples of product modules are "carbonated beverages," "laundry supplies," "ice cream in bulk" and "frozen yogurt." Similarly to Handbury (2013), we identify a variety as the combination of brand and product module (*i.e.* Häagen Dazs in the ice cream module is a different variety from Häagen Dazs in the frozen yogurt module). With this definition, there are about 70,000 different varieties sold in the market in a year, with the average household buying 350.[7] We also try the alternative of identifying varieties directly by UPCs. We exclude the category "general merchandise,"which is quite heterogeneous, contains some durable goods (such as electronics), and is only spottily reported by households, as well as all products with no UPC (such as fresh food products and bakery goods), which are reported only by a small

6. The product categories in KNCP survey are dry groceries, frozen foods, dairy, deli, packaged meat, fresh foods, non-food groceries, alcohol, general merchandise, and health and beauty aids, which account for 13% of total consumption expenditure (durables and non-durables) as calculated by the Consumer Expenditure Survey (CEX). The stores covered by KNCP are traditional grocery shops, drugstores, supermarkets, superstores, and club stores.

7. All white labels (also called private labels) within a product module have the same brand code and are identified as the same variety.

subsample of KNPC households. We take only households with expenditures in every month of a year, to make sure that their consumption behaviour is measured accurately (the results are robust to selecting households with expenditures in at least 10 months). Our baseline analysis is yearly, which automatically controls for seasonal changes in consumption baskets, but we also report results quarterly, the standard frequency for business cycle analysis. Since the focus is on changes, households in the sample in year t should also be present in year $t-1$. As discussed in Supplementary Appendix A, the growth rate of expenditure in this subsample is lower than the growth rate of aggregate expenditure in the full sample, but the correlation between the two series is high (close to 90%). All statistics are aggregated using Nielsen's sampling weights. Since the weight of a household could change over time, we use the average weight in year $t-1$ and t. We cover the period 2007–14, because KNCP was redesigned in 2006, increasing sample size and product coverage, and the data for 2015 were not available to us.

2.3. *Findings*

Figure 1(a) plots the growth rate of aggregate expenditure $\Delta E_t/E_{t-1}$ (solid blue line) and the contribution of the intensive margin I_t (dotted black line) and net additions N_t (dashed red line). Figure 1(b) further decomposes net additions N_t into additions A_t (dashed red line) and removals R_t (dotted black line). The series are at yearly frequency, and there is substantial turnover in consumption baskets, with additions accounting for about 30% of expenditure. Net additions and the intensive margin have roughly the same volatility and co-move positively with expenditure growth, with a correlation of over 90% (Table 1). Removals are relatively acyclical, while additions co-move strongly with expenditure. The "β-decomposition" row in Table 1 reports the estimated coefficient β_X from an OLS regression where the independent variable is expenditure growth, $\Delta E_t/E_{t-1}$, and the dependent variable X is reported by column (standard errors are in parenthesis). Formally:

$$X_t = \alpha_X + \beta_X \frac{\Delta E_t}{E_{t-1}} + \text{error},$$

where $X_t = I_t, N_t, A_t,\ R_t$. OLS is a linear operator, which implies that the coefficients for the intensive margin and net additions sum to 1 ($\beta_I + \beta_N = 1$) and that the coefficient for net additions, β_N, equals the difference between that for additions and that for removals ($\beta_N = \beta_A - \beta_R$). In this sense β_X can be interpreted as a measure of the contribution of X_t to the cyclical fluctuation in $\Delta E_t/E_{t-1}$. Using this metric, Table 1 shows that net additions N_t account for almost half of the variation in expenditure growth $\Delta E_t/E_{t-1}$, with additions A_t accounting for practically all of the fluctuation in N_t.

Panels (c) and (d) of Figure 1 are analogous to panels (a) and (b), but now the flows are quarterly. For seasonal adjustment, the quarterly series are computed as four-quarter moving averages. Additions and removals are now larger in absolute terms, but the cyclical properties of the series change very little in that A_t still explains a large share of the fluctuation in E_t and R_t only a small share (Table 1). Compared with the yearly frequency, the contribution of net additions is now somewhat greater and additions and removals tend to co-move slightly more strongly.

The quarterly series also indicate that at the end of the sample period the value of additions and removals was greater. This increase is not reflected in the yearly series, which jibes with the idea that households reduced the number of shopping trips during the recovery. When flows are calculated at high frequencies, this change in behaviour results in an artificial increase in additions and removals.

Fluctuations in the extensive margin may reflect changes in the sectoral or quality composition of the consumption basket or in the varieties available in the market. To study these issues we

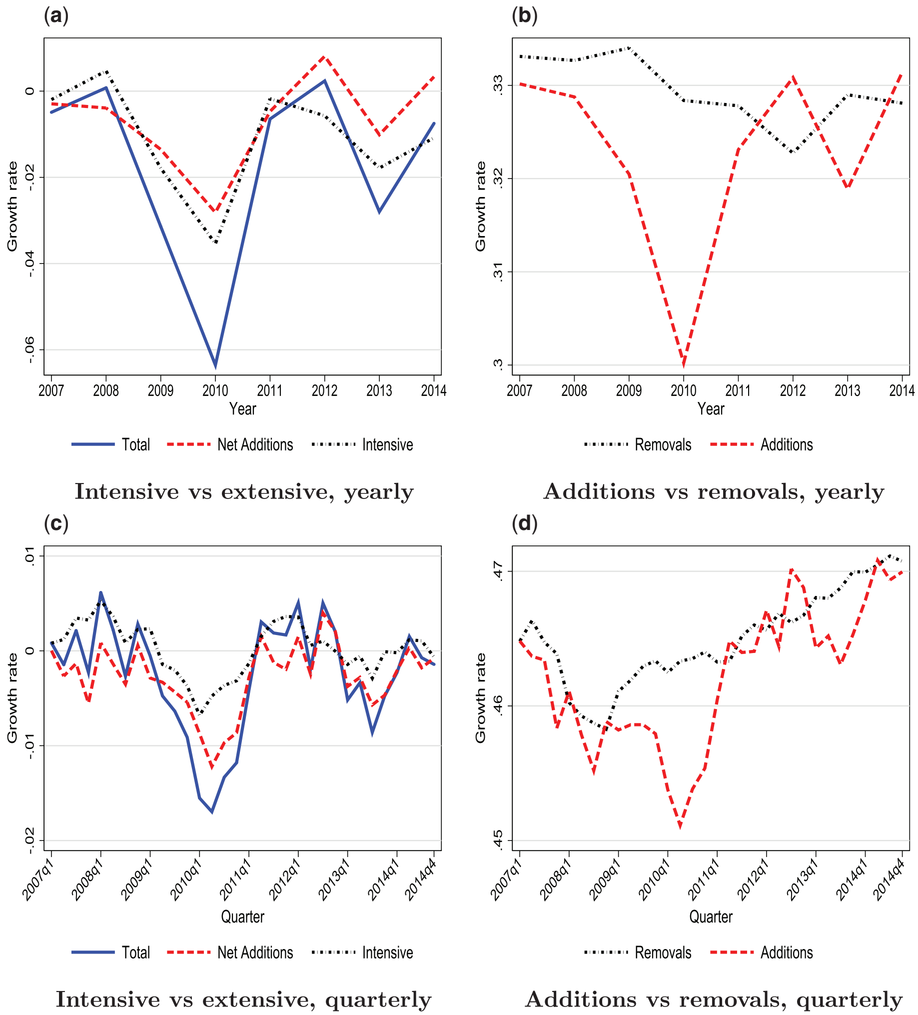


FIGURE 1

Flows in aggregate expenditure

Panel (a) and (c) plot the growth rat of expenditure, $\Delta E_t/E_{t-1}$, together with the contribution of the intensive margin I_t and net additions N_t. Panel (b) and (d) plot additions A_t and removals R_t. In the first row, the analysis is at yearly frequency, in the second quarterly. The quarterly series are 4-quarters moving averages. A variety is defined as a brand/product–module pair.

break the extensive margin down into *within* and *between* group components, defining the groups differently depending on the point at issue. Formally, let $\mathcal{V}_t$ be the set of varieties available in the market at time t and $\mathcal{V}_t^g$, $g=1,2...\mathcal{G}$ denote a partition of $\mathcal{V}_t$: $\bigcup_{g=1}^{\mathcal{G}} \mathcal{V}_t^g = \mathcal{V}_t$ and $\mathcal{V}_t^g \bigcap \mathcal{V}_t^{g'} = \emptyset$, $\forall g \neq g'$. The time-t expenditure of household h in varieties of group g are equal to

$$e_{ht}^g = \sum_{v \in \mathcal{V}_t^g} e_{vht}.$$

Given the partition $\mathcal{G}$, the *between-group* component of additions A_t^b is equal to the sum of all additions in groups where households had zero expenditure at $t-1$, while the between-group

TABLE 1
Descriptive statistics

	ΔE_t	I_t	N_t	A_t	R_t
a) Yearly frequency					
Standard deviation (%)	2.20	1.30	1.10	1.00	0.40
Correlation with ΔE_t	1.00	0.95	0.93	0.95	−0.12
β-Decomposition, β_X	1.00	0.54	0.46	0.44	−0.02
		(0.07)	(0.07)	(0.06)	(0.07)
b) Quarterly frequency					
Standard deviation (%)	0.60	0.30	0.40	0.50	0.40
Correlation with ΔE_t	1.00	0.91	0.94	0.65	0.02
β-Decomposition, β_X	1.00	0.43	0.57	0.58	0.01
		(0.04)	(0.04)	(0.12)	(0.11)

Notes: The row labelled "β-Decomposition" reports the OLS coefficient β_X from regressing the variable by column, $X_t = I_t, N_t, A_t, R_t$, against the percentage change in expenditure, $X_t = \alpha_X + \beta_X \Delta E_t / E_{t-1} + \text{error}$. The properties of OLS imply $\beta_I + \beta_N = 1$ and $\beta_N = \beta_A - \beta_R$. A variety is identified as a brand/product-module pair. Standard errors in parenthesis.

component of removals R_t^b is equal to the sum of all removals in groups where households have zero expenditure at t, so that

$$A_t^b = \sum_{g=1}^{\mathcal{G}} A_t^g, \tag{12}$$

$$R_t^b = \sum_{g=1}^{\mathcal{G}} R_t^g, \tag{13}$$

where A_t^g is the contribution of group g to the between-group component of additions

$$A_t^g = \frac{\sum_{h \in \mathcal{H}} e_{ht}^g \times \mathbb{I}(e_{ht-1}^g = 0) \times \mathbb{I}(e_{ht}^g > 0)}{E_{t-1}},$$

while R_t^g is its contribution to the between-group component of removals

$$R_t^g = \frac{\sum_{h \in \mathcal{H}} e_{ht-1}^g \times \mathbb{I}(e_{ht-1}^g > 0) \times \mathbb{I}(e_{ht}^g = 0)}{E_{t-1}}.$$

The within-group component of additions A_t^w and of removals R_t^w are equal to the sum of all additions and removals in groups where households spent a strictly positive amount both in $t-1$ and in t; these components are obtained as a residual:

$$A_t^w = A_t - A_t^b, \tag{14}$$

$$R_t^w = R_t - R_t^b. \tag{15}$$

Table 2 reports β-decompositions analogous to those in Table 1 for different partitions of the set of available varieties. We focus on the yearly analysis, with brief discussion of the quarterly results where significant differences emerge. We start by partitioning the varieties into Nielsen's 735 product modules. Panel (a) of Table 2 documents that even with this very fine sectoral breakdown additions fluctuate substantially in sectors where households were already actively buying varieties in the previous year. The within-group component of additions accounts for

TABLE 2
Within/between components, β-decompositions

Frequency:	Yearly			Quarterly		
Variable X_t:	N_t	A_t	R_t	N_t	A_t	R_t
Total contribution of X, $\beta_X^w+\beta_X^b$	0.46	0.44	−0.02	0.57	0.58	0.01
a) Changes in sectoral composition						
Within, β_X^w	0.27	0.27	0.00	0.20	0.22	0.02
Between, β_X^b	0.19	0.17	−0.02	0.37	0.36	−0.01
b) Quality substitution						
Within, β_X^w	0.20	0.20	0.00	0.15	0.13	−0.02
Between quality within product group, β_X^b	0.21	0.20	−0.01	0.25	0.29	0.04
Between product group, β_X^b	0.05	0.04	−0.01	0.18	0.17	−0.01
c) Varieties available in the market						
Within, β_X^w	0.41	0.40	−0.02	0.55	0.56	0.01
Between, β_X^b, due to new varieties	0.05	0.04	0.00	0.02	0.03	0.01

Notes: Each entry is the estimated OLS coefficient β_X^s from regressing the between component $s=b$ or the within component $s=w$ of the variable $X_t=N_t,A_t,R_t$ in column against expenditure growth: $X_t^s=\alpha_X^s+\beta_X^s\Delta E_t/E_{t-1}+$error. The first row reports the total contribution of variable X_t (the sum of its between and within components) to the fluctuation in $\Delta E_t/E_{t-1}$. A variety is identified by a brand/product–module pair. The sectors in panel (a) correspond to the 735 product modules defined by Nielsen. In panel (b), there are 950 groups corresponding to 95 product-groups defined by Nielsen, each partitioned into 10 quality bins corresponding to deciles of average prices within the product-group. In panel (c), β_X^w corresponds to varieties available in the market also at $t-1$, while β_X^b corresponds to varieties first introduced in the market at t.

more than half the overall cyclical contribution of net additions to the growth in expenditure. At quarterly frequency, the contribution of the between-sector component of gross and net additions increases, presumably reflecting seasonal patterns in the composition of the consumption basket.

Argente and Lee (2021) have observed that over the cycle households substitute products of different quality. Of course, quality substitution may be intensive or extensive. Substitution of products along the extensive margin would counterfactually predict that additions and removals should comove positively, which is prima facie evidence that substitution (across sectors or quality categories) is unlikely to drive our results. To analyse the issue more formally, we construct a measure of the quality of variety $\nu\in\mathcal{V}$ based on its average per unit price over time. In calculating the average unit price, we control for a full set of time dummies interacted with the 95 product group dummies (for additional detail, see Supplementary Appendix A). Within each product group, we assign varieties to ten different quality bins corresponding to the deciles of the quality distribution within the group, thus partitioning the variety space into 950 groups, $\mathcal{G}=950$. Panel (b) of Table 2 shows that quality substitution affects the cyclical properties of net and gross additions, but it does not fully account for them. At the yearly frequency, the contribution to expenditure growth of the within-quality component of net additions is as large as that of the between-quality component.[8] Changes between product groups account for no more than 5% of the total contribution of net and gross additions, and for removals they are almost negligible.

As shown by Broda and Weinstein (2010), the net entry of new varieties into the market is strongly pro-cyclical. It is important to determine whether the cyclicality of additions and removals depends on the net entry of new varieties into the market, or whether it arises also within the set of continuously available varieties. We accordingly partition the space of varieties at time t according to whether they are newly introduced, withdrawn, or continuously available both at

8. The between-quality component is also not fully consistent with quality substitution along the extensive margin that would imply a positive comovement between additions and removals.

$t-1$ and at t.[9] Panel (c) of Table 2 shows that, at the yearly frequency, fluctuations in net and gross additions occur mainly in continuously present varieties. For example, additions in continuously available varieties contribute about 39% of the fluctuation in expenditure growth, $\beta_A^w = 0.40$, while the analogous contribution of additions in new varieties is around 4%, $\beta_A^b = 0.04$. Overall, these findings are consistent with the thesis that firm product innovation is pro-cyclical, but changes in the net supply of varieties do not fully explain the observed changes in the consumption basket along the extensive margin. In Supplementary Appendix A, we further relate these findings to those in Broda and Weinstein (2010).[10]

Supplementary Appendix A reports on several additional exercises, which generally confirm the robustness of the previous results. In particular, we show that the previous patterns hold across households with different permanent income (as measured by their level of expenditure), for product varieties of different durability, across different U.S. regions, and also when measuring expenditures at constant rather than at current prices or when identifying additions to and removals from the household consumption basket using a longer reference period (two years); see Supplementary Appendix A for the full details.

3. RESPONSES TO AN INCOME SHOCK

Rather than reflecting genuine changes in household demand behaviour, the foregoing findings could be driven by general equilibrium effects or changes in marketing and pricing strategies. To analyse this issue, we examine the effects of the 2008 federal Economic Stimulus Payment (ESP) to households. Since the consumption response to ESP is gauged by comparing households who receive the payment randomly over time, and the regressions include a full set of time dummies to control for aggregate effects, we interpret the estimates as partial equilibrium responses—which follows (among others) Kaplan and Violante (2014), Kueng (2018), and Campbell and Hercowitz (2019).

Roughly, the ESP amounted to a transfer of \$300 to single-person households and \$600 to couples, which was reduced by 5% of the amount by which household gross income exceeded the threshold of \$75,000 for singles and \$150,000 for couples; see Parker *et al.* (2013) and Broda and Parker (2014) for details. On average, the ESP was equal to 3.1% of household personal consumption expenditure in the second quarter of 2008. As in Parker *et al.* (2013) and Broda and Parker (2014), we combined data from KNCP survey with additional information on the week when the household received the ESP, at some time between April and July 2008.[11] The timing of the transfer of the ESP was randomized by social security number. The response of consumption to its receipt is gauged by comparing households that received the payment at randomly different points in time. For each household h and week t in 2008, we calculate the percentage difference between expenditure in that week, denoted by e_{ht}, and its average weekly expenditure in the reference period 2004–7, denoted by $\bar{e}_h \equiv \sum_{v\in\mathcal{V}} \bar{e}_{vh}$, where

9. The introduction and withdrawal date of a variety is at the Designated Market Area (DMA) level and is identified combining household level (KNCP) and store level (The Nielsen Company c, henceforth KNRS) data; see Supplementary Appendix A for details.

10. When we identify a variety by UPC alone, the contribution of newly introduced varieties to fluctuations in additions increases by 20–25 percentage points over the contribution of 4% reported in Table 2, which is in line with the estimates in Table 7 of Broda and Weinstein (2010). This indicates that during booms firms use new UPCs of the same brand to attract new customers—a form of strategic marketing.

11. This operation can be performed thanks to the information contained in the Tax rebate survey in the Nielsen Panelview Survey Database (The Nielsen Company b).

$\bar{e}_{\nu h}$ is the average weekly expenditure of household h in variety ν in 2004–7:

$$\widetilde{g}_{ht} = \frac{e_{ht} - \bar{e}_h}{\bar{e}_h} = \widetilde{i}_{ht} + \widetilde{a}_{ht} - \widetilde{r}_{ht}.$$

$\widetilde{g}_{ht}$ is decomposed into a term due to the intensive margin $\widetilde{i}_{ht}$, one due to gross additions, $\widetilde{a}_{ht}$, and one due to removals $\widetilde{r}_{ht}$, which are defined similarly as before:

$$\widetilde{i}_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht} - \bar{e}_{\nu h}}{\bar{e}_{\nu h}} \times \mathbb{I}(\bar{e}_{\nu h} > 0) \times \mathbb{I}(e_{\nu ht} > 0), \tag{16}$$

$$\widetilde{a}_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht}}{\bar{e}_{\nu h}} \times \mathbb{I}(\bar{e}_{\nu h} = 0) \times \mathbb{I}(e_{\nu ht} > 0), \tag{17}$$

$$\widetilde{r}_{ht} = \sum_{\nu \in \mathcal{V}} \frac{e_{\nu ht-1}}{\bar{e}_{\nu h}} \times \mathbb{I}(\bar{e}_{\nu h} > 0) \times \mathbb{I}(e_{\nu ht} = 0). \tag{18}$$

The contribution of net additions is then measured by

$$\widetilde{n}_{ht} = \widetilde{a}_{ht} - \widetilde{r}_{ht}. \tag{19}$$

Notice that a product added to the consumption basket in a week of 2008 contributes to $\widetilde{a}_{ht}$ only if the household had never purchased it during the entire period 2004–7, which implies that additions are identified at least four times more restrictively than in Section 2, where the reference period was at most 1 year.[12] To measure persistent changes in the household consumption basket, we also construct a measure of *persistent additions*, $\widetilde{a}^{per}_{ht}$, equal to the subset of the additions in (17) which happen in products that the household will buy again at least once in one of the 52 weeks after t. We then run the following regressions

$$\widetilde{x}_{ht} = \alpha + \beta_{-1} LEAD_{ht} + \beta_0 CURRENT_{ht} + \sum_{\tau=1}^{8} \beta_\tau LAG_{h\tau t} + \psi_t + \epsilon_{ht}, \tag{20}$$

where the dependent variable is $\widetilde{x} = \widetilde{g}$, $\widetilde{i}$, $\widetilde{n}$, $\widetilde{a}$, $\widetilde{a}^{per}$, *LEAD* is a dummy variable equal to 1 in the four weeks before receipt of the ESP, *CURRENT* is equal to 1 in the week of receipt and the three following weeks, $LAG_{h\tau t}$ is equal to one if the household has received the ESP τ months before t and ψ_t are time dummies. In running (20), we weight households using their KNCP weights. Table 3 reports the results from estimating (20), where the dependent variable $\widetilde{x}$ appears in column. The table reports three coefficients corresponding to the anticipated response to receipt of the ESP, β_{-1}, the response on receipt, β_0, and the 4-week lagged response, β_1. We call these coefficients marginal propensities to consume out of the ESP. The estimates for different $\widetilde{x}$ decompose the overall marginal propensity to consume estimated by Broda and Parker (2014), MPC_E, into the sum of one marginal propensity to consume along the intensive margin, MPC_I, and another due to net additions, MPC_N, which can be further broken down into a component due to removals and one due to additions, MPC_A. Finally the additions can be temporary or persistent, the latter denoted by $\text{MPC}_\text{A-Per}$. The overall marginal propensity to consume upon receipt of the

12. Likewise, varieties sometimes purchased by the household in the period 2004–7 contribute to $\widetilde{r}_{ht}$ if they are not purchased in the specific week t of 2008.

TABLE 3
Decomposing the marginal propensity to consume to the ESP

Response to the ESP (%)	Total MPC_E	Intensive MPC_I	Net MPC_N	Gross MPC_A	Removals MPC_R
Month before, β_{-1}	2.69*	1.50	1.19*	1.57**	0.38*
	(1.47)	(1.04)	(0.65)	(0.64)	(0.21)
Month of receipt, β_0	6.08***	3.96***	2.11***	2.63***	0.52
	(1.84)	(1.34)	(0.82)	(0.82)	(0.33)
Month after, β_1	5.40**	2.94*	2.47**	3.33***	0.87*
	(2.40)	(1.74)	(1.05)	(1.07)	(0.47)
Number of observations	324,324	324,324	324,324	324,324	324,324
Number of households	6,237	6,237	6,237	6,237	6,237

Notes: Results from estimating (20) for $\widetilde{x}=\widetilde{g},\widetilde{i},\widetilde{n},\widetilde{a},\widetilde{r}$. Data are weekly. ESP stands for Economic Stimulus Payment in 2008. MPC stands for Marginal Propensity to Consume in total expenditure (column 1), intensive margin (column 2), net additions (column 3), gross additions (column 4), and removals (column 5). Additions and removals are calculated using 2004–7 as a reference period.

ESP is around 6%, which is in line with the estimates of Broda and Parker (2014). There is some evidence that expenditure increases in the 4 weeks before the receipt of the ESP, by around 2.5%. Net additions account for 30–40% of the total marginal propensity to consume upon receipt of the ESP. Net additions correspond almost perfectly to gross additions.

Table 4 shows that persistent additions $\widetilde{a}^{per}$ account for roughly a third of the response of additions $\widetilde{a}$: expenditures increase by roughly 1% in varieties that the household had never purchased in the previous 4 years and will repurchase again at least once in the year after receipt of the ESP, indicating that households respond to temporary income changes by adding new products, which then remain persistently in their consumption basket for several weeks after the income boost.

As in Section 2.3, we also decompose the response of additions $\widetilde{a}$ into a component within sectors and quality groups where the household had purchased some varieties in the previous four years and a component due to purchase of varieties in sectors or quality groups that had never entered the household consumption basket before. We partition the space of available varieties at time t into 950 different groups, corresponding to 10 quality bins within each of Nielsen's 95 product groups. Table 4 indicates that the within-quality within-product-group component accounts for more than 90% of the response of additions, MPC_A, implying that quality substitution does not drive the response of the extensive margin to the ESP. This evidence is in line with the observed lack of comovement between additions and removals: under substitution of products along the extensive margin additions and removals would comove positively.

The survey administered by Broda and Parker (2014) over the period April–June 2008 also asks the following question to Nielsen households: "*About how often do you or other household members make purchases that you later regret?*" The possible answers are: "*Never*"; "*Rarely*"; "*Occasionally*"; "*Often.*"; We study whether more additions are associated with greater regret. In the first half of 2008, we averaged the additions $\widetilde{a}_{ht}$ in (17). For the three terciles of the resulting distribution of average $\widetilde{a}_{ht}$'s we calculated the fraction of households selecting each of the previous four options. We find that the households spending more on additions (top tercile) are 7% more likely to occasionally regret their purchases than those spending less in additions (bottom tercile), see Supplementary Appendix A for further details. To better characterize how households adopt new varieties, in the Supplementary Appendix we also studied the time profile of expenditure in varieties newly added by the household to her consumption basket and find that (i) the first purchase of the household in a newly added variety is on average small in value, (ii) the probability of repurchasing the variety in the future is relatively low, but (iii) conditional on

TABLE 4
Components of the marginal propensity to consume in additions

Response to the ESP (MPC_A, %)	Persistent additions $MPC_{A\text{-Per}}$	Within quality and Within product groups	Between quality and within product groups	Between product groups
Month before, β_{-1}	0.65**	1.25**	0.08	0.24*
	(0.29)	(0.50)	(0.25)	(0.14)
Month of receipt, β_0	0.93**	2.33***	0.17	0.13
	(0.37)	(0.65)	(0.31)	(0.15)
Month after, β_1	1.42***	3.01***	0.12	0.20
	(0.52)	(0.86)	(0.39)	(0.18)
Number of observations	324,324	324,324	324,324	324,324
Number of households	6,237	6,237	6,237	6,237

Notes: In column 1 the dependent variable is additions in products repurchased at least once in one of the 52 weeks after t, $\widetilde{a}^{per}$. Columns 2, 3, and 4 decompose MPC_A in Table 3 as the sum of the three components indicated by column, once varieties are partitioned into 10 quality bins and 95 product groups.

repurchasing the household spends in the newly added variety as much as she spends in other varieties she regularly buys. Overall, this evidence suggests that at first the household is uncertain whether it will like the new variety and therefore spends little on it. If it turns out to like the new variety, it then treats it like the others it typically buys. If not, it stops buying it, with some regret for the initial purchase.

4. HOUSEHOLD PROBLEM: MCFADDEN MEETS RAMSEY

We build on a conventional random utility model of discrete choice of products à la McFadden (1974) (1973, 1974) to match the high level of additions observed in the data. Time t is discrete. In each period the household has a set of varieties she considers for consumption: the *consideration set*. Varieties in the consideration set are subject to preference shocks that produce turnover in the consumption basket. We embed the discrete choice model in a standard dynamic optimization problem à la Ramsey (1928) where the household decides saving and *adoption expenditure*, *i.e.*, how many varieties to sample so as to enlarge the consideration set. We first characterize the economy, then solve for the static maximization problem of allocating expenditures to varieties in the consideration set. Finally we turn to dynamic optimization. Section 7 studies the economy in general equilibrium.

4.1. *The economy*

The household is infinitely lived and maximizes the expected present value of the utility from consumption $u(c_t)$, with $u'>0$ and $u''<0$. The subjective discount factor is $\rho\in(0,1)$. In the economy there are $\mathcal{V}_t=[0,1]\times[0,v_t]$ varieties corresponding to a measure 1 of sectors, each containing v_t distinct varieties, see Figure 2. In sector $j\in[0,1]$ at time t, the household considers buying a *discrete* number of varieties $n_{jt}\geq 0$ that are in her consideration set for the sector $\Omega_{jt}\subseteq[0,v_t]$, see Figure 2. We denote by $q_{\nu j}$ the amount of variety $\nu\in\Omega_{jt}$ in sector $j\in[0,1]$ consumed. Consumption is equal to

$$c_t=\left[\int_0^1\left(\sum_{\nu\in\Omega_{jt}} z_{\nu jt}q_{\nu j}\right)^{\frac{\sigma-1}{\sigma}}dj\right]^{\frac{\sigma}{\sigma-1}}, \tag{21}$$

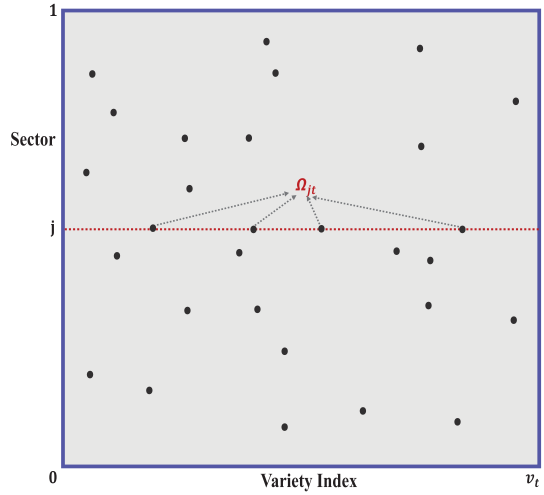


FIGURE 2

The space of varieties and the household consideration set.

Notes: A bullet point represents a variety in the household consideration set. The union of all points has the cardinality of the continuum.

which means that varieties are differentiated across sectors with a constant elasticity of substitution $\sigma > 1$; within each sector, they are perfectly substitutable. As in standard random utility models of discrete choice, the unit value of a variety $\nu \in \Omega_{jt}$ is subject to preference shocks $z_{\nu jt}$ which are iid drawings from a Fréchet distribution with shape parameter $\kappa > \sigma - 1$ and scale parameter equal to 1.[13]

All varieties are sold at the same price, equal to P_t in monetary terms. Hereafter, we set a variety in $\mathcal{V}_t$ as the numeraire. At t, the household obtains (gross) capital income $\iota_t a_{t-1}$ and other income y_t (endogenized in Section 7.1) and decides her *total expenditure* e_t and savings a_t subject to the constraint:

$$e_t + a_t \le \iota_t a_{t-1} + y_t. \tag{22}$$

Household total expenditure e_t is the sum of expenditures for consumption

$$s_t = \int_0^1 \sum_{\nu \in \Omega_{jt}} q_{\nu j} dj \tag{23}$$

and expenditures on experimenting with new varieties to be added to her time-t consideration sets, $x_t \in R^2_+$, so that

$$e_t \equiv s_t + x_t. \tag{24}$$

The *adoption expenditure* x_t represents the cost of buying units of varieties to sample in order to discover whether they are worth bringing into the household consideration set. Experimentation

13. The CDF of a Fréchet distribution is equal to $\Pr(X \le x) = e^{-\left(\frac{x}{s}\right)^{-\kappa}}$ with support $x > 0$, where κ and s are the shape and scale parameter, respectively. Its expected value is equal to

$$E(X) = \begin{cases} s\Gamma\left(1 - \frac{1}{\kappa}\right) & \text{if } \kappa > 1 \\ \infty & \text{if } \kappa \le 1 \end{cases}.$$

The Fréchet distribution is max-stable, which we use extensively to achieve analytical tractability.

is fully random over the space of varieties $\mathcal{V}_t$.[14] With adoption expenditure x, the household finds varieties to be added to her time-t consideration sets according to a Poisson process over the space $\mathcal{V}_t$ with intensity

$$\Lambda_t(x) = e^{\lambda_t}\Lambda(x), \tag{25}$$

where $\Lambda(x)$ is increasing and concave in x, $\Lambda'(x) > 0$ and $\Lambda''(x) < 0$.[15] Changes in the search technology λ_t may be due to firm advertising, the availability of varieties in the market v_t or household search effort. Newly found varieties in sector j are added to the consideration set Ω_{jt}. From time $t-1$ to t, there is an iid probability $\delta \in (0,1)$ that the household drops a variety from the consideration set, either because she (permanently) changes habits (or forgets about the variety), which happens with probability δ_p, or because the variety is withdrawn from the market, which happens with probability δ_f. As a result, $1-\delta \equiv \left(1-\delta_p\right)\left(1-\delta_f\right)$. We assume that the initial number of varieties (at time zero) in the household consideration set for a sector is distributed as a Poisson distribution with expected value μ_{-1}. In Appendix B, we show that the Poisson property is preserved over time so that:

Lemma 1. *Let $f_t(n)$ denote the fraction of sectors whose consideration set contains $n \geq 0$ varieties at time $t \geq 0$. If $f_0(n)$ is a Poisson distribution with mean μ_0, then $f_t(n)$ is also a Poisson distribution, $f_t(n) \equiv \frac{\mu_t^n e^{-\mu_t}}{n!}$, with mean μ_t which evolves as follows:*

$$\mu_t = (1-\delta)\,\mu_{t-1} + \Lambda_t(x_t). \tag{26}$$

4.2. *Static maximization*

For given consumption expenditure s_t in (23), consumption c_t is obtained by maximizing (21) with respect to $q_{\nu j} \geq 0\ \forall \nu \in \Omega_{jt}$ and $\forall j \in [0,1]$. The solution to the problem is characterized by the following proposition proved in Supplementary Appendix B:

Proposition 1. *Consumption in (21) satisfies $c_t = \frac{s_t}{p_t}$ where p_t is the welfare-relevant household price index equal to*

$$p_t = p(\mu_t) = \left[\Gamma\left(1 - \frac{\sigma-1}{\kappa}\right)\sum_{n=0}^{\infty} n^{\frac{\sigma-1}{\kappa}} f_t(n)\right]^{-\frac{1}{\sigma-1}}. \tag{27}$$

Household consumption expenditure satisfies $s_t = \sum_0^{\infty} s_{nt} f_t(n)$, where

$$s_{nt} = \frac{n^{\frac{\sigma-1}{\kappa}}}{\sum_{m=0}^{\infty} m^{\frac{\sigma-1}{\kappa}} f_t(m)} s_t \tag{28}$$

denotes average consumption expenditure in a sector with a consideration set of n varieties.

14. Random experimentation also implies that there is no memory of varieties unsuccessfully tried in the past. The assumption is that a variety might have to be tried more than once before the household starts to appreciate it and brings it into the consideration set.

15. This means that if the household spends $\widehat{\delta} \in R_+$ units on $\widehat{\delta}$ different varieties, the probability of finding one is $\Lambda_t(x)\widehat{\delta}$, the probability of finding none is $1-\Lambda_t(x)\widehat{\delta}$, and the probability of finding more than one is of an order smaller than $\widehat{\delta}$. Notice that if $x \in R_+^2$ the mass of varieties found belongs to R_+, while if $x \in R_+$ the number of varieties found is a (random) natural number. Finally notice that, since the amount spent on varieties added to the consideration set is infinitesimal, these expenditures yields no consumption utility in (21).

From Lemma 1, the welfare-relevant household price index p_t in (27) is a function of only the average number of varieties in the consideration set μ_t. p_t has a constant elasticity, $1/(\sigma-1)$, with respect to the mass of sectors with a non-empty consideration set, equal to $1-f_t(0)$. This reflects the *love-of-variety* motive built into the CES aggregator in (21). Given a non-empty consideration set in a sector, the size of the set still matters for the price index, because a greater number of varieties n_{jt} in Ω_{jt} increases the value of the variety consumed by the household: formally, $E\left(\max_{\nu\in\Omega_{jt}} z_{\nu jt}\right)=\Gamma(1-1/\kappa)n_{jt}^{1/\kappa}$ is increasing in $n_{jt}>0$ with elasticity $1/\kappa$. The marginal value of one more variety in the consideration set is greater when κ or σ is smaller: smaller κ implies that a specific variety is more likely to have little value, while smaller σ implies that varieties in a sector can be less easily replaced by varieties in other sectors. Both effects make a larger consideration set more valuable.

4.3. *Optimal adoption expenditure*

Given the law of motion of μ_t in (26), the budget constraint in (22), and the income process y_t, the household chooses total expenditure, $e_t\geq 0$, adoption expenditure $x_t\geq 0$, and savings a_t to maximize

$$\mathbb{E}_t\left[\sum_{j=t}^{\infty}\rho^{j-t}u\left(\frac{e_j-x_j}{p(\mu_j)}\right)\right]. \tag{29}$$

The following Proposition proved in Appendix B characterizes the solution to the problem:

Proposition 2. *Adoption expenditure x_t satisfies the following Euler condition $\forall t$*

$$1=\frac{\Lambda_t'(x_t)\eta(\mu_t)}{\mu_t}(e_t-x_t)+(1-\delta)\mathbb{E}_t\left[\rho_{t,t+1}\frac{\Lambda_t'(x_t)}{\Lambda_{t+1}'(x_{t+1})}\right], \tag{30}$$

where

$$\rho_{t,t+j}\equiv\rho\frac{p_t}{p_{t+j}}\frac{u'\left(c_{t+j}\right)}{u'\left(c_t\right)} \tag{31}$$

is the household discount factor at t for income in period $t+j$, and

$$\eta(\mu_t)\equiv-\frac{d\ln p(\mu_t)}{d\ln\mu_t}=\frac{1}{\sigma-1}\left[\frac{\sum_{n=0}^{\infty}n^{\frac{\sigma-1}{\kappa}+1}f(n;\mu_t)}{\sum_{n=0}^{\infty}n^{\frac{\sigma-1}{\kappa}}f(n;\mu_t)}-\mu_t\right] \tag{32}$$

is the elasticity of the household price index with respect to μ_t, which satisfies $\eta(\mu_t)\in[0,1/(\sigma-1)]$. Total expenditure e_t solves the following standard Euler condition $\forall t$

$$1=\mathbb{E}_t\left(\rho_{t,t+1}\iota_{t+1}\right). \tag{33}$$

The Euler condition in (30) implies that x_t maximizes (29) taking as given the optimal path of total expenditure e_t: conditional on e_t, the choice of x_t is independent of the sources of the fluctuations in e_t (say whether they are due to changes in income or financial returns). The left-hand side of (30) is the marginal cost of sampling the space of existing varieties. The right-hand side is the sum of the instantaneous gain plus its continuation value. The instantaneous gain comes from the reduction in the price index following an increase of $\Lambda_t'(x)$ in μ, which increases consumption c, for given total expenditure e. The continuation value is determined by noticing that, from tomorrow's standpoint, the household is indifferent between spending 1 unit on adoption today and $1-\delta$ tomorrow, since a fraction δ of today's investment gets lost. The instantaneous gain is greater, when total expenditure e_t is higher, because a given reduction in the price index is more beneficial. This is a *scale* effect typically present in models with love of variety. The continuation value is greater when today's consumption is temporarily higher, which increases $\rho_{t,t+1}$ in (31). As a result, the household spends more on adoption, which persistently lowers the household price index. Essentially, the adoption of more varieties is a form of investment which persistently reduces the welfare-relevant household price index and helps the household in achieving better *consumption smoothing*. The Euler condition for total expenditure in (33) can be extended to allow for more financial assets and adjustment costs in portfolio rebalancing, as in Kaplan and Violante (2014). This would generate empirically plausible values for the marginal propensity to consume, still leaving (30) unchanged (provided $x_t > 0$).

4.4. *Additions, removals, and the intensive margin*

As in (7), the growth rate of total expenditure can be expressed as equal to

$$\frac{e_t - e_{t-1}}{e_{t-1}} = N_{rt} + I_{rt} = A_{rt} - R_{rt} + I_{rt}, \tag{34}$$

where net additions N_{rt}, additions A_{rt}, removals R_{rt} and the intensive margin I_{rt} are defined as in Section (2.1), with $N_{rt} = A_{rt} - R_{rt}$. In Appendix B, we derive analytical expressions for these variables. Here we briefly discuss their key features, emphasizing the distinction between flows into and out of the consumption basket, which we observe, and flows due to changes in the consideration set, which we can only infer indirectly and which we refer to as *true* additions and removals. Additions are the sum of the following three terms:

$$A_{rt} = \frac{x_t}{e_{t-1}} + \frac{\Lambda_t(x_t)}{\mu_t}\frac{s_t}{e_{t-1}} + \left[\frac{(1-\delta)^2 \mu_{t-2}}{\mu_t}\frac{s_t}{e_{t-1}} - \tilde{e}_t^1\right]. \tag{35}$$

The first term on the right-hand side of (35) stands for adoption expenditure x_t, which by definition involves new varieties. The second term is the contribution of *true additions* to the household consideration set: expenditure on newly added varieties to the consideration set whose preference draw is the highest among the varieties in the consideration set, an event which happens with probability $\Lambda_t(x_t)/\mu_t$. Finally, the third term in square brackets measures additions to the consumption basket that do not reflect a change in the consideration set. These *noisy* additions are due to preference shocks that make the household purchase a variety that was already in her consideration set at time $t-1$ but was discarded in favour of another variety. Noisy additions are calculated as the difference between the expenditure at time t (as a share of e_{t-1}) in varieties already in the consideration set at $t-2$, which happens with probability $(1-\delta)^2\mu_{t-2}/\mu_t$, and the portion of this share on varieties that were also purchased at $t-1$, which is equal to $\tilde{e}_t^1$ (for the analytical expression of this, see Supplementary Appendix B).[16]

Analogously, removals can be expressed as

$$R_{rt} = \frac{x_{t-1}}{e_{t-1}} + \frac{\delta s_{t-1}}{e_{t-1}} + \left[\frac{(1-\delta)s_{t-1}}{e_{t-1}} - \tilde{e}_{t-1}^0\right]. \tag{36}$$

16. Notice that the expenditure at time t on varieties added to the consideration set at time $t-1$ always contributes to the intensive margin, since the variety was consumed for sure at $t-1$ as part of the household adoption expenditure.

The first term on the right-hand side of (36) is the contribution of past adoption expenditure x_{t-1}, which necessarily leads to removals because the portion of x_{t-1} spent on varieties newly added to the consideration set at $t-1$ has zero measure. The second term corresponds to *true* removals from the consideration set, which happens with probability δ. Finally, the third term measures removals due to preference shocks that make the household opt for a variety different from that consumed at $t-1$ even if the latter is still in the consideration set at t. These *noisy* removals are expressed as the difference between the share of $t-1$ expenditure on varieties still in the consideration set at t (probability $1-\delta$) minus the portion of this share on varieties purchased also at t, which is equal to $\tilde{e}^0_{t-1}$ (for an analytical expression, see Supplementary Appendix B). Finally the intensive margin is obtained as a residual using (34), which yields

$$I_{rt}=\frac{(1-\delta)\Lambda_{t-1}(x_{t-1})}{\mu_t}\frac{s_t}{e_{t-1}}+\tilde{e}^1_t-\tilde{e}^0_{t-1}. \tag{37}$$

Finally notice that the flows N_t, A_t, R_t, and I_t in Section (2.1) are nominal while the flows in (34)-(37) are real—we use a variety as the numeraire. Given the monetary price of a variety P_t, we use the following simple identities to go from real to nominal flows:

$$\frac{\Delta E_t}{E_{t-1}}=\frac{\frac{P_t}{P_{t-1}}e_t-e_{t-1}}{e_{t-1}},\quad A_t=\frac{P_t}{P_{t-1}}A_{rt},\quad R_t=R_{rt},\quad N_t=A_t-R_t,\quad I_t=\frac{\Delta E_t}{E_{t-1}}-N_t. \tag{38}$$

5. CALIBRATION

We calibrate the model by targeting detailed statistics from KNCP. The model is specified at the quarterly frequency and calibrated in a steady state with total expenditure $\bar{e}$ normalized to one and zero inflation, $P_t=P_{t-1}$. The consumption-utility is $u(c)=\left(c^{1-\gamma}-1\right)/(1-\gamma)$ and the Poisson arrival rate in (25) is $e^{\bar{\lambda}}\Lambda(\bar{x})$ with

$$\Lambda(x)=x\left[1-\frac{1}{1+\alpha}\left(\frac{x}{\chi}\right)^{\alpha}\right], \tag{39}$$

where $\bar{\lambda}$ measures steady state search efficiency, $\alpha\geq 0$ determines decreasing returns to adoption expenditure, and $\chi\geq 0$ is the maximum efficient level of adoption expenditure. Table 5 reports the calibrated parameter values with the associated calibration targets.

The curvature parameter of the utility function γ and the subjective discount factor ρ are set to the standard values of $\gamma=1$ (log-preferences) and $\rho=0.99$. To calibrate the exit rate of varieties from the consideration set δ, we notice that, in steady state, the share of expenditure at $t+\tau$ on varieties that the household has first purchased at t is equal to

$$A^F(\tau)=(1-\delta)^{\tau}\frac{\delta(\bar{e}-\bar{x})}{\bar{e}},\quad \tau\geq 1 \tag{40}$$

which uses the steady state identity $\Lambda(\bar{x})/\mu=\delta$. At t, the household adds $\Lambda(\bar{x})$ new varieties to her consideration set. Since varieties exit the consideration set at rate δ, the share of expenditure at $t+\tau$ on varieties added to the consideration set at t, as given by (40), falls at rate δ as τ increases. Solving for δ in (40), we obtain $\delta=1-[A^F(7)/A^F(3)]^{1/4}$, where we focus on an interval 4 quarters apart to control for seasonal effects in shopping behaviour. To evaluate $A^F(3)$ and $A^F(7)$, we consider a panel of about 20,000 households continuously present in KNCP from 2004 through 2008, thereby excluding the Great Recession that in KNCP first materializes in 2009. We identify

TABLE 5
Baseline calibration

Model		Data	
Parameter	Value	Moment	Value
$\bar{e}$	1	Steady state expenditure	1
ρ	0.99	Quarterly real interest rate	0.01
γ	1	Elasticity of inter-temporal substitution	1
δ	0.071	Attrition rate on new varieties, $A^F(7)/A^F(3)$	0.069
κ	11.4	Quarterly additions	0.490
$\bar{\lambda}$	0.89	Expenditure share on new varieties if $e=1$	0.179
σ	5.1	Expenditure share on new varieties if $e=0.398$	0.204
α	9.0	Expenditure share on new varieties if $e=0.893$	0.180
χ	0.19	Expenditure share on new varieties if $e=1.858$	0.150

all varieties purchased in I:07 (first quarter of 2007), that were never purchased by the household in any of the previous ℓ quarters for $\ell=1,2...12$. In IV:07, $\tau=3$, and IV:08, $\tau=7$, we calculate the average quarterly share of expenditure on the varieties purchased in I:07 but not purchased in any of the ℓ quarters before I:07. For both $\tau=3$ and $\tau=7$, the data are decreasing in ℓ and we fit an exponential regression model over ℓ—containing a constant and three terms in $\exp(-\tilde{\beta}_i\ell)$ $i=1,2,3$. We take the horizontal asymptote of the regression model (the constant) as measuring $A^F(\tau)$. We find $A^F(3)=0.0220$ and $A^F(7)=0.0165$, which imply a δ of roughly 7%.

To calibrate the five remaining parameters $[\bar{\lambda},\alpha,\chi,\kappa,\sigma]$, we target five additional moments in steady state. The first is an addition rate of 0.492, corresponding to its average level in 2007. The second is the fraction of household expenditure in a quarter on varieties that the household has never purchased before. In the model it corresponds to the share of expenditure in adoption and true additions, which after using the steady state identity $\Lambda(\bar{x})/\mu=\delta$, can be written as

$$A^R_\infty=\frac{\bar{x}+\delta(\bar{e}-\bar{x})}{\bar{e}}. \tag{41}$$

To estimate A^R_∞, we again rely on our sample of 20,000 households continuously present in KNCP before the Great Recession. In each quarter of 2007 we calculate the fraction of household expenditure on varieties that the household has not purchased in any of the previous $\ell=1,2...12$ quarters and fit the same exponential regression model over ℓ as before. The horizontal asymptote yields $A^R_\infty=0.179$, which together with the calibrated value of δ, implies $\bar{x}=11.74\%$. The remaining three moments are obtained by repeating the same exercise for households with different (average) expenditures in 2007. We take these statistics as representative of how adoption expenditure x and the adoption rate $\Lambda(x)$ would vary across steady states with different total expenditure e. We consider households with expenditures (i) in the bottom quintile of the distribution of expenditures $e=0.40$ (average expenditure in the group equal to 40% of average expenditure in the population); (ii) in the median quintile $e=0.89$; and (iii) in the top quintile $e=1.86$. As predicted by the model, wealthier households devote a smaller share of their expenditure to adoption. We target the value of A^R_∞ for $e=0.398$, $e=0.893$ and $e=1.858$ which is equal to 0.204, 0.180, and 0.150, respectively. Given the five targets, we solve a system of non-linear equations in the unknowns $[\bar{\lambda},\alpha,\chi,\kappa,\sigma]$.[17] The average number of varieties in the

17. Since $\lim_{x\to 0}\frac{\Lambda'(x)x}{\Lambda(x)}=1$ and $\lim_{x\to\infty}\frac{\Lambda'(x)x}{\Lambda(x)}=1+\alpha$, the parameters are identified as follows: at low e, x is low and (30) identifies the value of the elasticity $\eta(\mu)$ which is function of the parameters κ and σ governing preference for variety; given κ and σ, (30) at high value of e pins down the curvature of the search technology as parameterized by α and χ; finally $\bar{\lambda}$ targets the level of the addition rate.

household consideration set for a sector is equal to $\bar{\mu}=1.5$. The elasticity of $\Lambda(x)$ with respect to x at $\bar{x}$ is close to 1 (99%). The implied price elasticity of the demand for a variety ν is equal to 7.9 (see Supplementary Appendix E), which compares well with the elasticity of substitution of brands within product groups as estimated by Broda and Weinstein (2010) using Nielsen data comparable to ours over the pre-Great-Recession period. Their median estimate for the implied price elasticity of demand is equal to 7.5, see their Table 8.

6. QUANTITATIVE EVALUATION OF THE MODEL

We now evaluate the model quantitatively. First, we show that the model matches fairly closely the effects of the 2008 ESP as estimated in Section 3 and that a model with exogenous adoption fails to match the evidence. Then, we rely on the Kalman filter to estimate the time series of adoption expenditure and characterize the cyclical properties of the model. We show that the model accurately reproduces the cyclical dynamics of (gross and net) additions and removals as characterized in Section 2. Finally, we study whether the model is consistent with the cyclical properties of new varieties in the market. For the purpose we model firm incentives to innovate, endogenizing the number of varieties in the market as in Romer (1990) and Bilbiie *et al.* (2012). This will turn out to be useful also for studying the general equilibrium effects of fiscal transfers in Section 7.

6.1. *Response to the ESP*

To evaluate the effects of the 2008 ESP in the model, we take the response of total expenditure, e_t, to the ESP as given and solve for the optimal response of x_t implied by (30) using global (non-linear) methods. Given e_t and x_t, the dynamics of additions, removals, and the intensive margin is determined by (35), (36), and (37), respectively. The ESP is assumed to (unexpectedly) increase e_t by 4.72% in one quarter only, equivalent to the simple average of β_{-1}, β_0 and β_1 in column 1 of Table 3. We simulate the consumption histories of 100,000 households, initially in a steady state with constant expenditure $\bar{e}$, over six years (24 quarters). As in Section 3, net and gross additions are calculated using a four-year reference period, while persistent additions correspond to additions of varieties purchased again at least once in the following 4 quarters. We focus on the impact response of logged total expenditure (column 1 of Table 6), the intensive margin (column 2), net additions (column 3), additions (column 4) and persistent additions (column 5). We compare the model responses with the estimates in Tables 3 and 4, whose average and standard error (in parenthesis) are reported in the first row of Table 6. The second row of Table 6 also reports the estimates obtained by running the regression in (20) after (linearly) controlling for the average monthly price of the varieties purchased by the household, which might be a better comparison with our model that does not explicitly allow for price or other ex ante differences in products. The price control is the average logged price of varieties weighted using household expenditures and is calculated over the set varieties purchased by the household in the corresponding regression, which differs depending on whether the specification is for total expenditure, the intensive margin, or (net, gross, persistent) additions.[18] The third row of Table 6 reports the responses in the baseline model, the fourth the responses in a counterfactual model where adoption expenditure is assumed to remain constant at its steady state value. We take the counterfactual as a representation of the conventional view discussed in Section 1, where the household consideration set is (exogenously)

18. To make it comparable across-product groups, the log-price of a variety corresponds to the log of the average price of the variety in the month divided by the average price of all varieties in the product group.

TABLE 6
Response of expenditure to the 2008 tax rebate

Dollars spent on ESP (%)	Total MPC_E	Intensive MPC_I	Net MPC_N	Gross MPC_A	Persistent $MPC_{A^{pers}}$
Data					
3-month avg. of Table 3 or 4	4.72	2.80	1.92	2.51	1.00
	(1.73)	(1.25)	(0.77)	(0.78)	(0.37)
3-month avg. with price controls	5.36	2.79	1.91	2.56	0.91
	(1.73)	(1.25)	(0.77)	(0.77)	(0.35)
Model					
Baseline	4.72	2.60	2.12	2.79	0.88
Counterfactual with constant x_t	4.72	4.39	0.33	0.33	0.26

Notes: MPC stands for Marginal Propensity to Consume in total expenditure (column 1), intensive margin (column 2), net additions (column 3), additions (column 4), and persistent additions (column 5). The first row reports the average of the coefficients β_{-1}, β_0 and β_1 of Table 3; standard errors (in parentheses) are obtained using the delta method. The second row are the analogous β-coefficients after controlling for prices in the regression (20). The third row reports the model responses to a (one-quarter only) shock in logged expenditure $\ln e_t$ of 0.0472. The fourth row reports the response in the counterfactual model where adoption expenditure remains constant at its steady-state value. Additions and removals are calculated using a four-year reference period. Persistent additions are additions of varieties repurchased at least once in the following 4 quarters. The model parameter values are as in Table 5.

determined just by the aggregate supply of varieties, which given the source of identification in the data can be assumed to be unchanged.

The data indicate that net and gross additions account for more than a third of the overall response of total expenditure with more than a third of the increase in additions due to persistent additions. The model response of net, gross, and persistent additions is roughly in line with the data. The increase in adoption expenditure, x_t, is important for the result: x_t increases (by roughly 10%) first because varieties are generally more valuable, due to the scale effect, and secondly because the increase in x_t persistently reduces the household price index p_t, which enables the household to better smooth consumption over time. The rise in x_t makes the number of varieties in the consideration set of the household go up, which drives the increase in gross and persistent additions. The counterfactual model with constant adoption expenditure fails in replicating the data: in the counterfactual, the intensive margin accounts for more than 90% of the response of total expenditure, gross additions increase by 0.33 compared with 2.51 in the data, and persistent additions moves little (0.26 in the counterfactual model against 1.00 in the data).[19]

6.2. *Business cycle properties*

We recover the in-sample profile of adoption expenditure x_t using full information maximum likelihood. Since the time series of total expenditure e_t is taken as given, results are robust to the nature of the aggregate shocks that drive e_t. We assume that the search technology satisfies (25) with $\Lambda(x)$ given in (39) and search efficiency following the AR(1) process

$$\lambda_t = \bar{\lambda} + \varrho_\lambda \left(\lambda_{t-1} - \bar{\lambda}\right) + \epsilon_t^\lambda. \tag{42}$$

Logged total expenditure evolves as an autoregressive integrated moving average process, $B^e(L)\ln(e_t) = G^e(L)\epsilon_t^e$, where $B^e(L)$ and $G^e(L)$ are polynomials in the lag operator L. Based on an Akaike information criterion, we eventually choose an AR(1) process with serial correlation

19. In the counterfactual model, persistent additions increase just because, upon receipt of the ESP, the household spends more on all varieties and some of them will be repurchased again in the next 4 quarters due to random variation in the varieties that the household chooses to consume in a period.

TABLE 7
Parameter estimates

	ϱ_e	ϑ_e	ϱ_λ	ϑ_λ	$\vartheta_{e\lambda}$
ML estimates	0.82	0.013	0.20	0.006	-0.25
	(0.07)	(0.001)	(0.21)	(0.001)	(0.19)

Notes: Maximum likelihood estimates and standard errors of the parameters $[\varrho_e, \vartheta_e, \varrho_\lambda, \vartheta_\lambda, \vartheta_{e\lambda}]$. The likelihood function is calculated using the Kalman filter. The sample period is I:07-IV:14. Observables are net additions, N_{rt}, and logged expenditure, $\ln e_t$, both in real value. Standard errors in parenthesis.

TABLE 8
Business cycle statistics

	e_t	λ_t	x_t	c_t	p_t	μ_t	$\Lambda_t(x_t)$
Standard deviation	1.37	0.21	3.39	1.32	0.19	1.22	3.31
Correlation with e_t	1.00	-0.32	0.88	0.97	-0.66	0.66	0.87
Standard deviation if $\lambda_t = \bar{\lambda}$	1.37	0.00	3.52	1.42	0.24	1.56	3.48

Notes: In-sample estimates using the Kalman smoothing algorithm (period I:07-IV:14). All variables are in logs, expressed in real value, and calculated as 4-quarters moving averages. Standard deviations are expressed in percentage units.

ϱ_e. The innovations ϵ_t^λ and ϵ_t^e are both iid normal with zero mean and standard deviation equal to ϑ_λ and ϑ_e, respectively. Since households adjust their total expenditure endogenously, ϵ_t^e and ϵ_t^λ have correlation $\vartheta_{e\lambda}$ possibly different from zero. We log-linearize (26), (30), (35), and (36) and use the Kalman filter to evaluate the likelihood function of the series of quarterly net additions N_{rt} and logged total expenditure $\ln e_t$ of Section 2, converted into real value using (38) with P_t equal to the household personal consumption price deflator from the Bureau of Economic Analysis (U.S. Bureau of Economic Analysis (b)).[20] In writing the likelihood function we acknowledge that net additions are four-quarters moving averages (see Supplementary Appendix C). Given the parameter values of Table 5, we maximize the likelihood function with respect to the vector of parameters $[\varrho_e, \varrho_\lambda, \vartheta_e, \vartheta_\lambda, \vartheta_{e\lambda}]$ and the initial unobserved states of the system, *i.e.*, the values of μ_t, λ_t, and e_t in the pre-sample period. Table 7 reports the estimated parameters with the associated standard errors in parenthesis.[21] The point estimate of the correlation between total expenditure and search efficiency, $\vartheta_{e\lambda}$, is negative in line with the thesis that household search intensity is counter-cyclical.

We apply the Kalman smoothing algorithm to recover the in-sample profile of search efficiency λ_t, adoption expenditure x_t, consumption c_t, the price index p_t, the average number of varieties in the consideration set μ_t, and the adoption rate $\Lambda_t(x_t)$, all in logs. Table 8 reports standard deviations and correlations with total expenditure e_t. Adoption expenditure x_t is around two and a half times as volatile as e_t and the two series have a positive correlation of 88%. Since the consideration set expands when x_t increases, μ_t is positively correlated with e_t, while the welfare-relevant household price index p_t in (27) is negatively correlated with e_t, increasing by around 60 basis points at the trough of the recession. Since households use adoption expenditure to smooth consumption, c_t is less volatile than e_t. Search efficiency λ_t is counter-cyclical, but

20. We also correct for the negative bias in the trend of expenditure in KNCP by rescaling its average growth rate by a constant factor so as to match the overall increase of personal consumption expenditure from BEA (U.S. Bureau of Economic Analysis (a)) over the period 2007–14. Attanasio *et al.* (2006) and Bee *et al.* (2015) analyse the reasons for the negative bias in the trend of expenditure from household surveys (such as CEX and KNCP) relative to expenditure from BEA.

21. The initial unobserved states of the system are not statistically different from their steady state value; for brevity, they are not reported here.

TABLE 9
Cyclical contribution of additions and removals

	I_t	N_t	A_t	A_t^{adoption}	A_t^{true}	A_t^{noisy}
Standard deviation (%)	0.28	0.37	0.47	0.39	0.20	0.27
β-decomposition, β_X	0.43	0.57	0.54	0.17	0.13	0.24

Notes: In-sample estimates over the period I:07-IV:14. They are 4-quarter moving averages converted into nominal value using (38) and the index P_t (U.S. Bureau of Economic Analysis (b)). "β-Decomposition" is the OLS estimated coefficient β_X from regressing the variable in column, $X_t = I_t, N_t, A_t, A_t^{\text{adoption}}, A_t^{\text{true}}, A_t^{\text{noisy}}$, against the percentage change in (nominal) expenditure growth $\Delta E_t/E_{t-1}$: $X_t = \alpha_X + \beta_X \Delta E_t/E_{t-1} + \epsilon$.

its volatility contributes little to the cyclical volatility of variables: shocks to search efficiency attenuate just marginally the volatility of variables. This can be seen by looking at the third row of Table 8 which reports statistics after setting all shocks in (42) to zero, $\epsilon_t^{\lambda} = 0$, $\forall t$.

We use (35)–(37), the identity in (38) and the price deflator P_t to calculate the intensive margin I_t, net additions N_t, and additions A_t, all in nominal terms and expressed as 4-quarters moving averages as in Section 2. Table 9 reports their standard deviations and β-coefficients on (nominal) expenditure growth $\Delta E_t/E_{t-1}$, which are the model's counterparts of the estimates in panel (b) of Table 1. The model matches the empirical properties of net and gross additions reasonably well: their contributions to changes in expenditure growth, as measured by the β-coefficients, are 56 and 51% in the model, compared with 57 and 58% in the data. In columns 3–6 of Table 9, we report the standard deviations and β-coefficients of the three terms that compose additions in (35): adoption expenditure, true additions, and noisy additions (all evaluated in nominal terms). The sum of adoption expenditure and true additions accounts for roughly a half of the overall contribution of additions to the volatility of expenditure growth $\Delta E_t/E_{t-1}$.

We now evaluate whether the model matches the cyclicality of new varieties in the market and the contribution of additions in new varieties to the volatility of $\Delta E_t/E_{t-1}$—equal to 3% (panel (c) of Table 2). In the model, additions in new varieties are equal to:

$$A_t^n = \frac{P_t}{P_{t-1}} \left[\frac{x_t}{e_{t-1}} + \frac{\Lambda_t(x_t)}{\mu_t} \frac{s_t}{e_{t-1}} \right] \frac{v_t - (1-\delta_f)v_{t-1}}{v_t}, \tag{43}$$

which uses the fact that, due to random search, a share $1-(1-\delta_f)v_{t-1}/v_t$ of adoption expenditure and true additions are on varieties new to the market.

To endogenize the flow of new varieties, we assume that the cost of discovering a new variety $\xi > 0$ is equated to its value D_t:

$$\xi = D_t. \tag{44}$$

We also assume that a variety discovered at t is first on sale at $t+1$ and, due to the existence of a competitive fringe of producers, firms set a limit price equal to a constant markup $1/\varphi$ over the marginal cost of production $\varphi \in (0,1)$. As a result:

$$D_t = (1-\varphi)\mathbb{E}_t \left[\sum_{j=1}^{\infty} \left(1-\delta_f\right)^{j-1} \rho_{t,t+j} \left(\frac{e_{t+j} - x_{t+j}}{\mu_{t+j}} m_{t,t+j} + \frac{x_{t+j}}{v_{t+j}} \right) \right], \tag{45}$$

which is equal to the profits per unit of the variety sold, $1-\varphi$, times the present value of income from the variety. The discount factor is $\rho_{t,t+j}$ in (31) times the surviving probability of the variety $\left(1-\delta_f\right)^{j-1}$. Income at $t+j$ is the sum of two terms. First, there are $m_{t,t+j}$ *customers* of the variety— that is households with the variety in their consideration set—who (in expected value)

TABLE 10
Cyclical properties of the supply of varieties

Varieties in the market, $\ln v_t$	St. Dev.	Correlation with e_t	A_t^n: β-coeff.
Data	0.03	0.70	0.03
Baseline model	0.03	0.81	0.03
Counterfactual model, constant x_t	0.01	0.78	0.02

Notes: Logged number of varieties on the market in model and data (linearly detrended) over the period I:07-IV:14. The last column reports the contribution of additions in new varieties A_t^n to expenditure growth $\Delta E_t/E_{t-1}$ using a β-decomposition.

spend $(e_{t+j}-x_{t+j})/\mu_{t+j}$ on it. Second, the variety earns x_{t+j}/v_{t+j} as the result of household experimentation. The customers at $t+j$ are equal to

$$m_{t,t+j}=\sum_{i=1}^{j}(1-\delta_p)^{j-i}\frac{\Lambda_{t+i}\left(x_{t+i}\right)}{v_{t+i}}, \quad \forall j\geq 1 \tag{46}$$

since at each time $t+i$, $\forall i\leq j$, the firm obtains $\Lambda_{t+i}\left(x_{t+i}\right)/v_{t+i}$ new customers, increasing the number of customers at $t+j$ in proportion $(1-\delta_p)^{j-i}$. In Supplementary Appendix D.2, we use (44) to express $\ln v_{t+1}$ as a function of the past and future expected history of $\ln e_t$, $\ln c_t$, $\ln x_t$, and λ_t, given the information available at t. For each t over the period I:07-IV:14, these histories are calculated using the state space representation of the household problem previously estimated. We set $\delta_f=0.05$ (corresponding to the average attrition rate of varieties in the KNPC) and $\delta_p=1-(1-\delta)/\left(1-\delta_f\right)$. The cost of a new variety ξ matches a ratio of R&D expenditure to total consumption expenditure of 5% (in line with the data), while φ is such that (44) is satisfied in steady state with $v=1$. All other parameters values are as in Table 5.

Table 10 reports the standard deviation of the (logged) number of varieties in the market $\ln v_t$ and its correlation with total expenditure $\ln e_t$, in the data and in the model. Overall the model reproduces accurately the pattern of procyclical innovation in the data. Table 10 also reports the OLS β-coefficient obtained by regressing A_t^n in (43) on expenditure growth $\Delta E_t/E_{t-1}$ in the data, the baseline model, and the counterfactual model with constant adoption expenditure (third row of Table 10). The model matches well the data. Again endogenous adoption matters for the good fit: in the model with constant adoption the standard deviation of $\ln v_t$ falls by two-thirds, and the β-coefficient on $\Delta E_t/E_{t-1}$ by one-third.

7. IMPLICATIONS OF THE EXTENSIVE MARGIN

We now discuss how the endogenous adoption of consumer products by households affects the effects of fiscal transfers and the measurement of household-level inflation.

7.1. *Fiscal transfers over the Great Recession*

We quantify the effects of federal fiscal transfers during the U.S. Great Recession and its recovery. We show that the endogenous adoption of varieties amplifies the effects of fiscal transfers through general equilibrium effects. To break the Ricardian equivalence and allow fiscal transfers to stimulate consumption, we follow Krishnamurthy and Vissing-Jorgensen (2012) and Fisher (2015) in assuming that government bonds provide liquidity services to households.[22]

22. We have no reasons to believe that the quantitative conclusions of this section depend on the specific reason why government transfers stimulate the economy.

We consider an economy with nominal rigidities (due to sticky wages), which leave a role for aggregate demand. As in Section 6.2, the number of varieties is endogenous and as in Romer (1990) there are innovation spill-overs, which are the reason why innovation in the number of varieties available in the economy stimulates aggregate output and consumption. We assume that the economy is in a liquidity trap, to characterize the US economy over our sample period.

Assumptions. The technology to produce variety $(j,v) \in \mathcal{V}_t$ is

$$y_{vjt} = v_t^{\varpi} l_{vjt}, \tag{47}$$

where l_{vjt} is labour input. Labour productivity in (47) increases with the number of varieties v_t, with $\varpi \in [0,1]$, which builds on Romer (1990) where v_t enhances labour productivity by allowing greater division of labour.[23] Given our choice of the numeraire (the price of a variety is 1) and the constant markup over marginal cost we have that

$$w_t = \varphi v_t^{\varpi}. \tag{48}$$

As in Romer (1990) and Bilbiie *et al.* (2012), R&D is labour intensive: l_{dt} labour units in R&D yield $\frac{\varphi}{\xi} v_t^{\varpi} l_{dt}$ new varieties. Given (48), $\xi > 0$ is the cost of a new variety, which justifies the free-entry condition in (44). The number of varieties evolves according to

$$v_{t+1} = (1-\delta_f) v_t + \frac{w_t l_{dt}}{\xi}, \tag{49}$$

where $w_t l_{dt}$ is R&D investment.

We extend the household problem to allow for sticky wages modelled as in Erceg *et al.* (2000) and Auclert and Mitman (2019) and for government bonds, b_t, which pay a gross return r_{t+1} at $t+1$. All households are identical, post a nominal wage W_t and supply any amount of labour demanded at the posted wage. Adjusting the wage W_t involves quadratic adjustment costs $\kappa_t \equiv \kappa\left(\Pi_t^W\right) w_t \ell_t$ where $w_t \equiv W_t/P_t$ is the real wage, $w_t \ell_t$ is (aggregate) labour income, $\Pi_t^W \equiv W_t/W_{t-1}$ is wage inflation, and $\kappa(1) = \kappa'(1) = 0$ with $\kappa'' > 0$. The time t household budget constraint is

$$e_t + a_t + b_t \leq \iota_t a_{t-1} + r_t b_{t-1} + w_t \ell_t + \kappa_t - \tau_t, \tag{50}$$

where τ_t are taxes net of government transfers. Government bonds provide some liquidity services, $h(b_t)$, which implies that government transfers financed by issuing government debt stimulate expenditure.[24] The household maximizes the expected present value of the utility from consumption $u(c_t)$ and liquidity services, $h(b_t)$, net of the disutility of working ℓ_t, $\varepsilon(\ell_t)$:

$$\mathbb{E}_t \left\{ \sum_{j=t}^{\infty} \rho^{j-t} \left[u\left(c_j\right) + h\left(b_j\right) - \varepsilon\left(\ell_j\right) \right] \right\}. \tag{51}$$

By solving for the optimal posted nominal wage W_t, in Appendix G, we derive the following New Keynesian Phillips curve:

$$\Pi_t^W \left(\Pi_t^W - 1 \right) = \mathbb{E}_t \left[\rho_{t,t+1} \left(\Pi_{t+1}^W - 1 \right) \frac{w_{t+1} \ell_{t+1}}{w_t \ell_t} \right] + \hat{\kappa} \left[\frac{\theta_w}{\theta_w - 1} \frac{\varepsilon'(\ell_t)}{u'(c_t)} \frac{p_t}{w_t} - 1 \right], \tag{52}$$

23. Greater product variety could also allow firms to offer a more specialized product to existing customers, which would increase quality adjusted output. Under this alternative interpretation, the quality adjusted unit price of a variety would also increase.

24. In equilibrium, the aggregate supply of government bonds affects the liquidity premium paid by government bonds $\iota_t - r_t > 0$.

where $\hat{\kappa} \equiv (\theta_w - 1)/\kappa''$ determines the slope of the (linearized) New Keynesian Phillips curve.[25] Maximizing with respect to government bonds, b_t, implies that the expected liquidity premium of government bonds satisfies

$$h'(b_t) = \rho \mathbb{E}_t \left[(\iota_{t+1} - r_{t+1}) \frac{u'(c_{t+1})}{p(\mu_{t+1})} \right]. \tag{53}$$

As in Proposition 2, adoption expenditure, x_t, satisfies (30) and the optimal demand of assets a_t implies (33).

There is a mutual fund that owns all firms in the economy and issues one-period assets, a_t, paying a risk-free return ι_{t+1} at $t+1$. The fund breaks even $\forall t$, which implies that $\forall t$ the fund's disbursements are equal to firms' realized profits net of R&D investment

$$\iota_t a_{t-1} - a_t = (1-\varphi) e_t - w_t l_{dt}. \tag{54}$$

Let g denote government purchases of varieties, which we assume are fully wasted, spent uniformly across available varieties and constant over time. To guarantee that (44) and (45) hold, we posit a value added tax of $1-\varphi$ on firms selling products to the government. This implies the following government budget constraint

$$b_t = r_t b_{t-1} + \varphi g - \tau_t. \tag{55}$$

The lump sum tax τ_t is equal to the difference between the cost of servicing the debt plus the cost of government expenditure minus household transfers:

$$\tau_t = r_t b_{t-1} + \varphi g - \tau_t^{\ell} w_t \ell_t.$$

Transfers are a proportion τ_t^{ℓ} of aggregate labour income (*i.e.* they do not affect household labour supply decisions) with τ_t^{ℓ} that evolves according to

$$\tau_t^{\ell} = \bar{\tau}^{\ell} + \varrho_\tau \left(\tau_{t-1}^{\ell} - \bar{\tau}^{\ell} \right) + \epsilon_t^{\tau}, \tag{56}$$

where ϵ_t^{τ} represents a (positive) shock to transfers.

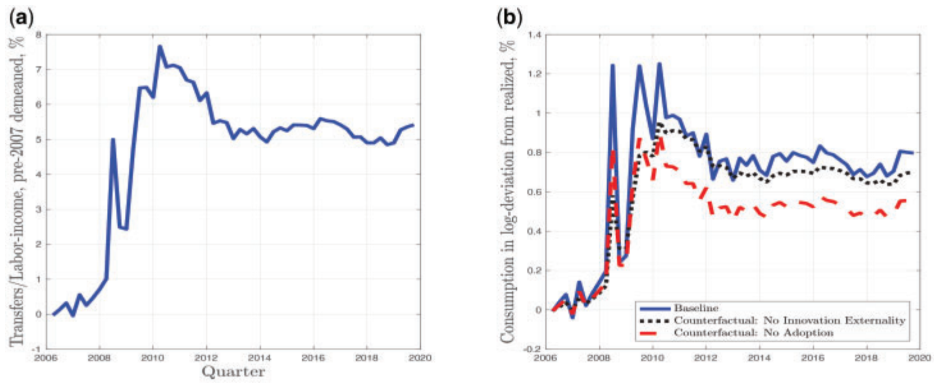
The real rate on government bonds satisfies $r_t = \mathcal{R}_{t-1}/\Pi_t^P$, where $\Pi_t^P \equiv \Pi_t^W w_{t-1}/w_t$ is price inflation and $\mathcal{R}_{t-1}$ is the nominal interest rate set by the monetary authority at $t-1$ and paid at t. Since over our sample period nominal interest rates were constant (due to the zero lower bound), we assume that, over the entire period, the monetary authority keeps $\mathcal{R}_t$ at its steady state value $\bar{\mathcal{R}}$ and with probability ϕ_0 reverts to a conventional Taylor rule: $\mathcal{R}_t = 1/\rho \left(\Pi_t^P \right)^{\bar{\phi}}$ (see Supplementary Appendix G for the details).[26]

The aggregate resource constraint equates net output to its uses so that

$$v_t^{\varpi} (\ell_t - l_{dt}) = e_t + g + \kappa_t. \tag{57}$$

25. The linearized Phillips curve is $\hat{\Pi}_t^w = \rho E_t \left(\hat{\Pi}_{t+1}^w \right) + \hat{\kappa} (\gamma \hat{c}_t + \varepsilon_1 \hat{\ell}_t + \hat{p}_t - \varpi \hat{v}_{t-1})$, where '$\hat{z}$' denotes z in log-deviation from its steady state value.

26. We set $\phi_0 = 1/6$, to target the expected duration of the liquidity trap, and $\overline{\phi} = 1.5$, a standard value in the literature.



Effects on transfers, τ_t^ℓ **Effects on log-consumption, $\ln c_t$**

FIGURE 3

Effects of transfers in the Great Recession and its recovery

Panel (a) shows the effects of transfer shocks ϵ_t^τ's on transfers over labour income, τ_t^ℓ. The solid blue line in panel (b) corresponds to the effects of ϵ_t^τ's on logged consumption $\ln c_t$. The dashed red line calculates the effects of ϵ_t^τ's in a version of the model where adoption expenditure x_t is assumed to remain at its steady state value throughout the entire sample period.

Equilibrium. An equilibrium is a tuple

$$\left(c_t, x_t, a_t, b_t, \mu_t, e_t, p_t, w_t, r_t, v_t, \ell_t, l_{dt}, \lambda_t, \tau_t^\ell, \mathcal{R}_t, D_t, \Pi_t^W, \Pi_t^P\right)$$

such that $\forall t$,

1. Each *household* maximizes utility at the adoption expenditure x_t, wage inflation Π_t^W and portfolio choices a_t and b_t, which satisfy (30), (33), (52), and (53), given μ_t in (26), e_t in (24), and p_t in (27);
2. *Firms* maximize profits so that v_t satisfies (44) with D_t given by (45);
3. The returns on assets and government bonds ι_t and r_t *clear the financial markets* at the asset supply a_t and b_t implied by (54) and (55), given the (constant) nominal interest rate $\mathcal{R}_t$ set by the monetary authority and price inflation $\Pi_t^P \equiv \Pi_t^W w_{t-1}/w_t$;
4. The *labour market* clears so that l_{dt} and ℓ_t satisfy (49) and (57) at wage w_t in (48);
5. The *driving forces* λ_t and τ_t^ℓ are given.

Calibration. Data on fiscal transfers come from NIPA, Table 3.1, as in Oh and Reis (2012).[27] We express transfers in proportion of aggregate labour income and estimate (56) over the pre-sample period 1993–2005. We obtain a coefficient of serial correlation $\varrho_\tau = .985$ and a mean value of $\bar{\tau}^\ell = 20.9\%$. Given ϱ_τ and $\bar{\tau}^\ell$, we use (56) to back up the shocks to transfers ϵ_t^τ's. The solid blue line in panel (a) of Figure 3 plots the effects of ϵ_t^τ's on τ_t^ℓ over our sample period (2006:I-2019:III): in 2010 transfers increased by almost 8 percentage points relative to aggregate labour income, stabilizing to an increase of around 5% points over the recovery period.

The disutility of working is: $\varepsilon(\ell) = \varepsilon_0/(1+\varepsilon_1) \times \ell^{1+\varepsilon_1}$ with ε_0 set to yield $\bar{e} = 1$ and $\varepsilon_1 = 1/3$, in line with the macroeconomic literature (see Peterman 2016). The utility from holding

27. Government transfers correspond to Current transfer payments in Table 3.1, equal to the sum of government social benefits to either persons or firms, plus other current transfer payments to the rest of the world and subsidies.

TABLE 11
Calibration of the general equilibrium parameters

Model		Data	
Parameter	Value	Moment	Value
δ_f	0.050	Obsolescence rate of varieties in KNPC	0.05
δ_p	0.013	Persistence of varieties in consideration set, δ	0.063
ξ	1	R&D expenditure, wl_d, over total expenditure, e	0.05
φ	0.93	Mass of varieties at initial steady state, v	1
ϱ_τ	0.985	Serial correlation of transfers, 1993–2007	0.985
$\overline{\tau}_\ell$	0.195	Mean value of transfer over labour income, 1993–2007	0.209
ϵ_0	1	Steady state expenditure, e	1
ϵ_1	1/3	Frisch elasticity of labour supply	3
ϖ	0.387	Micro estimates of firm R&D spill-overs	0.387
g	0.12	Government expenditure as a share of output	10%
h_0	0.07	Liquidity premium $\iota - r$	0.18%
h_1	0.5	Partial equilibrium MPC out of tax rebate	0.14
$\hat{\kappa}$	0.02	Slope of NKPC with wages changing once a year	0.02
θ_w	10	Estimates from the literature	10

government bonds is: $h(b) = h_0/(1-h_1) \times b^{1-h_1}$ with $h_0 = 0.07$ and $h_1 = 0.5$ set to match a (partial equilibrium) marginal propensity to consume out of a tax rebate of $\Delta e/\Delta\tau = 14\%$ (Broda and Parker 2014), and a steady-state liquidity premium $\iota - r$ of 18 basis points (Fisher 2015). To calibrate the parameter ϖ governing R&D spill-overs, we rely on Colino (2017) who estimates the elasticity of a firm productivity to the R&D stock of other firms in the economy (calculated using the perpetual inventory method), finding an elasticity of 0.387 (see Table 5, column 5), which is in the line with the analogous estimates by Bloom *et al.* (2013) and Lucking *et al.* (2019). The parameter governing the elasticity of the linearized Phillips curve $\hat{\kappa}$ is consistent with wages adjusting once every 4 quarters (Barattieri *et al.* 2014). We follow Christiano *et al.* (2005) in setting $\theta_w = 10$. Government expenditure g represents 10% of steady state gross output. Table 11 reports these additional parameter values. All the other values are as in Table 5.

Results. To evaluate the expansionary effects of transfers, we calculate by how much logged consumption $\ln c_t$ would have fallen if transfer shocks ϵ_t^τ's had remained equal to zero during the entire sample period.[28] This effect corresponds to the solid blue line in panel (b) of Figure 3: on average over the period, fiscal transfers increased consumption by 80 basis points per year; at the peak of the response (2009–11) consumption increased by 1.2%. The dashed red line in panel (b) of Figure 3 shows the effects of ϵ_t^τ's on $\ln c_t$ in a version of the model where adoption expenditure x_t is assumed to remain at its steady state value throughout the entire sample period. The cumulated response of consumption to the transfer shocks ϵ_t^τ's over our sample period is 42.2% greater in our model than in the constant-adoption-expenditure benchmark. We denote this percentage increase by $(\mathbf{c}^{\mathbf{IX}} - \mathbf{c}^{\mathbf{I0}})/\mathbf{c}^{\mathbf{I0}}$.

Decomposing the amplification effect. There are two reasons why an endogenous x_t amplifies the effects of transfer shocks in general equilibrium. First, there is an effect that works through *household-level inflation*: fiscal transfers stimulate adoption expenditure x_t that pushes down the price p_t today, generating expectations of higher future household level inflation, which, at

28. Notice that to calculate the effect of transfer payments shocks we do not need to take a stand on the drivers of the Great Recessions and the magnitude of the associated shocks. We solve the model linearly so the effects of shocks are additive and can be evaluated separately.

constant $\mathcal{R}_t$, reduces the household level real rate and stimulates aggregate demand—an effect particularly valuable for an economy at the liquidity trap. Secondly, there is an effect on the *demand for innovation*: the increase in x_t pushes up the value of a new product D_t in (45), because new firms find easier to accumulate a customer base, causing an increase in v_t larger in our model than in the counterfactual, which stimulates aggregate productivity. The dotted black line in panel (b) of Figure 3 corresponds to the response of consumption to fiscal transfers in a version of the model without technological spill-overs, $\varpi=0$, obtained by keeping the number of varieties available in the market constant at their steady state value. The key idea is that new innovating firms to sell their product need customers, who can be acquired only if households are willing to bring new varieties into their consumption basket, so an increase in household adoption expenditures stimulates innovation.

To separately quantify the contribution of the two effects, we calculate the cumulated response $\mathbf{Y}$ over the period 2006:I-2019:III (55 quarters) in the baseline model and in three different benchmarks. We focus on the cumulated response of the number of available varieties v_t, consumption c_t, and total expenditure e_t (all in logs). The cumulated response in the baseline model, with technological spill-overs and endogenous adoption, is denoted by $\mathbf{Y^{IX}}$ (the superscript indicates that both innovation and adoption are endogenous). The cumulated response in the first benchmark, denoted by $\mathbf{Y^{I0}}$, corresponds to the model with technological spill-overs and constant adoption expenditure (the analogous of the dashed red line in panel (b) of Figure 3). In the second and third benchmark, technological spill-overs are muted, $\varpi=0$: in the second, the cumulated response $\mathbf{Y^{0X}}$ is calculated under the assumption of endogenous adoption (the analogous of the dotted black line in panel (b) of Figure 3); in the third, the cumulated response $\mathbf{Y^{00}}$ is obtained under constant adoption expenditure. The amplification of endogenous adoption is measured by the difference between the cumulated response in the baseline model and the response in the model with constant adoption and it can be decomposed as follows:

$$\mathbf{Y^{IX}}-\mathbf{Y^{I0}}=\mathbf{Y^{0X}}-\mathbf{Y^{00}}+\left[\left(\mathbf{Y^{IX}}-\mathbf{Y^{0X}}\right)-\left(\mathbf{Y^{I0}}-\mathbf{Y^{00}}\right)\right]. \tag{58}$$

The first difference in the right hand side of (58), equal to $\mathbf{Y^{0X}}-\mathbf{Y^{00}}$, is the difference in the response of the two intermediate benchmarks with no spill-overs: it measures the contribution of the inflation effect. The double difference inside the square brackets in (58) measures how the differential response in a model with and without technological spill-overs varies due to endogenous adoption and quantifies how endogenous adoption amplifies the response through its effects on the demand for innovation. Table 12 reports the value of the three terms in (58) for the cumulated response of (logged) v_t, c_t, and e_t. Endogenous adoption increases the number of varieties in the market by roughly one percentage point per year, while consumption and total expenditure by around 0.8% per year. The effects through inflation and the demand for innovation account roughly equally for the amplification in the response of consumption and total expenditure to the fiscal stimulus.

Share of expenditures covered by search-for-love. So far we have assumed that our search-for-love mechanism characterizes all goods purchased by the household. We now evaluate whether the effects of transfers change when search-for-love characterizes only a share of total consumption expenditure, in the range of 45–65% according to the discussion in Supplementary Appendix H. We extend the DSGE model by assuming that households consume two goods: one is the *differentiated good* subject to search for love of the baseline model; the other is a *commodity*. To guarantee that the model calibration remains unchanged (see Supplementary Appendix H), the commodity is modelled exactly as the differentiated good, except that, for the commodity,

TABLE 12
The effect of endogenous adoption on cumulated responses

Variable	Total Effect $\mathbf{Y^{IX}}-\mathbf{Y^{I0}}$	Inflation effect $\mathbf{Y^{0X}}-\mathbf{Y^{00}}$	Demand for innovation $(\mathbf{Y^{IX}}-\mathbf{Y^{0X}})-(\mathbf{Y^{I0}}-\mathbf{Y^{00}})$
No. of varieties, $\ln v_t$	0.169	0.00	0.169
Consumption, $\ln c$	0.111	0.056	0.055
Total expenditure, $\ln e$	0.103	0.056	0.047

Notes: Decomposition of the cumulated effect of endogenous adoption on different variables (in logs) over the period 2006:I-2019:III. $\mathbf{Y^{IX}}$ is the cumulated response in the baseline model. $\mathbf{Y^{I0}}$ is the cumulated response in a model with technological spill-overs and constant adoption expenditure. $\mathbf{Y^{0X}}$ is the cumulated response in a model with no technological spill-overs, $\varpi=0$, and endogenous endogenous adoption. $\mathbf{Y^{00}}$ is the cumulated response in a model with no technological spill-overs, $\varpi=0$, and constant steady state adoption expenditures. The value of $\mathbf{Y^{I0}}$ for number of varieties, consumption, and total expenditure is 0.39, 0.262, and 0.231, respectively

adoption is exogenous and innovation spill-overs are absent. More specifically, we assume that the household has an instantaneous log utility from consumption, $\ln c_t$, with

$$c_t = c_{vt}^{\alpha_v} c_{ot}^{1-\alpha_v} \tag{59}$$

where c_{vt} is the consumption of the differentiated good as in (21), and c_{ot} is the consumption of the commodity. The commodity is produced using a-linear-in-labour production function, with one unit of labour yielding one unit of the commodity. We assume that the price of the commodity is a constant mark-up $1/\varphi$ on top of the marginal cost of production w_t and that a fixed amount of expenditures in the commodity $\bar{x}_o = \bar{x}\frac{1-\alpha_v}{\alpha_v}$ is wasted. Total expenditure is now given by

$$e_{vt} = e_{vt} + e_{ot},$$

where $e_{vt} = p_{vt}c_{vt} + x_t$ and $e_{ot} = \frac{w_t}{\varphi}c_{ot} + \bar{x}_o$ denotes total expenditure in the differentiated good and the commodity, respectively. The welfare relevant aggregate price index is now given by

$$p_t = \left(\frac{p_{vt}}{\alpha_v}\right)^{\alpha_v} \left[\frac{w_t}{\varphi(1-\alpha_v)}\right]^{1-\alpha_v} \tag{60}$$

where p_{vt} is the price of one unit of consumption in the differentiated good, which is the same function of μ_t as in (27) with μ_t still evolving according to (26). $\alpha_v \in [0,1]$ measures the share of total expenditure covered by our search-for-love mechanism.

For each possible value of α_v we evaluate the effects of the transfer shocks in panel (a) of Figure 3 on logged consumption, in a model with exogenous and endogenous adoption in the differentiated good. We then calculate $(\mathbf{c^{IX}}-\mathbf{c^{I0}})/\mathbf{c^{I0}}$ equal to the percentage increase in the cumulated response of logged consumption (over the period 2006:I-2019:III) in the model with endogenous adoption relative to the model with exogenous adoption. $(\mathbf{c^{IX}}-\mathbf{c^{I0}})/\mathbf{c^{I0}}$ measures by how much search-for-love amplifies the effects of government transfers on consumption. Figure 4 plots $(\mathbf{c^{IX}}-\mathbf{c^{I0}})/\mathbf{c^{I0}}$ as a function of α_v. The analysis in Figure 3 and Table 12 corresponds to $\alpha_v=1$, where $(\mathbf{c^{IX}}-\mathbf{c^{I0}})/\mathbf{c^{I0}}=0.42$. The relation in Figure 4 is concave, with the amplification remaining above 30% for α_v greater than 0.45. For α_v close to 0.65 the amplification is more than 35% quite close to the value of 0.42 obtained in the baseline specification with $\alpha_v=1$. Even if the differentiated variety subject to search-for-love covers just a fraction of total consumption expenditure, the amplification remains sizable because the two goods are complementary, so higher consumption in the differentiated variety also stimulates consumption and production in the commodity, amplifying the effects of fiscal transfers on consumption.

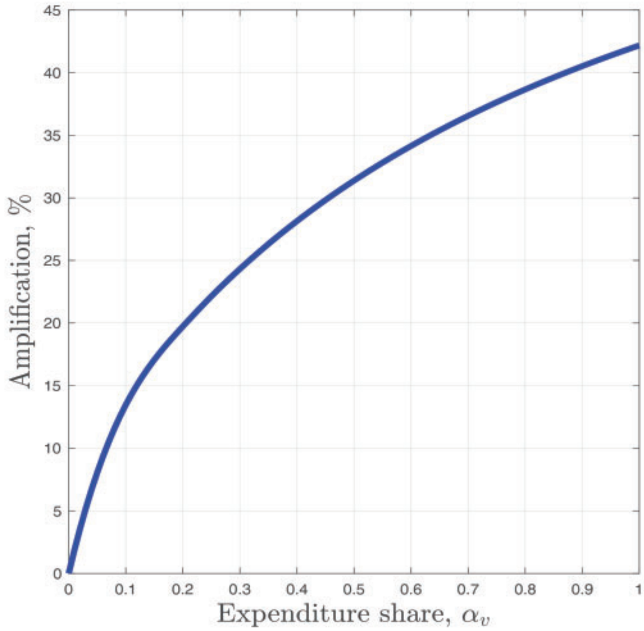


FIGURE 4

Amplification of transfers due to search-for-love.

7.2. *Measurement of inflation*

We now show that, in recessions, inflation measures based on a representative household who consumes all varieties available in the market (such as the CPI) tend to underestimate true household-level inflation, when household adoption of consumer products is endogenous. As many others Broda and Weinstein (2010); Neiman and Vavra (2018); Redding and Weinstein (2019), we study the inflation bias in the consumption categories covered by KNCP. In the model, true household-level inflation is equal to $\Delta \ln (P_t p_t)$ (identical for all households due to symmetry), where Δ is the first difference operator. CPI-inflation is equal to $\Delta \ln P_t$. To see the nature of the bias in CPI-inflation notice that

$$P_t p_t = \left[\int_0^{1-e^{-\mu_t}} \left(\frac{P_t}{\hat{z}_{\nu jt}} \right)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}, \tag{61}$$

where $\hat{z}_{jt} \equiv \max_{i \in \Omega_{jt}} \{z_{\nu jt}\}$ is the consumption utility of the variety consumed in sector j, and $1-e^{-\mu_t} = 1-f_t(0)$ is the number of varieties consumed by an household, equal to the number of sectors with at least one variety in the consideration set. After taking logs in (61) and some algebra, we obtain that

$$\ln(P_t p_t) = \ln P_t - \frac{1}{\sigma-1} \ln \Gamma \left(1 - \frac{\sigma\text{-}1}{\kappa} \right) - \frac{1}{\sigma-1} \ln(1-f_t(0)) - \frac{1}{\sigma-1} \ln \mathbb{E}_t \left[n^{\frac{\sigma-1}{\kappa}} \middle| n > 0 \right]. \tag{62}$$

An increase in μ_t makes p_t in (62) fall because the number of varieties purchased by an household increases (third term in the right-hand side of (62)) and also because the average value of each purchase goes up (fourth term in the right hand side of (62)). Since CPI-inflation misses both

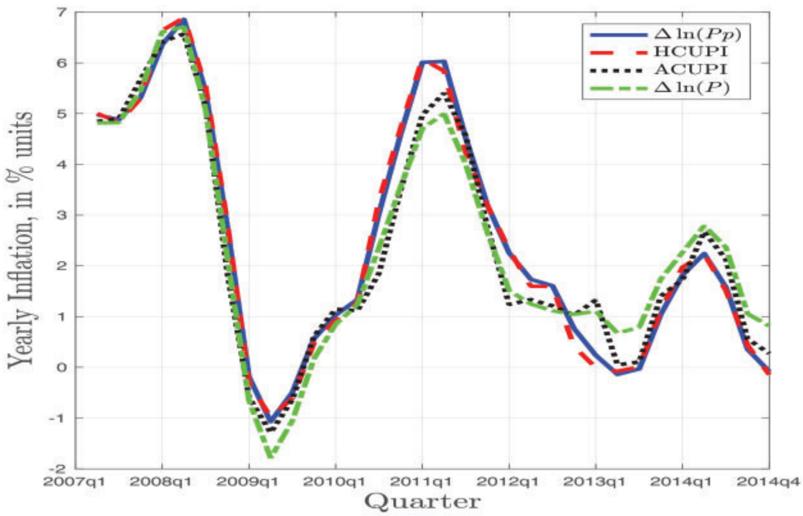


FIGURE 5

Different measures of inflation

effects, it tends to underestimate true household level inflation when adoption expenditure x_t and thereby μ_t fall.

The dash dotted green line in Figure 5 corresponds to CPI inflation $\Delta\ln P_t$, where P_t is the index for food and beverages purchased for off-premises consumption. The solid blue line corresponds to the model implied household level inflation, $\Delta\ln(P_t p_t)$, calculated using P_t and the time series for v_t, x_t, and μ_t estimated in Section 6 (see Supplementary Appendix F for further details).[29] Inflation is calculated year-on-year as 4-quarter changes in log price indexes. The first row of Table 13 also reports statistics for the bias in CPI inflation as measured by $\Delta\ln p_t$. The bias is negatively correlated with total expenditure and with adoption expenditure, it is highly serially correlated (correlation close to 90%) and it is sizable: at the through of the Great Recession, the CPI underestimates yearly inflation by more than 1%.

To show that the bias is a general feature of price indexes based on a representative household, we compare $\Delta\ln(P_t p_t)$ with inflation measured using the CES unified price index (CUPI) by Redding and Weinstein (2019). CUPI corrects the CPI to allow for time varying preference shocks and love of variety, as in Feenstra (1994), still maintaining the assumption of a representative household who consumes all varieties in the market.

Following Redding and Weinstein (2019) we postulate the existence of a *representative household* with CES preferences over the set of available varieties $\mathcal{V}_t \in R^2_+$

$$C_t^A = \left(\int_0^1 C_{jt}^{\frac{\sigma_b - 1}{\sigma_b}} dj \right)^{\frac{\sigma_b}{\sigma_b - 1}} \quad \text{with} \quad C_{jt} = \left[\int_0^{v_t} \left(\varphi_{\nu jt} e_{\nu jt} \right)^{\frac{\sigma_w - 1}{\sigma_w}} d\nu \right]^{\frac{\sigma_w}{\sigma_w - 1}}, \tag{63}$$

and $\sigma_b, \sigma_w > 1$, where $e_{\nu jt}$ denotes time-t aggregate expenditure in variety $\nu \in [0, v_t]$ in sector $j \in [0, 1]$, whose utility value is $\varphi_{\nu jt}$. Since all sectors are symmetric and varieties are sold at the

29. Since all measures of inflation—$\Delta\ln(Pp)$, ACUPI, and HCUPI (see below)—are calculated through the lenses of our model where all varieties are sold at the same price, we sidestep the concern that prices in the data are subject to mismeasurement.

same nominal price P_t, the exact price index implied by (63) is

$$P_t p_t^A = \left[\int_0^{\nu_t} \left(\frac{P_t}{\varphi_{\nu jt}} \right)^{1-\sigma_w} d\nu \right]^{\frac{1}{1-\sigma_w}}. \tag{64}$$

Redding and Weinstein (2019) show that the representative household inflation $\Phi^{ACUPI} \equiv \Delta \ln \left(P_t p_t^A \right)$ can be expressed in terms of observable statistics. They normalize the preference shocks $\varphi_{\nu jt}$'s to be time invariant on average so that $\forall t$

$$\int_{\Omega_{jt}^A} \ln \varphi_{\nu jt} d\nu = \int_{\Omega_{jt}^A} \ln \varphi_{\nu jt-1} d\nu, \tag{65}$$

where Ω_{jt}^A denotes the set of varieties in sector j consumed by the representative household both at $t-1$ and at t, which has mass $N_t^A \equiv (1-\delta_f)\nu_{t-1}$. Then, they show (see Supplementary Appendix F) that under (65)

$$\Phi^{ACUPI} \equiv \Delta \ln \left(P_t p_t^A \right) = \frac{1}{\sigma_w - 1} \Delta \ln \lambda_t^{AF} + \Phi^{ACCV}, \tag{66}$$

where λ_t^{AF} is the aggregate expenditure in all varieties in Ω_{jt}^A as a share of total expenditure

$$\lambda_t^{AF} = \frac{\int_{\Omega_{jt}^A} e_{\nu jt} d\nu}{e_t},$$

while Φ^{ACCV} corresponds to the CES exact price index for common varieties equal to

$$\Phi^{ACCV} = \Delta \ln P_t + \frac{1}{\sigma_w - 1} \frac{\int_{\Omega_{jt}^A} \Delta \ln s_{\nu jt}^A d\nu}{N_t^A}. \tag{67}$$

In (67), $s_{\nu jt}^A \equiv e_{\nu jt} / (e_t \lambda_t^{AF})$ denotes aggregate expenditure on variety νj as a share of the expenditure by the representative household on all varieties in Ω_{jt}^A.[30]

We use the estimated time series of Section 6, set $\sigma_w = \sigma$, and calculate the model implied Φ^{ACUPI} in (66) (see Supplementary Appendix F). Φ^{ACUPI} corresponds to the dotted black line in Figure 5. Table 13 reports statistics for the bias in ACUPI-inflation, $\Delta \ln (P_t p_t) - \Phi^{ACUPI}$. Again the bias is negatively correlated with adoption expenditure x_t and it is quantitatively similar to the bias in CPI inflation.

There are two closely related reasons why the difference between $\Delta \ln (P_t p_t)$ and $\Delta \ln (P_t p_t^A)$ increases when x_t falls. First, $P_t p_t$ in (61) depends (negatively) on the number of varieties consumed by an household which is increasing in μ_t, while $P_t p_t^A$ in (64) depends on all varieties available in the market, ν_t. Secondly, the average consumption utility $\hat{z}_{jt}$ in (61) increases with

30. The term $\frac{1}{\sigma_w - 1} \Delta \ln \lambda_t^{AF}$ in (66) is the correction by Feenstra (1994) to measure how the net entry of varieties in the consumption basket of the representative household affects welfare under love of variety. The second term in the right hand side of (67) measures the effect of time varying preferences. With $\sigma_w > 1$, this term falls when expenditure shares become more dispersed: an increase in the dispersion of $\varphi_{\nu jt}$'s increases welfare because varieties with low $\varphi_{\nu jt}$'s are substituted with others with high $\varphi_{\nu jt}$'s.

TABLE 13
Biases in the measurement of household level inflation

	Mean	St. Dev.	Max	Min	Autocorr.	Corr. with $\ln e_t$	Corr. with $\ln x_t$
Bias in CPI-inflation							
$\Delta\ln(P_t p_t)-\Delta\ln P_t$	0.09	0.56	1.20	−0.90	0.89	−0.60	−0.70
Bias in CUPI-inflation							
$\Delta\ln(P_t p_t)-\Phi^{ACUPI}$	0.15	0.52	1.18	−1.09	0.62	−0.75	−0.80
$\Delta\ln(P_t p_t)-\Phi^{HCUPI}$	0.01	0.12	0.35	−0.28	0.25	0.09	0.43
$-\frac{\int_{\Omega_t^H}\Delta\ln\widehat{z}_{jt}dj}{N_t^H}$	0.00	0.04	0.08	−0.06	0.89	−0.72	−0.73
$\frac{1}{\sigma-1}\Delta\ln(\frac{e_t}{e_t-x_t})$	0.01	0.13	0.37	−0.29	0.24	0.28	0.60

Notes: Number are expressed in % units.

μ_t, while the preference shocks φ_{vjt}'s in (64) are assumed to have a constant mean. Both effects make the difference between $\Delta\ln(P_t p_t)$ and $\Delta\ln(P_t p_t^A)$ increases when x_t and thereby μ_t fall.

To further show the importance of the bias due to the assumption of a representative household who consumes all varieties in the market, we construct the CUPI by Redding and Weinstein (2019) at the household level—recognizing that different households consume a different basket of varieties—and show that the bias gets substantially reduced. We denote by Ω_{it}^H the set of varieties that household i consumes at $t-1$ and at t. We show in Supplementary Appendix F that true household level inflation can be written as

$$\Delta\ln(P_t p_t)=\Phi_t^{HCUPI}-\frac{\int_{\Omega_{it}^H}\Delta\ln\widehat{z}_{jt}dj}{N_t^H}+\frac{1}{\sigma-1}\Delta\ln\left(\frac{e_t}{e_t-x_t}\right), \tag{68}$$

where $N_t^H\in[0,1]$ is the mass of varieties in Ω_{it}^H, while Φ_t^{HCUPI} corresponds to the household level CUPI by Redding and Weinstein (2019)

$$\Phi_t^{HCUPI}\equiv\frac{1}{\sigma-1}\Delta\ln\lambda_t^{HF}+\Phi_t^{HCCV}, \tag{69}$$

which is equal for all households—*i.e.*, is independent of i. In (69), λ_t^{HF} denotes the time-t expenditure on all varieties in Ω_{it}^H as a fraction of total expenditure e_t, while Φ_t^{HCCV} is the analogue of (67) at the household level equal to

$$\Phi_t^{HCCV}\equiv\Delta\ln P_t+\frac{1}{\sigma-1}\frac{\int_{\Omega_{it}^H}\Delta\ln s_{jt}^H dj}{N_t^H}, \tag{70}$$

where s_{jt}^H denotes the expenditure in sector j of an household as a share of $e_t\lambda_t^{HF}$. The second term in the right hand side of (68) arises because the normalization in (65) does not hold: the consumption utility $\hat{z}_{jt}$ is increasing in the number of varieties in the consideration set of sector j, so its expected value is increasing in μ_t. The third term in the right hand side of (68) is increasing in x_t and arises because x_t is a form of investment which has no direct effects on current household consumption utility.

We calculate the model implied Φ_t^{HCUPI} using the estimated series of Section 6. Φ_t^{HCUPI} corresponds to the dashed red line in Figure 5. Table 13 also reports statistics for the bias in HCUPI-inflation as measured by $\Delta\ln(P_t p_t)-\Phi^{HCUPI}$ as well as for its components—*i.e.,* the second and third term in the right-hand side of (68). Since HCUPI better identifies the set of varieties that enter an household consideration set, the bias in HCUPI inflation is smaller and less cyclical. The bias in HCUPI-inflation comoves positively with adoption expenditure and reaches a maximum of 35 basis point per year. The bias is mainly due to the third term in the right-hand side of (68), which arises because adoption is a "cost" with only indirect effects on current consumption.[31]

8. CONCLUSIONS

We have shown that in response to income shocks, households adopt consumer products that were already available in the market. There are two reasons for this. First, varieties are more valuable when expenditure is higher, owing to a scale effect. Second, adopting new varieties allows the household to smooth consumption better over time. This process of endogenous adoption of consumer products has novel implications for the effects of fiscal transfers and the measurement of household-level inflation.

Our model can be extended along several dimensions. Following the lead of Handbury (2013), the model could accommodate quality substitution of products by assuming that household permanent income affects her preferences for quality. This would naturally lead to the conclusion that quality substitution and the between quality component of gross additions would respond mostly to permanent rather than temporary shocks, in line with the empirical evidence. In its current form, the model does not admit a balanced growth path, for two reasons: first, the elasticity of the household adoption rate to adoption expenditure is less than 1; and second, the elasticity of the welfare-relevant household price index with respect to the number of varieties in the consideration set is not constant. It would be easy to normalize the functional forms of the adoption technology and the price index so as to keep them constant along a balanced growth path. An alternative approach is discussed in Supplementary Appendix I, where firm innovation, rather than increasing the number of varieties within a sector, leads to the formation of new sectors. Following Menzio (2020), it could also be that, as the economy grows, producers design more specialized products which would increase household incentives to search for varieties as well as reduce the probability of finding varieties to add to the consideration set. In principle, this can be used to construct a balanced growth path with a constant ratio of adoption to total expenditure and a constant number of varieties in the consideration set which delivers a growing utility to the household.

We think that the idea that households adjust consumption along the extensive margin by bringing new varieties into the consumption basket also raises some interesting questions for further research. For example, Neiman and Vavra (2018) document a fall in the number of varieties purchased by households and an increased segmentation in the products that they do buy. In theory this could be due to a prolonged contraction in household adoption expenditure, perhaps owing to greater income uncertainty or lower expected income, making households less prone to experiment with new varieties. We have also emphasized the implications of household adoption for firm innovation, but household adoption would also matter for entry decisions in foreign markets which, as stressed by Melitz and Redding (2015), is a prime determinant of the welfare gains from trade in new trade models.

31. The second term in the right-hand side of (68) is small because changes in μ_t, which drive changes in preferences, not only affect the mean number of varieties in the consideration set of households but also their variance (the mean and the variance of the Poisson distribution are indeed equal). As a result the welfare gains of the increase in μ_t are already well characterized by changes in the dispersion of household level consumption shares in (70), in line with the logic by Redding and Weinstein (2019).

Supplementary Data

Supplementary data are available at *Review of Economic Studies* online. And the replication packages are available at https://dx.doi.org/10.5281/zenodo.4751609.

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Data Availability Statement

The analysis is based on data from the Nielsen Company (US), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at the University of Chicago Booth School of Business https://www.chicagobooth.edu/research/kilts/datasets/nielsen. The authors did not have special access privileges and interested parties can access the data by purchasing them through the Kilts Center. For inquiries, please contact marketingdata@chicagobooth.edu.

Ancillary data are obtained from the U.S. Bureau of Economic Analysis, retrieved from FRED, Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org/series) on August 1st 2018. Their mnemonics are: DFXARC1Q027SBEA, DFXARG3Q086SBEA, and TTLHH.

The data and code underlying this research is available on Zenodo at: http://doi.org/10.5281/zenodo.4751609.

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