HOUSEHOLD HETEROGENEITY, TRADE AND MACROECONOMICS

By

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Economic policy uncertainty and stock market participation

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The nature of the cooperation and the roles of the individual co-authors and approximate share of each co-author in the joint work: the paper was developed in close co-operation with Dimitris Georgarakos throughout all stages of the research project. We contributed equally to the idea of the paper and formulated together the main research question. Dimitris Georgarakos designed the identification strategy and we shared the tasks of empirical estimation and writing as well.

The Relative Importance of Taste Shocks and Price Movements in the Variation of Cost of Living: Evidence from Barcode Data

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Abstract

Chapter 1: Economic Policy Uncertainty and Stock Market Participation
Co-author: Dimitris Georgarakos

Do economic policy uncertainty news affect household stockholding? To answer this question we create a novel measure of household exposure to economic policy uncertainty news by combining survey information on the hours a household spends in reading newspapers and the frequency of such news in the popular press during a household's pre-interview period. After controlling for household fixed effects, month-year fixed effects and time-varying cognitive skills, we find that households with more exposure to economic policy uncertainty news are less likely to invest in stocks directly or through mutual funds. This effect is independent from the VIX and household stock-price expectations.

Chapter 2: The Relative Importance of Taste Shocks and Price Movements in the Variation of Cost of Living: Evidence from Barcode Data
Co-author: Philip Vermeulen

Intertemporal consumer preference shifts, although common in modern macroeconomic models as drivers of demand shocks, have important but largely unexplored implications for price index theory and thus, for empirically measured price changes. The current practice of inflation measurement basically ignores taste changes and this study aims to fill in this gap. We derive a cost-of-living index in the presence of intertemporal preference shifts and show that such taste changes tend to lower the cost of living. Using a large barcode level dataset that covers 331 product groups and ten countries, we then uncover the importance of taste changes in explaining consumer demand shifts across close substitutes. We also analyze how measured consumer price inflation alters after allowing for taste adjustment over time and under CES preferences. To do so, we estimate the elasticity of substitution between varieties of the same good and use those to calculate goods price indexes. Our results show that the median elasticity of substitution is around 4 and we find that the average annual goods price inflation is on average about 1.1 percentage points lower when taking into account consumer taste shifts compared to standard goods price indexes. Our results indicate that taste changes are an important hitherto ignored factor in the measurement of cost of living changes.

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Chapter 3: A Model of Trade in Used Durable Goods

This chapter examines the role of secondary markets in durable goods in cross-country trade dynamics, with a special focus on the car industry. It contributes to the literature by providing a better understanding of the drivers of high trade volatility in durable goods. Empirically, it documents patterns in new and used car trade flows for a sample of European Union countries. Further, it develops a two-country general equilibrium model of trade in which countries can trade on the various vintages of a durable good. Countries can differ in their initial endowment, growth rate in the car sector and the representative household's preference for new versus older vintages. Adjustment in the level and age composition of the car stock can occur by new car production or international trade. This relationship is responsible for the dynamics of the model. Trade patterns are determined by comparative advantages. The model predicts that the country that experiences a high growth rate in new car production has comparative advantage in new cars and becomes a new car exporter. Further, the country that dislikes old cars relatively less will consume used cars and export new cars. Cross-country differences in tastes and growth rate in new car production influence cross-country trade dynamics. A sudden negative supply shock triggers stock adjustment in the country hit by the shock which generates large initial trade flows and muted but persistent trade flows thereafter. The chapter presents a numerical example and simulation results for the model that uses parameters calibrated to the primary and secondary car market in Germany and Hungary.

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CHAPTER 1
ECONOMIC POLICY UNCERTAINTY AND STOCK MARKET PARTICIPATION

1.1 Introduction

The uncertainty induced by fiscal, monetary and regulatory policies has important repercussions for economic activity and is considered a leading factor behind the post-crisis sluggish recovery. Existing studies have mainly examined the effects of policy-related uncertainty on the investment decisions of institutional investors and firms (e.g. Baker, Bloom, and Davis, 2016). On the other hand, far less is known about the impact of policy uncertainty on households, how this uncertainty actually reaches them and what types of uncertainty might be most relevant for household investment. For example, while the VIX index has been extensively used as a measure of uncertainty for financial markets, households might be more reactive to types of uncertainty that are immediately exposed to, such as uncertainty about economic policy.

This paper examines the effects of economic policy uncertainty on household investment decisions. To this end, we propose a novel measure of direct exposure to economic policy uncertainty news that is household-specific. In particular, we combine information on the hours households spend in reading newspapers and the frequency of articles denoting policy-related uncertainty in the popular press, measured according to a widely used news-based index. Next, we use our measure to investigate whether economic policy uncertainty news affect household stock market participation as well as ownership of other assets such as government and corporate bonds. We find that households with a greater exposure to news about economic policy uncertainty are less likely to hold stocks directly or through mutual funds.

The news-based index of economic policy uncertainty (EPU) that we utilize draws from the seminal work of Baker, Bloom and Davis (2016, BBD henceforth).[1] The index aims to capture uncertainty about whether policymakers are going to change the prevailing policy, which policy actions policymakers will choose, uncertainty about the economic and non-economic consequences of these actions and uncertainty related to political events, such as presidential elections. It is constructed based on the word count of articles denoting uncertainty about fiscal, monetary and regulatory policies in the popular press in the United States. BBD use information on firms' revenues dependence on government spending to measure firm exposure to EPU and examine its consequences for firms' investment, hiring and stock market volatility[2]. In addition, Gulen and Ion

[1] We use the terms 'economic policy uncertainty', 'policy uncertainty' and 'policy-related uncertainty' interchangeably throughout the paper. We refer to EPU to denote the news-based index introduced by BBD.

[2] In an early contribution, Guiso and Parigi (1999) use as a proxy for uncertainty subjective information from a survey of firm owners and CEO's regarding the future demand of their own firm's product. Bloom et al. (2007) proxy

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(2016) consider firms which face higher irreversible investment costs to be more affected by EPU, as they have a stronger incentive to wait until background uncertainty diminishes. Instead, we examine the extent to which policy-related uncertainty influences household financial decisions. To this end, we consider the time households spend in reading news as a direct channel through which households are likely to get exposed to policy uncertainty.

We use longitudinal data from the US Health and Retirement Study and its supplement, the Consumption and Activities Mail Survey that interview a nationally representative sample of households fifty years and older. These households possess the largest fraction of assets in the United States and their investment decisions are likely to have broader aggregate implications.[3] As we discuss in detail in the data section, the surveys we use provide an ideal set-up for addressing the research question at hand. Importantly, they offer all necessary information on household financial assets as well as various demographic and behavioral indicators that earlier studies have shown to affect stockholding.[4] A distinctive feature of the data is that information is collected on respondents' time use, and in particular, on time spent in reading the news (from paper and online). We match the survey data with the EPU index calculated over the months preceding each household interview and exploit the fact that the underlying policy uncertainty varies randomly across households assigned in different interview months.

Our paper makes a number of empirical contributions. First, we propose a household-specific measure of direct exposure to economic policy uncertainty news. The measure can be used to examine the role of news-based policy uncertainty for various household decisions.

Second, we investigate using this measure the effects of policy uncertainty news on household investment decisions. We mainly focus on stockholding (i.e. a well-researched decision in the household finance literature) as we would like to examine whether news-based policy uncertainty has an independent effect, beyond any factors identified by previous studies. We estimate that a one standard deviation increase in the EPU index implies a 6% net decrease in the unconditional probability of owning stocks directly or through mutual funds. Our finding suggests that news reading is an important channel for households to learn about the uncertainties related to policymakers' future course of action. Similar to the investor in Pástor and Veronesi (2013), better informed households become uncertain about whether and which new policies will be adapted and respond stronger to news related to economic policy uncertainty compared to less informed households. This result

for firm uncertainty by share price volatility.

[3] According to the 2007-2010 US Surveys of Consumer Finances, this age group of households owns 78% of gross equities and 75% of net wealth held by the total population.

[4] Data from the Health and Retirement Study have been extensively used in empirical household finance literature. For example, Hong, Kubik, and Stein (2004), Rosen and Wu (2004), and Bogan (2008) examine, respectively, the effects of sociability, reported health, and Internet use on stockholding decisions. Christelis, Georgarakos, and Haliassos (2013) use data from the same survey combined with comparable data from Europe to examine differences in household portfolios across the Atlantic.

relates to the empirical implications of theories of limited stock market participation based on ambiguity aversion. These theories allow for the distinction between choices regarding future outcomes with a known probability distribution (risk) and future outcomes linked to unknown probabilities (uncertainty) and predict that ambiguity averse investors will not hold stocks even if there are no other frictions present in the market (Dow and da Costa Werlang, 1992; Trojani and Vanini, 2004; Routledge and Zin, 2009). A common finding of these models is that agents demand an ambiguity premium (over and above the classic risk premium) to hold assets with uncertain returns (see Epstein and Schneider, 2010; Gollier, 2011, and the empirical findings in Dimmock et al., 2016). Thus, we provide empirical support to the literature showing that Knightian uncertainty and ambiguity aversion help better explain, compared to the standard subjective expected utility framework, the observed investor behavior.

In addition, we examine participation in other financial asset categories.[5] We find that fluctuations in EPU do not have an impact on owning stocks through individual retirement accounts (IRAs), consistent with existing evidence on considerable household inertia in reshuffling retirement portfolios. As regards bonds, we estimate a strong negative impact of EPU on ownership of corporate bonds, while we find no effect on government bonds.

Third, our data record household stock market expectations, thus allowing us to estimate the effect of policy-related uncertainty net of the effect of expectations about the level of the stock market index (first-moment effect). Disentangling the two in a direct way has not been possible in earlier applications using micro data on firms.[6]

We take a number of steps in order to ensure that our estimation strategy uncovers genuine effects. These steps are discussed in detail in the relevant section, yet one can summarize them briefly as follows. First, we identify the effect of interest through the interaction term of time every household spends in reading the news and the EPU news-based index during that household's pre-interview period. The index varies randomly across households interviewed in different months in a survey year, as household assignment into interview months is exogenous to prevailing policy uncertainty. Information on time reading newspapers is collected in every wave shortly prior to the period over which the EPU index is calculated (i.e. it is pre-determined relative to follow-up fluctuations in EPU). Thus, both components of the interaction term exhibit cross-sectional and temporal variation. This allows us to estimate a double fixed effects model that takes into account both household fixed effects (accounting for any household-specific, time invariant household unobserved attributes) and month of interview-year fixed effects (accounting for any aggregate factors that vary by month, including the EPU index in levels). Further to this, we take into account a num-

[5] We focus on participation in various asset categories and not on invested amounts as changes in amounts over time may be due to both active (due to trading) and passive (due to market valuation) reasons. As a result, it is hard to isolate the effects of EPU on active changes in invested amounts.

[6] For example, BBD control for expectations by using a measure of forecasted federal purchases.

ber of household-specific time-varying characteristics, such as cognitive skills measured in every wave.

Second, we take into account interaction terms of hours reading news with various time-varying aggregate indicators (S&P 500, VIX, CPI, GDP growth, Oil prices, etc.) and show that the estimate of interest remains unaffected. In addition, we estimate placebo regressions in which we use the EPU index computed over news published in Swedish, instead of US major newspapers.

Third, we examine whether hours reading news correlate with unobserved time-varying household characteristics. We find that our baseline estimate is robust in a very rich specification that takes into account all time-varying controls that existing household finance literature has shown to be relevant for stock investing (e.g. cognition, health, risk aversion, optimism, sociability, engagement in voluntary activities, Internet use, etc.). Furthermore, we interact the EPU index with hours spent in reading books, which represents a similar activity to newspaper reading and the two should be equally affected by household (time-varying) unobservables. Reassuringly, we estimate an insignificant effect of the interaction of hours reading books with the EPU index, which reflects the limited – through book reading – exposure to news-based uncertainty. Moreover, we use an IV estimation in which we instrument the news uncertainty index in the popular press with a measure of uncertainty deduced from the Federal Reserve's Beige Book (i.e. a source of information that households are assumed not having direct exposure to). While the two measures are correlated, it is unlikely that uncertainty recorded in the Beige Book impacts stockholding through household unobservables.

Fourth, we use information on how closely respondents report to follow stock market developments in every wave to account for those who spend more hours in reading the news because they consider investing in stocks. Moreover, we re-estimate our baseline specification by taking the lagged value of hours reading newspapers from the previous wave and interact this with contemporaneous values of the EPU index and our findings are not affected. Instead, when we interact hours reading newspapers with lagged values of the EPU index taken from the pre-interview period of the previous wave (i.e. a period that should not be relevant for current asset choices), our main estimate turns, as one would expect, insignificant.

The remainder of the paper is organized as follows. Section 1.2 reviews the related literature. Section 1.3 describes the data used. Section 1.4 provides details on the empirical strategy, while Section 1.5 discusses the baseline results. Section 1.6 shows results from a number of robustness checks and Section 1.7 provides additional findings on the relationship between EPU and ownership of stock IRAs and corporate and government bonds.

1.2 Related literature

The concept of uncertainty can be traced back to the insights of Knight (1921), who draws a theoretical distinction between future events with a known probability distribution ('risk') over a set of events for which these probabilities are unknown ('uncertainty'). Recent studies document that uncertainty varies over time and postulate that this variation can be viewed either as exogenous or as a response to business cycle fluctuations (Bloom, 2009, 2014; Jurado, Ludvigson, and Ng, 2015; Ludvigson, Ma, and Ng, 2015). These studies provide evidence on the depressing short-run aggregate economic consequences of an increase in uncertainty and suggest various possible mechanisms at work. In some of these models, uncertainty depresses real activity through the real options effect. By raising the option value of waiting, it affects either firms' incentives leading them to delay their investment and hiring (Bloom, 2009; Bernanke, 1983) or triggers a cautious response from households who raise their precautionary saving that ultimately dampens household consumption (Romer, 1990; Fernández-Villaverde et al., 2011; Bloom, 2014).[7]

Despite the extensive literature exploring linkages between uncertainty and aggregate economic outcomes and the theoretical models providing relevant micro-foundations, there is limited empirical micro evidence on the effects of fluctuations in uncertainty on firms and households. Using the run-up to the 1998 German general elections, Giavazzi and McMahon (2012) find that increased political uncertainty contributed to higher household saving. Julio and Yook (2012) use data on firms and find that political uncertainty reduces firm investment. Di Maggio et al. (2016) develop a county-level uncertainty index based on excess returns of publicly listed firms and show that it has an impact on household borrowing. Leahy and Whited (1996), Guiso and Parigi (1999), Bloom, Bond, and Van Reenen (2007) examine firm level data and document a strong negative relationship between uncertainty and investment. In these papers uncertainty is either proxied with firm level stock-price volatility or measured based on a self-reported distribution of expectations about future demand.

Our paper uses a household-specific measure of economic policy uncertainty that draws on the frequency counts of news in the popular press. The measure has been recently utilized to explore the relationship between firm-level investment and uncertainty related to policy and regulatory conditions (see BBD and Gulen and Ion, 2016). Firms that are more dependent on government spending or that face some irreversible investment costs are assumed to be exposed more to policy-related

[7]Gilchrist, Sim, and Zakrajšek (2014) point to financial frictions as the main mechanism through which uncertainty can lead to lower investment. Pastor and Veronesi (2012) measure movements in stock prices after a policy change announcement, while BBD suggest that the slow recovery from the Great Recession is associated with higher policy uncertainty during the period 2007 to 2009. Although a large body of literature examines the negative repercussions of uncertainty, there are also studies pointing into the fact that uncertainty may have a positive effect on long-run growth. In these models, uncertainty stimulates research and development when firms faced with heightened uncertainty are more eager to innovate (Bar-Ilan and Strange, 1996; Kraft et al., 2013).

uncertainty. Both papers document a negative relationship between aggregate policy uncertainty and average firm investment. Instead, we consider a direct channel (i.e. time reading newspapers) of household exposure to news in the press.[8]

Our study also contributes to the growing household finance literature that has examined how various socio-economic factors influence stock market participation, but has not assessed the role of economic policy uncertainty (Guiso and Sodini, 2013, provide a recent thorough review). When faced with decisions that involve risk and uncertainty agents tend to be ambiguity averse (i.e. they prefer choices with known over unknown probabilities of future outcomes; see Ellsberg (1961). As a result, agents require an ambiguity premium to hold assets with uncertain returns (over and above the classic risk premium), which increases with aversion toward uncertainty (see Maccheroni, Marinacci, and Ruffino, 2013; Gollier, 2011; Izhakian and Benninga, 2011). In the presence of uncertainty, stock market participation should be lower than predicted by standard portfolio models, and there should be a negative relationship between uncertainty and participation in the stock market (Easley and O'Hara, 2009; Epstein and Schneider, 2010). Dimmock et al. (2016) introduce in a US household survey questions based on Ellsberg urns to measure individuals' ambiguity aversion. They find that more ambiguity averse individuals are less likely to invest in stocks and that they hold under-diversified portfolios. This is related to the empirical predictions of asset pricing theories that consider investor behaviour when investors are unsure about the probability law generating asset returns. Dow and Werlang (1992) and Trojani and Vanini (2004) for example, show that applications of utility models that distinguish between risk aversion and ambiguity aversion can naturally generate limited stock market participation. Dow and Werlang (1992) additionally formally prove the existence of a no-trade region in asset prices. Anderson et al. (2009) empirically demonstrate that investors command a premium as compensation for uncertainty and conclude that uncertainty has an important effect for cross-sectional expected returns. Jeong et al. (2015) find that this premium is economically significant and ambiguity aversion explains up to 45% of the observed equity premium. Uhlig (2010) and Boyarchenko (2012) both study the role of uncertainty aversion in the recent financial crisis and argue that uncertainty aversion helps explain the large fall in asset prices and large increase in credit default swaps that would otherwise be puzzling considering only risk averse investor behaviour. Our empirical analysis is related to the theoretical work by Pástor and Veronesi (2013). The authors explicitly consider uncertainty generated by political news. In their model, prices react to political news because investors cannot fully anticipate which government policies will be adapted in the future. As a consequence, investors facing increased political uncertainty, require a political risk premium as compensation for uncertainty related to the outcome of political events such as debates and negotiations.

[8] Aguiar, Hurst and Karabarbounis (2016) is one of the few studies that exploits household data on time use to examine the time allocation into various activities. They find that leisure and home-production absorbs most of the foregone market work hours during the Great Recession.

1.3 Data

We use data from the Health and Retirement Study (HRS), a nationally representative, longitudinal survey offering detailed information on various household demographic characteristics as well as on their incomes and wealth.[9] The HRS was launched in 1992 and interviews every other year about 20,000 Americans aged 50 and over. The survey interviews are conducted over several months in the course of a year and, importantly, households are assigned to interview months independently from the prevailing policy uncertainty. As we explain below, this random allocation of households across interview months helps to identify the effect of interest. We augment the information from the HRS with data from the Consumption and Activities Mail Survey (CAMS), a supplemental survey sent by mail to a random sub-sample of HRS respondents in the fall of the year following the main interview. Since 2001, CAMS collects information on individual time use with reference to various activities and on household consumption patterns.

Respondents participating in CAMS are explicitly asked to report the "hours spent last week in reading newspapers or magazines" (i.e. including reading from papers and online), which represents a direct channel of 'exposure' to the EPU news. They are also requested to report separately the hours spent last week in: "reading books"; "watching programs or movies/ videos on TV"; "using the computer"; as well as the hours devoted in other activities such as working, socializing with friends, engaging in voluntary activities, entertaining and sleeping.[10]

The HRS (supplemented with CAMS) is the dataset that best serves our purposes because it collects high quality data on asset investment, time spent in reading newspapers, and the design of the survey allows us to credibly identify the effect of interest. We mainly examine the effect of exposure to policy uncertainty news on stocks owned directly or through mutual funds. Table A.9 shows ownership rates and transitions in participation status per two consecutive survey waves. On average, about 29% of households own stocks during the period under study. Roughly one-fifth of households surveyed in a given wave have entered the stock market since the previous wave, while a similar fraction exits the stock market before the follow-up wave. These switches corroborate existing evidence on important trading activity of stocks held directly or through mutual funds.[11] Moreover, one should note that households aged more than fifty years old in the US hold a significant fraction of total population resources. Therefore, it is instructive to investigate the extent to which policy uncertainty influences their investment choices.

We make use of all available waves of the HRS matched with CAMS, that is all seven waves from 2002 (matched with 2001 CAMS) to 2014 (matched with 2013 CAMS).[12] Table A.1 shows

[9]Hauser and Willis (2004) provide a detailed overview of the survey.

[10] In the robustness section, we check whether EPU influences stockholding through hours spent in various activities.

[11]As also noted in footnote 5, it is hard to infer active trading by comparing amounts invested in stocks across consecutive waves.

[12] For our analysis, we mostly rely on the HRS files created by the RAND Center for the Study of Aging.

summary statistics of the various household socio-economic characteristics used in the regression analysis as well as of the hours spent per month in various activities[13].

We supplement the HRS data with information on the economic policy uncertainty that every household is exposed to in the period preceding the main interview. We employ the EPU index developed by BBD.[14] The index is calculated on a monthly basis utilizing information only from news publications. Thus, it conforms naturally to the hours spent in reading newspapers, which represent a direct channel through which households are exposed to economic policy uncertainty news.

Based on computer automated search algorithms, the index quantifies references to uncertainty as found in news articles from ten major newspapers: USA Today, the Miami Herald, the Chicago Tribune, the Washington Post, the Los Angeles Times, the Boston Globe, the San Francisco Chronicle, the Dallas Morning News, The New York Times, and the Wall Street Journal. An article is considered relevant for the construction of the index if it contains keywords related to all three categories: economy, uncertainty and policy. Specifically, for an article to be included in the sample, it has to contain at least one word from "economy, economic"; one word denoting uncertainty ("uncertain, uncertainty"); and at least one policy term from the list "regulation, deficit, legislation, congress, white house, Federal Reserve, the Fed, regulations, regulatory, deficits, congressional, legislative, and legislature". The index has been adjusted for the changing volume of news over time.[15]

The EPU index aims to measure the portion of the overall economic uncertainty attributed to the political and regulatory system. The index has been found to spike near tight presidential elections, wars and terrorist attacks, the failure of Lehman Brothers, the 2011 debt-ceiling dispute and other major disputes over fiscal policy (for details see BBD).[16]

[13]We find no evidence that hours reading newspapers would vary systematically with wealth. The correlation between total net wealth and hours reading newspapers in our sample is 0.11.

[14]We use the monthly EPU downloaded from http://www.policyuncertainty.com/ (version February 28, 2017). This index is also used in the baseline analysis of Baker et al. (2016) combined with two other indicators to construct a broader, overall policy-related economic uncertainty measure. The latter is calculated as a weighted average of the news-based index, tax code expiration data, and economic forecasters' disagreement about policy relevant variables: the CPI and future government spending. For our analysis, the index of main interest is the first component since it focuses on the written news media as a messenger (see Alexopoulos, Cohen, et al., 2009), to convey information on underlying economic policy uncertainty.

[15] For each of the ten newspapers, the number of selected articles each month is scaled by the total number of articles in the respective newspaper and month. These individual series are subsequently normalized to unit standard deviation over the period January 1985 to December 2009 and summed within each month. The resulting multi-paper index is then normalized to have an average value of 100 over the period January 1985 to December 2009.

[16]BBD perform numerous robustness checks to validate the index. They show that the index conveys independent information on uncertainty, over and above the VIX index (a frequently used indicator of uncertainty computed from financial market data) and forecasts from the Survey of Professional Forecasters of government purchases.

1.4 Empirical strategy

The design of the survey offers an almost ideal setup to construct a measure of exposure to economic policy uncertainty news that is household-specific. For better exposition of the survey design, Figure 1 shows a timeline of the interview phases. First, the survey records, in the fall of a given year (e.g. in 2001), the hours (per week) that households spend in reading newspapers. Second, starting in the first months of the follow-up year (2002), the survey contacts again households for the baseline interview. The baseline interviews, in which households indicate stock ownership and other asset investment, take place in different months in the course of the year. One should note that the month of the interview is exogenous to prevailing EPU. We exploit this random allocation of households in different interview months and calculate for each household the EPU index denoting the frequency counts of economic policy uncertainty news in the popular press over the months preceding the interview.

We measure every household's exposure to economic policy uncertainty news by defining the product of the hours (per month) spent in reading the news times the (monthly) EPU index measured over the period prior to the month of the interview. The hours spent in reading newspapers are recorded shortly prior to the months over which EPU is computed, thus they should not be determined by follow-up variation in the EPU. In Figure A.2 we depict the EPU since 2001 and the interview months over which our sample spans. We also show summary statistics of the EPU over this period between interview and non-interview months (see Appendix Table A.10).

Our measure implies that between two households that spend the same amount of time in reading newspapers, the one that is matched with a higher EPU over the months prior to the (randomly assigned) interview month is exposed more to economic policy uncertainty news. Likewise, between two households that are interviewed in the same month (and thus are matched with the same EPU prior to their interviews), the one that spends more time in reading the news is assumed to be exposed more to economic policy uncertainty news. This notion follows the fact that two agents who are exposed to the same amount of information respond asymmetrically to negative and positive news.

Individuals' propensity to weight more the negative than the positive news has been widely documented in political science and psychology research. For example, Soroka (2006) shows that public concern tends to respond asymmetrically to positive and negative news and negative news receive more weight when attitudes are formed. Experimental studies also find evidence that the effect of a unit increase in negative news is larger than that of a unit decrease. Information pertaining to bad events receives more thorough and elaborate processing than information about good events, which in turn may lead to paying more attention to unfavorable information (Klinger, Barta, and Maxeiner, 1980; Baumeister et al., 2001). Such an asymmetry is also in line with the tenets of prospect theory and loss aversion Kahneman and Tversky (1979).[17]

Our household-specific measure of exposure to economic policy uncertainty news exhibits cross sectional and temporal variation in both its components (i.e. time spent in reading newspapers and the EPU index). Therefore, given that our sample is a panel, we can identify the effect of interest, while controlling for household fixed effects as well as for month-of-interview-year fixed effects. Household fixed effects allow us to take into account any household-specific, time invariant unobserved characteristics, such as preferences, that may correlate with stock investing. In addition, month-of-interview-year fixed effects absorb any aggregate time varying factors, such as stock market performance, that are likely to influence stockholding. The specification allows to identify separately the effect of hours spent in reading newspapers (through within household variation over time) while the effect of the EPU index alone is absorbed by the month-of-interview-year fixed effects. The estimated effect on the former term combined with that of the interaction term represent the influence of exposure to general information through newspaper reading.

Our unit of analysis is the household, as stockholding and net wealth are defined at the household level. In non-single households, hours spent in reading newspapers and other demographics are defined over the financial respondent (i.e. the person in charge of managing the household finances). More specifically, we estimate the following double fixed effects specification:

$$\begin{aligned} Y_{i,t,m} = \beta_1 log\overline{EPU}_{t,m-1} * \log(hours\ reading\ newspapers)_{i,\ t-1} \\ + \beta_2 \log(hours\ reading\ newspapers)_{i,\ t-1} + \beta_3 X_{i,t,m} + \alpha_i + \gamma_{t,m} + \varepsilon_{i,t,m} \end{aligned} \quad (1.1)$$

where $Y_{i,t,m}$ is a binary indicator denoting ownership of stocks held directly or through mutual funds for household i that is interviewed in month m during the baseline interview year t. $\overline{EPU}_{t,m-1}$ is the average EPU evaluated over the months between January and the month prior to the interview month m for every household (i.e. $\frac{1}{m-1}\sum_{m=1,t}^{m-1,t} EPU_m$).[18] The hours per month that the financial respondent of household i spends in reading newspapers is recorded in the fall prior to baseline interview year (during which EPU is calculated) and is denoted by $hours\ reading\ newspapers_{i,\ t-1}$.[19] $X_{i,t,m}$ consists of an array of household-specific, time-varying characteristics, recorded in the month of the interview. The specification also accounts for individual fixed effects (α_i) which take into consideration all household-specific, time invariant unobserved factors. Moreover, it controls for

[17]Epstein and Schneider (2008) for example propose a model of information processing that focuses on investors' knowledge about signal quality. In their model, when the quality of news is hard to judge, investors will act under the worst-case assessment of quality. Good news will be considered hardly reliable, while bad news will be evaluated as highly reliable. As a result, investors react more strongly to bad news than to good news.

[18] In the robustness section we show results from alternative specifications in which we define average EPU over three months and one month prior to every household interview.

[19] Hours reading news and hours spent in other activities (later used in robustness specifications) have been censored at the top 1% of the respective distributions to eliminate the influence of outliers.

month-year-of-interview fixed effects, which absorb any time-varying by month-year-of-interview factors ($\gamma_{t,m}$), including $\overline{EPU}_{t,m-1}$. Standard errors are double clustered at the household and month-year-of-interview level to allow for possible cross-sectional and serial correlation dependence in the error term $\varepsilon_{i,t,m}$.

The novelty our empirical specification is the first term on the right hand side. The choice of the dependent variable reflects the standard approach in the empirical literature studying limited stock market participation and our aim to be able to isolate the influence of economic policy uncertainty news on active (due to trading) household financial decisions.

1.5 Results

Baseline regression results from different specifications are shown in Table A.3. We first estimate a basic specification that includes the interaction term of interest, the hours reading newspapers as well as a full set of household and time fixed effects.[20] We find that higher exposure to EPU news makes stockholding less probable and the relevant effect is statistically significant at 1%. In particular, we estimate that a one-standard deviation increase over the mean EPU implies a 1.8 p.p. lower probability of owning stocks directly or through mutual funds for a typical household with an average reading news time.[21] Given that 29% of households in the sample own such assets, the estimated effect implies a more than 6% net contribution to the unconditional ownership probability.

While it is beyond the scope of our study, one could also calculate the net implied effect of hours reading news by taking into account the estimates of both the interaction and the respective level term. According to these, an assumed one-standard deviation increase in the hours reading news, given a mean EPU, implies only a slightly higher (0.2 p.p.) probability of owning stocks. Estimation results from the same model without an interaction term show economically unimportant and imprecisely estimated effects of the level term of hours reading (p-value = 0.096). Therefore, there is not any explicit association between owning stocks and variation in the hours reading (any kind of) news. We discuss below further robustness checks that also refute a mechanical relationship between hours reading news and changes in stock ownership status in the period under study.

Next, we augment specification (1) by adding a set of household-specific, time-varying cognitive indicators. There is cross-sectional evidence that cognitive abilities and financial sophistication influence stockholding (see Christelis, Jappelli, and Padula, 2010 and Van Rooij, Lusardi, and Alessie, 2011, respectively). Moreover, while it is reasonable to assume that a household that

[20] Given that we estimate a model with household fixed effects, we implicitly take into account a standard set of determinants used in (cross sectional) household finance studies, such as age, gender, race, religious denomination and education (which does not vary over time for older households).

[21] The calculation is based on mean (standard deviation) EPU of 120 (45) and the mean (monthly) reading news time of 20 hours.

spends more time in reading newspapers than another household should be exposed to more information contained in newspaper articles, one may argue that the two households also differ in their information processing abilities (Wilson, 2000; Toplak, West, and Stanovich, 2014).

In view of the above, one should note that our fixed effects specification takes into account fixed unobserved differences (e.g. in IQ) across respondents. In addition, we explicitly control for time-varying cognitive indicators that are shown in the reading research and cognitive psychology literature to be strong predictors for cognitive performance and reading comprehension.[22]

More specifically, we take into account as a measure of memory capacity, a word recall score denoting the number of words correctly recalled by the respondent out of a list of ten that is read by the interviewer. Furthermore, we control for respondents' mathematical skills by means of a numeracy score, denoting the number of correct answers to five successive subtractions of the same number. Apart from these two measures we also take into account independent information based on interviewers' post-interview assessment as regards respondents' general understanding of questions and ability to recall information during the interview. We find that (time-varying) word recall ability associates positively with stockholding, nevertheless the inclusion of cognitive indicators does not alter the estimated relationship of interest. In addition, we have estimated models (non-reported) in which we interact our main interaction term with cognitive abilities and do not find evidence for a differential response to news-based policy uncertainty. In separate specifications we are interested in whether households with greater levels of cognitive ability respond differently to news, given the time spent in reading news, and find that this differential effect of cognitive abilities is insignificant.[23]

In specification (3) we further add various time-varying demographic characteristics such as household size and labor status. In addition, we account for self-reported health and limitations in ADLs, as there is evidence to suggest that those in poor health are less likely to invest in stocks Rosen and Wu (2004). To control for psychological outlook, we also include a dummy for feeling depressed most of the time over the week prior to the interview. We take into consideration the sociability indicator of Hong, Kubik, and Stein (2004), namely whether respondents know their neighbors, as social interactions can induce stockholding by lowering information-related costs. In a similar vein, we enrich our specification with a dummy denoting regular Internet usage because there is evidence that it encourages stock ownership by facilitating access to financial information Bogan (2008). In order to capture possible differences due to region-specific factors we include dummies representing the nine US Census divisions. We also control for whether respondents

[22] This literature provides evidence that reading comprehension associates with readers' decoding skills (ability to read text accurately) and language comprehension (e.g. García and Cain, 2014). In our estimation we take into account interviewer's assessment on every respondent's overall understanding of questions during interview. There is also evidence for an association between performance on reading tasks and memory Gersten et al. (2001), that we account for by the score in a memory test and the interviewer's assessment on respondent's memory performance.

[23] These results are not reported in this paper but available from the authors on request.

participate in voluntary organizations as a measure of social engagement and whether they intend to leave any bequests.

In addition to the aforementioned demographic characteristics, specification (3) accounts for household economic resources. In particular, we control for household net income and net total wealth by means of dummies representing quartiles of the respective distributions. While estimates on various socio-economic characteristics display the expected sign they are mostly statistically insignificant as we control for household fixed effects and standard errors are clustered at a higher than the household level.[24] In any case, controlling for this very rich set of time-varying characteristics leaves the estimated relationship of interest virtually unaffected.

In specification (5), we control in addition for household stock market expectations.[25] It is instructive to take into account expectations, as the effect we identify may reflect heterogeneity in expectations about the stock market index and not in uncertainty about economic policy per se.[26] The expectations question is asked in every survey except from the 2002 and 2014 waves where it is asked only over a random sub-sample of surveyed households. In addition, there are many missing values (in roughly one third of the responses) across all survey years.[27] As a result, specification (5) is estimated over a considerably smaller sample compared to the baseline one, but our main results remain resilient to this drop in the sample size. We also find that higher stock market expectations associate positively with stockholding.

Results from this specification point into the fact that household-specific uncertainty (second-moment) about economic policy has an independent effect on stockholding from household (first-moment) expectations regarding the stock market index level. Our finding provides support to the notion that the measure of exposure to EPU news represents the uncertainty component and not a level effect of an (expected) negative macroeconomic shock. The distinction is important because shocks that slow down economic activity typically entail a first-moment (level) and a second-moment (uncertainty) component. While the former refers to changes in the level of various economic indicators, the latter relates to non-forecastable changes in the volatility of these indicators (see Bloom, 2009, Bloom, 2014).[28]

[24] In the robustness section, we also present results with additional controls for risk aversion, social capital and optimism.

[25] Respondents are asked to report the percent chance in one year time the “mutual funds shares invested in blue chip stocks like those in the Dow Jones Industrial Average will be worth more than they are today” (i.e. at the time of the interview).

[26] BBD use information on forecasted federal purchases to account for firm future expectations. Our data allows us instead to control directly for household-specific stock market expectations.

[27] This follows the fact that a higher than usual number of respondents does not know to answer this question, while a significant fraction of those answering 50% indicate afterwards that they reported so because they were unsure about the chances (and thus are classified as missing).

[28] There is growing evidence that uncertainty rises during recessions, pointing to a feedback effect from recessions to uncertainty (see Bloom, 2014 and Jurado, Ludvigson, and Ng, 2015). For example, at the start of the Great Recession, the series of negative events in financial markets represented bad news for the economy and also raised uncertainty. The

Last, as we use micro data and our measure of exposure to economic policy uncertainty news is household-specific, we can extend our baseline specification to examine whether the main effect of interest varies by population subgroups. We re-estimate specification (4) by adding a triple interaction term that allows the effect of the interaction term of hours reading news and EPU to differ for households with a college degree. The insignificant coefficient on this triple interaction term (p-value = 0.39) suggests that the effect of exposure to news about economic policy uncertainty on stockholding does not systematically differ between educated and less educated households.

1.6 Robustness

In this section, we perform a number of robustness checks that provide additional support to our baseline findings. The first set of robustness checks examines the possibility of omitted aggregate factors (other than EPU), that, if they were interacted with hours spent in reading newspapers, they would have rendered the interaction term of interest insignificant. As discussed, any time-varying aggregate factors are absorbed by month-year-of-interview fixed effects. Nevertheless, some factors may still play a role through their interaction with hours households spend in reading the news.

To mitigate this concern we re-estimate our baseline specification with a full set of household controls (specification (4), Table A.3), while taking into account the interaction term of interest and a number of time-varying aggregate factors interacted with hours reading newspapers.[29] Results are shown in Table A.4, while Table A.12 in the Appendix provides details on each of the indicators used. In the first specification, we add an interaction term of hours reading news with the S&P 500 index, to check whether stock market performance has an incremental effect on the likelihood of those who read news to invest in stocks. Adding this interaction term leaves our estimate of interest virtually unaffected.

Next, we interact the number of hours reading newspapers with the VIX index (i.e. the 30-day implied volatility index on the S&P 500 index options), which represents a common measure of uncertainty related to equity returns. The VIX correlates with EPU as both indices capture a common uncertainty component, nevertheless, as BBD show, the latter index measures additional uncertainty due to economic policy that is not captured by the former. When we control for both interaction terms, we find that the interaction term of the hours reading news with EPU is qualitatively unchanged and significant at 10%, while that with VIX is insignificant. This result suggests that the estimated effect on stockholding channeled through newspaper reading mainly regards the economic uncertainty due to government and regulatory policies and not due to equity market

ensued economic downturn and the policy responses to the worsening of economic conditions reinforced uncertainty, which in turn amplified the initial market shock (Bloom, 2017).

[29] For symmetry, we assign each of these factors in an analogous way we assigned EPU to households. For example, real GDP growth is defined for every household as the average real GDP growth evaluated over the months running from January of the survey year to the month prior to the interview.

volatility per se.

Furthermore, we consider interaction terms of hours reading news with various other indicators such as professional forecaster disagreement about future CPI, oil prices, real GDP growth, federal funds rates and CPI. In all these cases, the inclusion of additional interaction terms leaves the baseline estimate of interest broadly unaffected.

In addition, we estimate a placebo regression in which we consider the EPU index calculated for Swedish newspapers (see Armelius, Hull, and Köhler, 2017). While this index displays a correlation of almost .5 with its counterpart one for the US, it does not have any independent explanatory power when it is interacted with hours that US households spend in reading (presumably domestic) newspapers.

The second set of robustness checks explores whether the interaction of the EPU index with the hours allocated into a number of (other than reading newspapers) activities has an independent effect on stockholding. As discussed, an advantage of our measure of household exposure to economic policy uncertainty news is that it is constructed by combining two indicators that are conceptually well connected (i.e. the number counts of economic policy uncertainty news that appear in the US popular press and the number of hours spent in reading newspapers). Nevertheless, for robustness, we also examine whether EPU could influence household stock investing through the time spent in other activities.

To this end, we re-estimate our baseline specification (specification (4), Table A.3) by controlling for, one at a time, interaction term of the hours spent in various activities with EPU. Results are shown in Table A.4. First, in specification (1), we interact the hours spent in reading books with the EPU. Reading books represents an activity that is quite similar to newspaper reading and they should both correlate with a comparable set of household unobservables (e.g. time-varying intellectual curiosity). Nevertheless, the former activity should imply much less exposure to economic policy uncertainty news than the latter. Indeed, the estimated coefficient of the interaction term between time spent in reading books and the EPU is relatively small and highly insignificant (p-value = 0.69). Moreover, one should note that the corresponding level term is insignificant. These results lend further support to our baseline estimate capturing genuine effects.

Next, we experiment with interaction terms between the EPU and hours spent in 'using the computer' or 'watching programs or movies/ videos on TV' and neither of them is significant. While one cannot assume out some exposure to economic policy uncertainty news through these activities, it is quite unlikely to be as direct and strong as it is through newspaper reading (which may well regard online articles). Likewise, we find no significant effects when we interact EPU with hours working, hours socializing with friends, hours involved in voluntary activities, hours entertaining and hours sleeping.[30]

[30] Hours socializing with friends include hours spend in visiting friends, talking with friends over the phone, and

In the third set of robustness checks we add to our extended baseline specification (4) in Table A.3 some additional household-specific covariates that may influence our results through their within-household variation over time. The first covariate regards an (inverse) risk aversion indicator. We recover this from a series of questions involving income gambles with mean preserving spreads which allow us to construct a four-scale indicator denoting willingness to assume higher risks.[31] HRS does not ask these questions since 2008 and onwards, while in the pre-2008 waves the questions are not always asked to both members in couples. We facilitate sufficient number of observations on the risk aversion indicator by considering the value of the partner when the indicator is missing for the financial respondent in couples and by taking the minimum reported risk aversion over the years for which the relevant indicator is missing. In Table A.5, column (1), we show results when we add the (inverse) risk aversion indicator. Having accounted for household heterogeneity in (time-invariant) risk aversion, we find that 'within' variation in households' willingness to assume risks displays the expected association with stock holding (p-value = 0.187) and that our baseline estimate remains unaffected. Also, we estimate a specification in which we interact willingness to assume risks with EPU news and find that policy uncertainty does not influence stock holding via (time-varying) risk aversion (p-value = 0.402).

The second covariate regards a social capital indicator. Trust and social capital in general have been shown to influence stockholding as they reflect households' perceived likelihood of being cheated by financial intermediaries (see Guiso, Sapienza, and Zingales, 2008 and Georgarakos and Pasini (2011)). Literature on social capital has established that trust in other people tends to change slowly over time, given that social capital entails a large inherited component of social values and norms (Tabellini, 2010). Thus, household fixed effects in our specification should have captured most of the heterogeneity in trust. As HRS does not ask how much respondents trust other people in general, we control in our baseline specification for participation in voluntary organizations as a measure of social engagement. For robustness, we add to the baseline specification charity donations as an indirect measure of social capital.[32] Controlling for (time-varying) charitable contributions leaves our main results unaffected (Table A.5, column (2)).

Last, we use as an indicator of (time-varying) optimism the self-reported probability to survive upon age 75 (which is the common age threshold with reference to which households across all survey years are asked to report their life expectancy). Our findings are unaffected when we re-estimate our baseline specification over financial respondents younger than 75 and take into account

helping friends, neighbors, or relatives who do not live with the respondent. Hours involved in voluntary work include hours doing voluntary work for charitable and other organizations, attending religious services, and attending meetings of clubs or religious groups. Hours entertaining include hours playing cards or games, attending concerts or movies, singing or playing a musical instrument, and doing art projects.

[31] We use the variable on risk aversion that has been constructed in the RAND version of the HRS.

[32] The survey asks whether the respondent (or his spouse) has "donated any money, property, or possessions totalling $500 or more to religious or other charitable organizations".

individual life expectancy (Table A.5, column (3)).

The fourth set of robustness checks looks into the possibility households that consider investing in stocks to increase the hours reading the news in the popular press. To this end, we use information from a special question that asks households to report how closely they follow the stock market.[33] As it is shown in Table A.5, column (4), taking into account changes in household propensity to follow stock market across waves leaves our estimates on the interaction term of interest and on the hours reading news unaffected.

An alternative way to address this issue as well as the possibility that the hours reading news vary due to fluctuations in EPU is to apply an IV estimation. In this context, an instrument should correlate with EPU (i.e. be relevant) but should not immediately affect how many hours households read the news or correlate with household time-varying unobserved characteristics that influence stockholding. To this end, we use as an instrument an uncertainty indicator based on text analysis of the Federal Reserve Bank report known as the Beige Book.[34] The Beige Book is prepared and published before the regularly scheduled FOMC meetings, summarizing the views of market experts, business contacts and other relevant sources on current economic conditions. We assume that the uncertainty contained in Beige Book correlates with economic policy uncertainty news published in the popular press, but it represents an exogenous source of information that presumably does not influence directly the hours that households read news.

Table A.6 shows results from the IV estimation of the double fixed effects baseline model (specification (4), Table A.3) in which uncertainty contained in Beige Book is used as an instrument for EPU. The derived F-statistic from the first-stage regression is 118.6 (i.e. well above the rule of thumb threshold of 10 used to assess the strength of an instrument). According to the IV estimate from the second-stage regression an assumed one-standard deviation increase over the mean EPU, and for average reading news hours, implies a 2.3 p.p. lower likelihood of owning stocks directly or through mutual funds (i.e. comparable to the estimated magnitude from the baseline specification).

As an additional robustness check, we re-estimate our baseline specification by using the lagged value of hours reading newspapers from the previous wave that a household participates in and interacting it with contemporaneous values of the EPU index.[35] Results are shown in Table A.7,

[33] Survey respondents are asked to report ”how closely do you follow stock market: very closely, somewhat, or not at all?”. The question is not asked in 2002 and 2006; we fill in these gaps by using the reported values in 2004 and 2008, respectively.

[34] We use the BBD text-based uncertainty indicator for the Beige Books which they construct to show that it correlates strongly with the EPU index. This alternative index counts the frequency of “uncertain” in each Beige Book report and is subsequently normalized to account for the varying length of the reports and rescaled to preserve average frequency count per report. Given that these reports are published eight times per year we apply linear interpolation to deduce a monthly-based index.

[35] This means that we use hours reading reported (at least) two years before a given interview year. As a result, observations from the first wave (2002) and from households interviewed in only two waves cannot be used in the estimation.

specification (1). Despite the drop in the estimation sample, our findings are hardly affected. This suggests that the effects we identify do not reflect some short-term variation in reading hours (that could be linked to a change in stock ownership status or to short-term fluctuations in EPU), but, more likely, some time-persistent cross-household heterogeneity.

On the other hand, we also experiment with an interaction term that matches hours reading newspapers with placebo values of the EPU index taken from the pre-interview period of the same household in the previous survey wave. In this case we find that the estimate of interest turns out to be, as expected, quantitatively unimportant and statistically insignificant (Table A.7, specification (2)).

The last set of robustness checks reflects on the calculation of the EPU attributed to individual households in our sample. In our baseline specifications we calculated the EPU as the monthly average over the months between January of the HRS baseline survey year and the month prior to every household interview. We re-estimate our baseline specifications exploiting two alternative calculations for the EPU that is assigned to each household. The first regards the monthly average of the EPU calculated over the three months prior to each household interview. The second uses the EPU only from the month prior to the interview. We employ these two alternative measures and re-estimate the entire set of five specifications shown in Table A.3. The respective results for the three-month and one-month EPU are shown on the left and right hand side panels of Table **??** and are broadly comparable to those we have discussed above.

1.7 Economic policy uncertainty and other financial asset holdings

In this section, we examine whether household exposure to news about economic policy uncertainty also affects ownership of stock IRAs and bonds. Note that recent studies have pointed into an asymmetry in household management towards different types of stockholding (see Bilias, Georgarakos, and Haliassos, 2010). On the one hand, households tend to trade relatively frequently directly held stocks. On the other hand, households exhibit significant inertia in adjusting the risk composition of their retirement portfolios over long periods in time (see Ameriks and Zeldes, 2004) and any adjustments are mostly retirement related.[36] Consistent with considerable inertia in managing retirement portfolios, we find no effects of exposure to EPU news on stock IRAs (results are shown on specification (1), Table A.8).

Bonds typically represent a less risky investment alternative to stocks. Nevertheless, the influence of economic policy uncertainty on bondholding can be quite different for different types of bonds. The data allows us to distinguish between household investments in two types of bonds,

[36] As shown in Holden and Schrass, 2016, the majority of IRA investors was unresponsive to financial events between 2007 and 2014 and IRA withdrawals were driven by age-related tax rules and retirement decisions. In our specifications, such transitions are accounted for by household fixed effect and by the retirement dummy.

namely government bonds and corporate bonds. US government bonds can be viewed as safe investments that should be little affected by policy-related uncertainty. By contrast, corporate bonds could be influenced by policy uncertainty to the extent to which prevailing uncertainty is likely to impact the issuing corporations. Moreover, corporate bonds represent more specialized and information intensive assets compared to government bonds. According to results shown in column (2) of Table A.8 we do not find a significant association between exposure to EPU news and ownership of government bonds. On the other hand, we find that greater exposure to EPU reduces significantly the likelihood of holding corporate bonds. The implied effect due to a one standard deviation increase in EPU over mean EPU and for a household with average news reading time is -1 p.p. Given that only 6.6% of households own corporate bonds, the implied contribution of the assumed increase in EPU on the unconditional ownership probability is about 15%.

1.8 Conclusions

We use US survey data on households older than fifty years of age (i.e. a group that possesses a significant fraction of society's financial resources) to examine how and whether prevailing policy uncertainty influences their decision to hold certain financial asset types. To this end, we create a novel measure of household exposure to economic policy uncertainty news by combining information on the time households spend in reading the news with the occurrence of words denoting policy uncertainty in articles published in the popular press. We measure the latter using the BBD text uncertainty index calculated over the months preceding each household interview. The fact that both components of our measure vary across households and time allows estimating a double fixed effects model that takes into account both household-specific and time-varying unobserved heterogeneity.

We find that households that are exposed more to policy uncertainty are less likely to own stocks directly or through mutual funds. We estimate this effect independently from the market volatility index and household (first-moment) expectations about the stock market index. In addition, these households have a lower probability to own corporate bonds. On the other hand, we do not find any significant effect due to heterogeneous household exposure to policy-related uncertainty news on the probability to own stock IRAs or government bonds.

Our findings reveal a channel through which policy uncertainty influences individual choices and assess its impact on household financial risk taking. More generally, our measure of household exposure to policy uncertainty news may be used to study household decisions in contexts other than financial investing.

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CHAPTER 2
THE RELATIVE IMPORTANCE OF TASTE SHOCKS AND PRICE MOVEMENTS IN THE VARIATION OF COST OF LIVING: EVIDENCE FROM BARCODE DATA

2.1 Introduction

The standard price index theory abstracts from changes in preferences in the empirical calculation of the cost-of-living index. This implies that any change in consumption patterns will be attributed to either a shift in income or movements in relative prices. In this chapter we are interested in, how measured price changes differ if taste changes are accounted for.

The conceptual foundations of the cost-of-living index have evolved over time and are strongly connected to changing ideas about the concept of utility. The standard neoclassical price index theory assumes optimizing consumer behavior, and well-defined preferences that can be represented with a utility function. Early on, price index theorists have recognized that the ultimate satisfaction from consumption is influenced by subjective judgements, tastes (Stapleford, 2013). Because utility is an ordinal concept, just by observing consumer purchasing decisions, preferences and tastes themselves are not observable. This makes intertemporal and interpersonal comparisons conceptually difficult. As tastes alter the shape of the utility function, theoretical problems arise if tastes change over time. The standard cost-of-living index is defined as the minimum change in expenditure required to keep a consumer indifferent between two price regimes, when this consumer is fixed in time and space (Stapleford, 2013). However, tastes may alter between two situations or over time[1], for example due to advertising, social norms, fashion or the environment (Frisch, 1936; Allen, 1949; Fisher and Shell, 1968) which has implications for the measured cost-of-living index.

Although, the vast majority of the economics literature ignores taste changes, accounting for movements in tastes would bring theory closer to reality. Redding and Weinstein (2019) for example document that the movements in micro level price and expenditure data are hard to reconcile with being the result of only price and income changes. The authors conclude that taste changes can help rationalize observed variations in expenditure at the micro level.

Second, changing tastes influence how we think about price change and inflation measurement. Balk (1989) shows that a pure taste change (holding prices fixed) always lowers the cost of living[2]. Intuitively, if prices are constant and tastes can alter, the consumer can still buy the same base period basket of goods and stay therefore on the indifference curve that goes through the base period

[1]For a review on the historical evolution of the theoretical discussion about the cost-of-living index, see Stapleford (2013).

[2]See corrolary 5 in Balk (1989).

basket. However, as tastes have changed, the curvature of the indifference curve going through the base period basket has changed, and a move along the new curve that leads to a cheaper but an ”equally well off” basket will be possible.

In this chapter, we first discuss theoretically such a cost-of-living index that takes into account taste changes. We use insights from the price index theory literature by Fisher and Shell (1972), Samuelson and Swamy (1974), Basmann et al. (1984), Balk (1989) and Redding and Weinstein (2019) and our definition of the cost-of-living index in the presence of taste changes follows Basmann et al. (1984) and Balk (1989). The proposed index compares the base period expenditure to the expenditure necessary under current preferences and prices to reach the indifference curve through the base period optimal basket. To derive an analytic form for the cost-of-living index we introduce taste changes in a nested Cobb-Douglas-CES utility framework, where utility is derived by consuming from a Cobb-Douglas aggregate of different product groups which are themselves CES aggregates of individual products. We allow for different elasticity of substitution within product groups and derive the theoretical cost-of-living index. Here we are related to Redding and Weinstein (2016) who derive a theoretical cost-of-living index, which the authors call the ”unified price index”, for a nested CES utility framework, where product groups and upper level aggregates both have a CES functional form. However, we differ with respect to Redding and Weinstein (2016) in our cost-of-living concept. In their analysis, changes in the cost-of-living solely depend on price and expenditure changes and not directly on changes in preferences. Contrary to this, the cost-of-living index we propose, based on Basmann et al. (1984) and Balk (1989), directly depends on shifts in preferences. Our cost-of-living index measure allows for the possibility that varying tastes shift the measured cost of living independently from an actual price change.

We also contribute to the empirical measurement of price indexes. Using a rich barcode level dataset from which we can observe actual price and expenditure data for 10 euro area countries and 331 product groups, we apply our analytical framework to calculate the taste-adjusted cost-of-living index and compare it with price indexes frequently used in official statistics. To do so, we follow the methodology in Feenstra (1994) and Broda and Weinstein (2006, 2010) to estimate the elasticities of substitution within product groups and use these elasticities to calculate the theoretical cost-of-living index. The results show that taste changes are an important element in our understanding of the evolution of cost-of-living over time. The calculated theoretical price index that takes into account taste changes is on average 1.1 percentage points lower than an index that ignores potential variability in consumer preferences over time. The estimated magnitude of the difference between the taste-adjusted and non-adjusted price index can be especially relevant in a low inflation environment.

The rest of the paper is structured as follows. Section 2.2 develops the theoretical framework to the taste-adjusted cost-of-living index and provides details for our analysis, Section 2.3 describes the dataset used for our empirical estimation and Section 2.4 presents the results.

2.2 Theoretical framework

2.2.1 Taste shocks and a cost of living index

In this section we first lay out the formal definition of the standard cost-of-living index. We do so as it sets the notation used later in the chapter and helps us introduce the notion of taste change and discuss its implications for a cost-of-living concept. The theoretical discussion in this section builds on the contributions of important price index theorists, such as Fisher and Shell (1972), Samuelson and Swamy (1974), Basmann et al. (1984), Balk (1989) and Redding and Weinstein (2016), who all discuss taste changes in a utility framework.

Let $U(\boldsymbol{q})$ represent the utility of the consumer obtained by consumption bundle $\boldsymbol{q}$ and let $\boldsymbol{p}$ be the corresponding price vector. The expenditure function is then given by:

$$e(U_0, \boldsymbol{p}) = \min_{\boldsymbol{q}} \{\boldsymbol{pq} : U(\boldsymbol{q}) = U_0\} \tag{2.1}$$

Along the expenditure function we also introduce the money metric function m, which is defined over consumption bundles and prices rather than utility levels and prices[3]:

$$m(\boldsymbol{q}_0, \boldsymbol{p}) = \min_{\boldsymbol{q}} \{\boldsymbol{pq} : U(\boldsymbol{q}) = U(\boldsymbol{q_0})\} \tag{2.2}$$

where the relation between the expenditure function and the money metric utility function is given by $e(U(\boldsymbol{q_0}), \boldsymbol{p}) = m(\boldsymbol{q_0}, \boldsymbol{p})$. A cost-of-living index measures the change in expenditures needed to sustain a given level of utility when prices change. The Konüs (1939) cost-of-living index at price vectors $\boldsymbol{p_2}$ and $\boldsymbol{p_1}$ and consumption bundle $\boldsymbol{q_0}$ is defined as the ratio of two particular values of the expenditure function or money metric function:

$$P_K(\boldsymbol{q_0}, \boldsymbol{p_2}, \boldsymbol{p_1}) = \frac{e(U(\boldsymbol{q_0}), \boldsymbol{p_2})}{e(U(\boldsymbol{q_0}), \boldsymbol{p_1})} = \frac{m(\boldsymbol{q_0}, \boldsymbol{p_2})}{m(\boldsymbol{q_0}, \boldsymbol{p_1})} \tag{2.3}$$

As discussed in more detail in Diewert (2009), equation (2.3) defines a family of cost-of-living indexes, one per reference quantity vector $\boldsymbol{q_0}$ (except in the case of homothetic preferences where the cost-of-living index is independent of the bundle $\boldsymbol{q_0}$). This formulation of the price index reveals that the standard neoclassical literature operates with a fixed base period utility. This way it is able to develop a cost-of-living index with a well defined meaning when holding consumer's utility

[3] This function goes back to McKenzie (1957) who defined $M_x(p)$ being the minimum income to attain a basket at least as good as x at price vector p. Samuelson (1974) called this function, for a fixed price vector a money-metric utility.

function fixed. Intuitively, the consumer is indifferent between having available a budget to spend $P_K(\boldsymbol{q_0}, \boldsymbol{p_2}, \boldsymbol{p_1})m(\boldsymbol{q_0}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_2}$ or having a budget to spend $m(\boldsymbol{q_0}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_1}$. Note that in this definition time does not necessarily play a role. The objective of the cost-of-living index is to compare two constraint sets, i.e. price vectors and incomes under which the consumer is indifferent. Conditional on the assumption that utility surfaces don't change over time, the concept of the cost-of-living becomes a meaningful one also over time[4].

However, preferences can change. There is no good theoretical reason why consumers should have constant preferences over time. Even simple introspection shows that what one likes today might be quite different from what one fancied yesterday. Allowing for taste changes has implications for the utility and the cost-of-living index, as such a change seems to imply a change in the utility surface. Fisher and Shell (1972) define a ”good-augmenting” taste change in good i as the change in a taste parameter i in a utility function. To allow for taste changes, it seems that one does not simply want a relabelling of the indifference curves but to allow for a change of curvature in the indifference curves (i.e. a change in the substitutability between items). The implications for the curvature can be introduced by augmenting the arguments of the utility function with taste parameters. Such a formulation of the utility function explicitly recognizes that the ultimate satisfaction from consumption is influenced by tastes and allows formally for a change in utilities.

In what follows, we are related to Fisher and Shell (1972) in that we define utility as a function of consumption and taste parameters. To fix ideas, let $U(\boldsymbol{q}, \boldsymbol{\varphi})$ represent the utility of the consumer obtained by consumption bundle $\boldsymbol{q}$ under tastes $\boldsymbol{\varphi}$. The taste parameter $\boldsymbol{\varphi}$ is a vector of taste parameters that shift preferences over time. We will focus on innovations in tastes that occur exogenously. Then the money metric function becomes:

$$m(\boldsymbol{q_0}, \boldsymbol{\varphi}, \boldsymbol{p}) = \min_{\boldsymbol{q}} \{\boldsymbol{pq} : U(\boldsymbol{q}, \boldsymbol{\varphi}) = U(\boldsymbol{q_0}, \boldsymbol{\varphi})\} \tag{2.4}$$

The traditional cost-of-living index compares expenditures so that the consumer can obtain two different baskets under different prices, where she is ”indifferent” between these two baskets. We will rely on the terminology ”indifferent” to be applied for comparisons *within* the same utility surface, i.e. ”indifferent” means staying on the same indifference curve within that surface. When the utility surface changes between two periods, being ”indifferent” can only be used as a concept when referring to a fixed utility surface. However, it remains possible to define a cost-of living

[4]Fisher and Shell (1972) argue that even if indifference curves remain unchanged, one can never be certain that over time they are not relabelled. This implies that intertemporal comparison, in their view, is in principle never possible. The authors argue argue: ”While it is apparently natural to say that a man whose tastes have remained constant is just as well off today as he was yesterday if he is on the same indifference curve in both periods, the appeal of that proposition is no more than apparent. In both period's the man's utility function is determined only up to a monotonic transformation; how can we possibly know whether the level of true utility (whatever that may mean) corresponding to a given indifference curve is the same in both periods? The man's efficiency as a pleasure-making machine may have changed without changing his tastes.”

concept under changing preferences.

Imagine two periods, where $(\boldsymbol{p_1}, \boldsymbol{\varphi_1})$ are the prices and tastes of period one and $(\boldsymbol{p_2}, \boldsymbol{\varphi_2})$ are the prices and tastes of period two. The consumption bundle $\boldsymbol{q_0}$ now has two indifference curves that pass through, $U(\boldsymbol{q_0}, \boldsymbol{\varphi_1})$ and $U(\boldsymbol{q_0}, \boldsymbol{\varphi_2})$. Under ordinal preferences, both levels of utility are incomparable.[5] They occur under different tastes. Three different cost of living concepts can now be defined. The first one using period one preferences only, the second one using period two preferences only and the third one using both preferences.

In the presence of taste changes, a family of cost-of-living indexes that encompasses all three concepts can be defined as follows.

$$P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1}) \equiv \frac{m(\boldsymbol{q_0}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})} \tag{2.5}$$

The above index family is indexed by a consumption bundle, two price vectors and two taste parameters with $(\boldsymbol{p_1}, \boldsymbol{\varphi_1})$ the prices and taste of period one and $(\boldsymbol{p_2}, \boldsymbol{\varphi_2})$ the prices and tastes of period two. It follows that the minimum expenditures needed under different price vectors can be established under period 1 preferences, under period 2 preferences and under both period preferences. This implies three different concepts of cost-of-living, which have different meanings.

The first concept uses period one preferences and is defined as $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_2}, \boldsymbol{p_1})$. Using $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_2}, \boldsymbol{p_1})$, the consumer with tastes $\boldsymbol{\varphi_1}$ is indifferent *under period 1 preferences* between a budget to spend $m(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})$ and $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_2}, \boldsymbol{p_1})m(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})$. This concept compares the expenditures needed under the first period's preferences to be indifferent between the two price vectors. It is the standard cost-of-living concept under fixed preferences. Under changing tastes, however, the consumer will be faced with different preferences and at the same time she is faced with a different price vector (price vector $\boldsymbol{p_2}$ occurs at a time when she has tastes $\boldsymbol{\varphi_2}$). Therefore, being compensated by this cost-of-living index, does not take into account the preference shift.

Similarly, the second concept uses period two preferences. Using, $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1})$, the consumer with tastes $\boldsymbol{\varphi_2}$ is indifferent between having available a budget to spend $m(\boldsymbol{q_0}, \boldsymbol{\varphi_2}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_1}$ or $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1})m(\boldsymbol{q_0}, \boldsymbol{\varphi_2}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_2}$. Intuitively, such a price index compares the expenditures needed for the consumer with preferences from the second period, to be indifferent between the two price vectors. It again ignores the fact that the consumer has different preferences and is faced with a different prices.

We introduce a third concept, denoted by $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1})$ that does not impose constant tastes for the definition of the cost-of-living index. Note that it would be misleading to say that

[5]"Under ordinal preferences" is important here. One could develop a cardinal theory of utility where taste shocks shift the cardinal utility but utilities remain comparable.

consumers are indifferent between a expenditures $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1}) m(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_2}$ and $m(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})$ under the price vector $\boldsymbol{p_1}$, because tastes have shifted from $\boldsymbol{\varphi_1}$ to $\boldsymbol{\varphi_2}$. The concept of indifference does not apply here either. However, $P_N(\boldsymbol{q_0}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1})$ is still a useful concept, especially when measured at $\boldsymbol{q_0} = \boldsymbol{q_1}$, with $\boldsymbol{q_1}$ being the optimal consumption basket when faced with prices $\boldsymbol{p_1}$ and tastes $\boldsymbol{\varphi_1}$.

Let $P_N(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2}, \boldsymbol{p_1}) = \frac{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})}$ define the monetary compensation needed to allow the consumer, faced with price vector $\boldsymbol{p_2}$ and tastes $\boldsymbol{\varphi_2}$, to obtain a level of utility that goes through the base period consumption bundle (that at an earlier time was optimal at the then prevailing prices and tastes). In other words, the consumer will be ”indifferent” (at tastes $\boldsymbol{\varphi_2}$) between getting the base period consumption bundle or being faced with the new price vector and getting the monetary compensation. With the monetary compensation, and being faced with the new price vector, the consumer would choose a basket that is different from the base period basket, but one from which it would derive the same level of utility.

One could imagine a benevolent planner who has the power to change consumers' budget but is faced with uncontrollable price and taste changes. It is not immediately clear which of those three concepts the planner would use, i.e. under changing tastes, consumers' income can be compensated for price changes (and taste changes) referring to three different concepts. The compensation can refer to the old preferences, such that under those preferences the consumer would have been equally well of, i.e. as if the consumer tastes didn't change. The compensation can refer to the new preferences so that under those new preferences the consumer would be equally well off under both price vectors, or the compensation takes into account both period preferences.

The third concept, which we will also rely on in this chapter, follows Basmann et al. (1984)[6] and Balk (1989) and defines a cost-of-living index between a base period and a current period by comparing the budgets needed in the two periods to reach the now different indifference curves that go through some fixed (base period) bundle of goods. Balk (1989) introduces the term *”equally well off”* in a world of changing preferences. Under changing preferences, ”equally well off” is defined as being on indifference curves that go through some fixed basket of goods and is, therefore, a relative notion that is related to this consumption basket. Note that the concept proposed by Balk (1989) does not imply that the consumer has the same level of utility. In a world of ordinal utility with shifting preferences, that becomes a meaningless statement. Being ”indifferent” under fixed preferences has been replaced by being ”equally well off” under shifting preferences.

It is worth rewriting the third cost-of-living index as the result of two effects, a pure price

[6] The third concept is identical to what Basmann et al. (1984) calls $BCLI_2$, the basic-cost-of-living index. (see page 6 of Basmann et al. (1984).

compensation and a taste change compensation.

$$P_N(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{\varphi_2},\boldsymbol{p_2},\boldsymbol{p_1}) = \frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_2})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}\frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})} \tag{2.6}$$

Equivalently:

$$P_N(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{\varphi_2},\boldsymbol{p_2},\boldsymbol{p_1}) = P_N(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{\varphi_2},\boldsymbol{p_2},\boldsymbol{p_1})\frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})} \tag{2.7}$$

The first factor in equation (2.6) is the standard cost-of-living index. The second factor $\frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})}$ measures the effect of a pure taste change. It quantifies the change in expenditure which would be necessary if a pure taste change occurred while keeping the price vector constant and an indifference curve was reached in the second period that passed through the first period's optimal basket.

2.2.2 Expenditure change as the product of a pure price, taste and quantity index

Under consumer expenditure minimization the expenditure change between period 1 and period 2 can be written as the product of a pure price change index, a taste change index and a quantity index. Let $\boldsymbol{q_1}$ and $\boldsymbol{q_2}$ be the optimal consumption baskets under period 1 and period 2 tastes, respectively. Then we have:

$$\frac{\boldsymbol{p_2q_2}}{\boldsymbol{p_1q_1}} = \frac{m(\boldsymbol{q_2},\boldsymbol{\varphi_2},\boldsymbol{p_2})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})} \tag{2.8}$$

which can be rewritten as:

$$\frac{\boldsymbol{p_2q_2}}{\boldsymbol{p_1q_1}} \equiv \frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_2})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}\frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})}\frac{m(\boldsymbol{q_2},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})} \tag{2.9}$$

where the first term, Γ_p, measures the effect of a pure price change, from $\boldsymbol{p_1}$ to $\boldsymbol{p_2}$ (holding tastes and quantity constant), the second term, Γ_φ, defines a pure taste change, from $\boldsymbol{\varphi_1}$ to $\boldsymbol{\varphi_2}$ and the third term, Γ_q, a pure quantity change from $\boldsymbol{q_1}$ to $\boldsymbol{q_2}$:

$$\frac{\boldsymbol{p_2q_2}}{\boldsymbol{p_1q_1}} = \Gamma_p\Gamma_\varphi\Gamma_q \tag{2.10}$$

Then the cost-of-living index under a pure taste change is the ratio of two expenditures with fixed base period prices and quantities but varying tastes:

$$P_N(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{\varphi_2},\boldsymbol{p_1},\boldsymbol{p_1}) = \frac{m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1})}{m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1})} \tag{2.11}$$

Consider the base period basket $\boldsymbol{q_1}$ to be the optimal basket under prices $\boldsymbol{p_1}$ and tastes $\boldsymbol{\varphi_1}$. Further, $m(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{p_1}) = \boldsymbol{p_1}\boldsymbol{q_1}$. Let $\boldsymbol{q_*}$ be the optimal basket under prices $\boldsymbol{p_1}$ and tastes $\boldsymbol{\varphi_2}$. Then we have that $m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1}) = \boldsymbol{p_1}\boldsymbol{q_*}$. Balk (1989) shows theoretically that $m(\boldsymbol{q_1},\boldsymbol{\varphi_2},\boldsymbol{p_1}) \leq \boldsymbol{p_1}\boldsymbol{q_1}$, and $\boldsymbol{p_1}\boldsymbol{q_*} \leq \boldsymbol{p_1}\boldsymbol{q_1}$, which implies $P_N(\boldsymbol{q_1},\boldsymbol{\varphi_1},\boldsymbol{\varphi_2},\boldsymbol{p_1},\boldsymbol{p_1}) \leq 1$. A pure taste change reduces the cost of living and, therefore, we expect that the standard approach to inflation measurement that does not account for varying tastes, will be upward biased.

In the remaining part of the chapter we will proceed as follows. We derive and empirically estimate the taste-adjusted cost-of-living index for a nested Cobb-Douglas-CES utility framework. To do so, we first solve the consumer optimization problem for nested CES preferences, derive the price index formulae introduced formally in the this section, then solve the firm optimal pricing decision, discuss the structural estimation of the parameters and then present the empirical results.

2.2.3 The consumer problem

We assume that consumers have homogeneous preferences and can be described by a representative consumer that derives utility from a nested constant elasticity of substitution utility. As a typical consumption basket includes products from multiple product groups, and consumers prefer to consume many product varieties within a product group, a nested utility structure provides a natural approach to model observed purchasing patterns. At the upper level the representative consumer maximizes a Cobb-Douglas utility function over product groups. At the lower level, the representative consumer maximizes a constant elasticity of substitution (CES) utility function over product varieties within a product group. Our modeling choice for the utility function is motivated by both theoretical considerations and empirical tractability. We employ a Cobb-Douglas utility function at the upper level because the data used later in the empirical estimation reveal relatively constant product group expenditure shares over time. The CES functional form that we apply at the lower level is widely used in quantitative economic analysis and is a prominent tool to characterise production in growth models and preferences in international trade models. It is also a standard choice for modeling aggregate consumption over a large number of goods. Further, the consensus in the literature on price index theory is that the price index formula derived from this framework could be of practical use for index calculation to statistical agencies. Its empirical application is however still limited. We will exploit that the CES allows for flexible substitution patterns. In particular, for our analysis it will be relevant that with the CES utility function, the elasticity of substitution among varieties within one product group may vary across product groups.

Formally, consumer utility at any time t, U_t, is a Cobb-Douglas aggregate of CES sub-utilities

U_{gt} of product groups $g \in G$.

$$U_t = \prod_{g \in G} U_{gt}^{\alpha_g} \;\; with \;\; \sum_{g \in G} \alpha_g = 1 \tag{2.12}$$

$$U_{gt} = \Big(\sum_{i \in I_g} (\varphi_{igt} c_{igt})^{\frac{\sigma_g - 1}{\sigma_g}} \Big)^{\frac{\sigma_g}{\sigma_g - 1}} \tag{2.13}$$

where c_{igt} is consumption of variety i in product group g at time t, and I_g is the set of all varieties in product group g and σ_g is the elasticity of substitution which can vary across product groups. Importantly, the parameters φ_{igt} capture consumer taste (or subjective quality as experienced by the consumer) for variety i in product group g. The taste parameters may vary across verieties and over time.

Taste changes defined here are changes in the experienced utility of the consumer of an item whose characteristics remain unaltered. We focus on the traditional one period framework of the cost-of-living index and random, exogeneous taste changes. Our discussion on varying tastes is closely related to two other mechanisms, the quality bias and habit formation[7]. Quality change is well defined in the price index literature (Feenstra, 1994). It generally coincides with the introduction of new varieties of a product or in product changes and alters some measurable attributes of a product. Changes in quality affect market shares such that when varieties tend to experience an increase in their quality, the measured price index will be upward biased (White, 1999). Another mechanism is presented in Atkin (2013), where due to endogeneous taste changes the measured price change underestimates the perceived price increase when due to habit formation consumers prefer to consume cheaper varieties.

Utility maximization (or expenditure minimization) of the consumer implies the following demand for variety i in product group g (see Appendix B.1.1):

$$c_{igt} = \varphi_{igt}^{\sigma_g - 1} p_{igt}^{-\sigma_g} P_{gt}^{\sigma_g - 1} E_{gt} \tag{2.14}$$

where p_{igt} is the price of variety i and P_{gt} is the CES price aggregate for product group g:

$$P_{gt} = P_g(\boldsymbol{p_{gt}}, \boldsymbol{\varphi_{gt}}) = \Big(\sum_{i \in I_g} \Big(\frac{p_{igt}}{\varphi_{igt}} \Big)^{1-\sigma_g} \Big)^{\frac{1}{1-\sigma_g}} \tag{2.15}$$

[7]Numerous papers proposed an extension of the one-period framework to a multi period framework (Pollack, 1975; Philips and Spinnewyn, 1984) to examine questions that typically make more sense in a multi period horizon. This line of research is related to endogeneous changes in tastes through habit formation. In these models past consumption influences the marginal utility of future consumption and thereby future tastes. This framework has been proposed to study alternatives to the assumption that consumers maximize time-separable and time-invariant utility and models directly the relationship between past and future consumption.

and $\boldsymbol{p_{gt}}$ is the price vector of items in product group g, $\boldsymbol{\varphi_{gt}}$ is the taste vector of items in product group g and E_{gt} is total expenditure on product group g. From the demand equation (2.14) it is clear that holding prices fixed, a higher taste for item i raises its demand. As the subutility U_{gt} of each product group is a CES aggregate, it is well known that its exact price index is a Sato-Vartia aggregate (see Vartia, 1976; Sato, 1976, and the derivation in Appendix B.3.2). We have for product group g,

$$\frac{P_{gt}}{P_{gt-1}} = \prod_{i \in I_g} \left(\frac{p_{igt}}{p_{igt-1}}\right)^{w_{igt}} \left(\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)^{w_{igt}} \tag{2.16}$$

and log-change weights w_{igt} which are defined as,

$$w_{igt} = \frac{f(s_{igt}, s_{igt-1})}{\sum_{i \in I_g} f(s_{igt}, s_{igt-1})} \tag{2.17}$$

with $s_{igt} = \frac{p_{igt}c_{igt}}{E_{gt}}$ the share of expenditure of item i in product group g, and applying the log-change function[8] $f(y,x) = \frac{y-x}{\ln y - \ln x}$ Importantly, under the assumption of varying tastes, the exact price index of product group g will vary, not only with prices, but also with variations in taste over time. We will refer to the ratio $\frac{\varphi_{igt-1}}{\varphi_{igt}}$ as relative taste shocks. Equation (2.16) defines the taste shock adjusted Sato-Vartia price index. It is equal to the standard Sato-Vartia index multiplied by a weighted average of taste shocks.

In Appendix B.3.4 we show that the taste shocks of individual varieties can be written as a function of prices, expenditure shares and the elasticity of substitution:

$$\frac{\varphi_{igt-1}}{\varphi_{igt}} = \left(\frac{p_{igt-1}}{\prod p_{igt-1}^{\frac{1}{N_g}}} \left(\frac{s_{igt-1}}{\prod s_{it-1}^{\frac{1}{N_g}}} \right)^{-\frac{1}{1-\sigma_g}} \right) \left(\frac{p_{igt}}{\prod p_{igt}^{\frac{1}{N_g}}} \left(\frac{s_{igt}}{\prod s_{it}^{\frac{1}{N_g}}} \right)^{-\frac{1}{1-\sigma_g}} \right)^{-1} \tag{2.18}$$

where N_g is the number of varieties in product group g. Where prices and expenditure shares are observed, the elasticity of substitution is not. Measuring therefore the impact of taste shocks on our exact price index requires us to obtain an estimate of the elasticity of substitution for every product group.

Consider the case when conditional on prices being fixed, tastes would increase (decrease) unanimously by the same factor for all varieties. These general taste changes have no implications for the observed purchasing behaviour of consumers (expenditures are unchanged) but potentially affect the measured price change, as it is evident from equation (2.16). Therefore, we need to rule out the possibility of a measured non-zero price change when all taste parameters change by the same factor. To do so, we shut down this channel in the model. We use the property of the CES utility function, that the CES unit expenditure function is homogeneous of degree -1 in tastes and

[8] For $y = x$ the log change function takes the form $f(x,x) = x$

apply the normalization that the geometric mean of taste parameters is constant and equal to 1 for every product group g and any period t. Intuitively, this assumption implies that on average demand shocks cancel out.

$$\prod_{i\in I_g} \varphi_{igt} = 1 \tag{2.19}$$

2.2.4 Price index formulae

This section lays out the results from our derivations in the Appendix and presents the product group level and overall price index results. Appendix B.3.3 derives that the pure price index at the product group level is a Sato-Vartia index:

$$\Gamma_{pgt} = \prod_{i\in I_g} \left(\frac{p_{igt}}{p_{igt-1}}\right)^{w_{igt}} \tag{2.20}$$

The taste change index at the product group level then becomes (for the derivation see Appendix B.3.2):

$$\Gamma_{\varphi gt} = \prod_{i\in I_g} \left(\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)^{w_{igt}} \tag{2.21}$$

The quantity index at the product group level is:

$$\Gamma_{cgt} = \frac{\left(\sum_{i\in I_g} (\varphi_{igt} c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}}}{\left(\sum_{i\in I_g} (\varphi_{igt} c_{igt-1})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}}} \tag{2.22}$$

The overall pure price index is:

$$\Gamma_{pt} = \prod_{g\in G} \left(\prod_{i\in I_g} \left(\frac{p_{igt}}{p_{igt-1}}\right)^{w_{igt}}\right)^{\alpha_g} \tag{2.23}$$

The taste change index at the aggregate level becomes:

$$\Gamma_{\varphi t} = \prod_{g\in G} \left(\prod_{i\in I_g} \left(\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)^{w_{igt}}\right)^{\alpha_g} \tag{2.24}$$

And the quantity index at the aggregate level can be written as:

$$\Gamma_{ct} = \frac{\prod_{g\in G}\left(\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt-1})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}}\right)^{\alpha_g}}{\prod_{g\in G}\left(\left(\sum_{i\in I_g}(\varphi_{igt-1}c_{igt-1})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}}\right)^{\alpha_g}} \tag{2.25}$$

The cost-of-living is then defined, at the product group level as: $\Gamma_{gt} = \Gamma_{pgt}\Gamma_{\varphi gt}\Gamma_{cgt}$ and at the aggregate level as $\Gamma_t = \Gamma_{pt}\Gamma_{\varphi t}\Gamma_{ct}$.

2.2.5 Profit maximization

We assume that each product variety is produced by a one-product firm. Firms within a product group compete in a Bertrand fashion, but firms supplying products belonging to different product groups do not strategically interact with each other. This setup implies that firms will have a non-zero price markup. Firms choose their price to maximize total firm profit. Importantly, price setting implies that firms internalize their impact on the product group price aggregate, P_{gt}, but ignore their impact on the aggregate price of consumption.

Firms' profit maximization problem is formulated in the spirit of Atkeson and Burstein (2008) and contains elements that allow for an analysis of firm heterogeneity as in Hottman et al. (2016), but we will focus on using this framework to derive and estimate a taste-adjusted cost-of-living index.

All firms face a product group specific fixed market entry cost, H_{gt}, which implies that only most productive firms can enter the market (Melitz, 2003). Further, firms are heterogeneous in terms that they face different variable costs, V_{igt} and therefore will be different in their producer prices.

$$V_{igt}(c_{igt}) = z_{igt}c_{igt}^{1+\delta_g} \tag{2.26}$$

where z_{igt} is a firm specific cost shifter and δ_g is the elasticity of the marginal cost with respect to output, which we assume is the same for each firm within a product group. Then the producer's profit maximization problem is:

$$\Pi_{igt} = p_{igt}c_{igt} - V_{igt}(c_{igt}) - H_{gt} \tag{2.27}$$

where in equilibrium supply of item i has to equal its demand:

$$c_{igt} = \varphi_{igt}^{\sigma_g-1}p_{igt}^{-\sigma_g}P_{gt}^{\sigma_g-1}E_{gt} \tag{2.28}$$

The first order condition of the profit maximization problem is:

$$\frac{\partial \Pi_{igt}}{\partial p_{igt}} = 0$$

Solving the above first order condition, we get the following expression for the supply curve for item i (for the derivation see Appendix B.2):

$$p_{igt} = \mu_{igt} z_{igt} (1+\delta_g) c_{igt}^{\delta_g} \tag{2.29}$$

where $z_{igt}(1+\delta_g)c_{igt}^{\delta_g}$ is the marginal cost and μ_{igt} is the price markup:

$$\mu_{igt} = \frac{-\sigma_g + (\sigma_g - 1)\varepsilon_{igt}}{(\sigma_g - 1)(\varepsilon_{igt} - 1)} \tag{2.30}$$

ε_{igt} denotes the elasticity of the product group price aggregate with respect to the firm price for item i and is equal to the expenditure share of item i in product group g, s_{igt} (for the derivation, see Appendix B.1.2, in particular, equations (B.28) and (B.30)). As in Atkeson and Burstein (2008), the firm markup is increasing in the firm's product group expenditure share. For an equilibrium price, p_{igt}, to exist, we assume that σ_g is different from 1 (and ε_{igt} is different from 1). Intuitively, this assumption requires that no firm is a monopoly producer in its product group.

2.2.6 Structural estimation

The goal of this subsection is to construct estimates for the model parameters needed to empirically estimate a taste-adjusted cost-of-living index, which depends on the product group level elasticity of substitution between varieties in a product group and tastes, none of which are observed. The estimation procedure follows closely the identification strategy presented in Feenstra (1994) and Broda and Weinstein (2006, 2010) and involves the following steps. First, we show in Appendix B.3.4 that the relative taste change for item i, $\frac{\varphi_{igt-1}}{\varphi_{igt}}$ can be expressed as a function of item prices, p_{igt}, item level expenditure shares, s_{igt}, and the elasticity of substitution, σ_g. Since we observe prices and quantities, we are able to calculate expenditure shares. Therefore, the only unobserved parameter remaining is the elasticity of substitution. As a second step, we estimate σ_g. To estimate the elasticity of substitution we rely on the item level demand and supply equations. To address endogeneity concerns, we will transform these by taking first a time difference and then a difference relative to a reference item. Further, we impose standard identifying assumptions on the double-differenced values of demand and cost shifters. Finally, we use the estimated elasticities, price observations and expenditure shares to calculate relative taste changes which we will then plug in to the derived price index formulae.

To derive the transformed demand equation, our starting point is the item level expenditure share from equation (B.27) and firm level pricing rule from equation (B.49) (see derivation in Appendix B.1.2 and B.2).

$$s_{igt} = \frac{\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{1-\sigma_g}}{P_{gt}^{1-\sigma_g}} \tag{2.31}$$

As a first step, we take the natural logarithm of both sides of equation (2.31) and then take a first difference in time, i.e. $\Delta^t \ln s_{igt} = \ln s_{igt} - \ln s_{igt-1}$. Next, we take the difference relative to a reference item, which we define as the item having the largest expenditure share within the product group over the whole observation period. Formally:

$$\ln s_{igt} = (1-\sigma_g)\ln p_{igt} - (1-\sigma_g)\ln \varphi_{igt} + (\sigma_g - 1)\ln P_{gt} \tag{2.32}$$

$$\Delta^{k,t} \ln s_{igt} = (1-\sigma_g)\Delta^{k,t} \ln p_{igt} + (\sigma_g - 1)\Delta^{k,t} \ln \varphi_{igt} \tag{2.33}$$

$$\Delta^{k,t} \ln s_{igt} = (1-\sigma_g)\Delta^{k,t} \ln p_{igt} + \omega_{igt} \tag{2.34}$$

with $\omega_{igt} = (\sigma_g - 1)\Delta^{k,t} \ln \varphi_{igt}$ represents a demand shock that may shift the demand for item i but not the demand of other items and $\Delta^{k,t}$ is the double-difference operator and defines $\Delta^{k,t} \ln s_{igt} = \Delta^t \ln s_{igt} - \Delta^t \ln s_{kgt}$. Equation (2.34) defines relative demand. Our parameter of interest is σ_g, however, due to simultaneity, a simple regression estimation of the above relationship would potentially lead to inconsistent estimates for σ_g. Therefore, we also rely on the information contained in firms' pricing rule. As a next step, we take the pricing rule from equation (2.29) and substitute for the marginal cost. Here we use the following equality between demand, prices and shares $c_{igt}^{\delta_g} = \frac{s_{igt}}{p_{igt}}$. Then we double difference the natural logarithm of the expression obtained in the previous step, both in time and relative to the largest item within the product group. Thus we derive an expression for the relative item supply (see Appendix B.2 for a detailed derivation).

$$\Delta^{k,t} \ln p_{igt} = \frac{\delta_g}{1+\delta_g}\Delta^{k,t} \ln s_{igt} + \kappa_{igt} \tag{2.35}$$

with κ_{igt} is the supply shock that may shift supply for item i relative to other items. Our identifying assumption is that the within-product group demand and supply shocks are orthogonal, i.e. $E_t(\omega_{igt}\kappa_{igt}) = 0$. Following (Feenstra, 1994) and (Broda and Weinstein, 2006), we define moment conditions for each item within a product group and apply the generalized method of moments to estimate the elasticities. $G(\beta_g)$ defines our set of moment conditions:

$$G(\beta_g) = E_t\left(\boldsymbol{\omega_{gt}}\boldsymbol{\kappa_{gt}}\right) = 0 \tag{2.36}$$

where $\beta_g = \binom{\sigma_g}{\delta_{gt}}$. We stack the moment conditions for all varieties within a product group to form a GMM objective function:

$$\hat{\beta}_g = \underset{\beta_g}{\operatorname{argmin}}\, G^{\star}(\beta_g)' W G^{\star}(\beta_g)\ \forall g \tag{2.37}$$

where W is a positive definite weighting matrix.

2.3 Data

To construct our exact cost-of-living index, we use a large scanner dataset provided by the marketing research firm AC Nielsen. The dataset is multidimensional, and our sample contains monthly[9]. price and quantity information for 10 euro area countries (Austria, Belgium, Germany, Spain, France Greece, Ireland, Italy, Netherlands and Portugal), 45 product categories[10] over the two year period of 2009-2010. Data collection at the most disaggregated level occurs at the country, region[11], product, brand, pack size and store type level. AC Nielsen defines 4 brands within each product group and within each brand 3 pack sizes. In every country and product group, brands are selected to cover two pan-European brands and the two most popular local brands. The product group, brand, pack size combination defines a stock keeping unit (SKU's), to which we will refer to as variety or item[12]. An SKU is uniquely identified by its 12-digit numerical Universal Product Code (UPC)[13].

An important dimension for our analysis is the store type level information. Store type categories are constructed using information on the physical size of the store, and other information like the local market structure and turnover share. Based on size (the store's sales area in square metres), the following categories are defined: hypermarkets (more than 2500 square metres); large supermarkets (1000-2500 square metres); small supermarkets (400-1000 square metres); superettes (100-400 square metres); groceries (traditional stores or groceries with less than 100 square metres). Additionally, the following shop types were defined: convenience stores or petrol stations;

[9]The data frequency in the original data from AC Nielsen was in some cases different across countries in the sample. This was later harmonized to monthly frequency. The steps taken for this data manipulation are detailed in Meyler (2013).

[10]The product categories covered by the dataset are the following: babyfood; laundry detergent; beer; margarine; bouillon; milk, refrigerated; butter; milk, ultra-high-temperature; cat food; olive oil; cereals; panty liners; chewing gum; paper towels ; chocolate; pasta, dry; cigarettes; peas, frozen; cleaners (all purpose); peas, tinned; coffee, ground; Rice; coffee, instant; shampoo; condoms; shave preps; carbonated soft drinks; soups, wet; deodorant; sugar; diapers; toiletpaper; dishwasher tablet; toothpaste; dog food; tuna, tinned; fabric softener; vodka; fish, frozen; water, sparkling; ice cream; water, still; jam, strawberry; whiskey; juice,100%; fruit.

[11]For our analysis we do not exploit the regional dimension.

[12]Examples for varieties include: all purpose cleaners, Mister proper 1 liter and 1 liter Dreyer vanilla ice cream. And we assume that the substitution elasticities within "all purpose cleaner" and within "ice cream" might be different.

[13]Even minor changes, such as in packaging, lead producers to introduce a different UPC, mainly for stocking and bookkeeping reasons.

and drug stores; discounters; kiosks; tobacco stores and alcohol stores. Not all store types are available in every country. The data provided by AC Nielsen are described in more detail in (Ciapanna and Rondinelli, 2014; Reiff and Rumler, 2014).

In our empirical estimation we use 331 country-product group pairs (i.e. ice cream in Austria is a different group but from ice cream in The Netherlands) and 15844 country, store type, SKU combinations.

2.4 Results

2.4.1 Elasticity of substitution

Using the estimation strategy discussed above, we estimate elasticity of substitution parameters, σ_g, for 331 product groups. Table 2.1 shows the distribution of the estimated 331 elasticity of substitution parameters. The results show that varieties within product groups are imperfect substitutes, moreover, high degree of consumer substitution takes place within most of the product groups studied, and that there is large variation in the elasticity of substitution between product groups.

Across product groups σ_g ranges from 2.3 at the 5th percentile to 28 at the 95th percentile, with a median elasticity of 4.1. This can be interpreted that at the median a one percent price increase of a particular item causes the sales of that item to drop by 4.1%. To assess how our results compare to similar estimates in the literature, ideally we would like to consider studies that used similar datasets, possibly for the same countries. However, the set of such studies is limited. One exception is the paper by Hottman et al. (2016) who use the Nielsen HomeScan database for the US to estimate elasticity of substitution both within and between multiproduct firms for the same product group. Because our model assumes that each firm produces a single variety, we compare our estimates to their results for the between firm elasticity of substitution. The median estimate obtained in Hottman et al. (2016) is 3.9 which is very close to our estimate of 4.1. The estimated range for σ_f in Hottman et al. (2016), which lies between 2.6 at the 10th percentile and 7.3 at the 90th percentile also resembles our estimates, 2.5 at the 10th percentile and 14 at the 90th percentile.

The choice of the function to model consumers' utility has important consequences for our estimates. The larger the substitution taking place between individual items, the more sensitive is the price index to relative price changes. The Cobb-Douglas utility function is the limit case of the CES function when $\sigma \rightarrow 1$, and it is the Jevons index (geometric Laspeyres price index) that derives from the Cobb-Douglas utility function. In the other limit case, the CES utility becomes the Leontief utility function when $\sigma \rightarrow 0$. In the latter case the price index that derives from the Leontief utility function is the Laspeyres price index. It is therefore interesting to test whether the assumption underlying the CES utility function $\sigma_g > 0, \sigma_g \neq 1$ is an accurate description of consumers' substitution patterns. Therefore, we test the null hypothesis $H_0 : \sigma_g = 0$. Using a

Table 2.1: Distribution of the elasticity of substitution, σ_g

Percentile	σ_g
p1	2.0
p5	2.3
p10	2.5
p25	3.1
p50	4.1
p75	6.3
p90	14
p95	28
p99	152

standard t-test and a critical value of 1.96, for the majority of the cases the elasticity parameter is significantly different from 0, and the null could not be rejected for 44 product groups from a total of 331.

2.4.2 Product group price indexes

In this section we analyze different product group price indices. We pool the annual inflation estimates of 331 product groups to show the across product group distribution of annual inflation. We compare the inflation measured by our cost-of-living index Γ_{gt} which allows for taste changes with four traditional price indexes that abstract from taste variation: the Sato-Vartia index ($\Gamma_{Sato-Vartia,gt}$), the Jevons index ($\Gamma_{Jevons,gt}$), the Fisher index ($\Gamma_{Fisher,gt}$) and the Laspeyres index ($\Gamma_{Laspeyres,gt}$). The distribution of inflation measured by the different indexes is given in Table 2.2.

Table 2.2: Product group level price index (y-on-y change in percentages)

Index	**min**	**p10**	**p25**	**p50**	**p75**	**p90**	**max**	**mean**	**sd**
Γ_{gt}	-43.4	-9.4	-4.8	-1.8	0.5	3.2	41.2	-2.4	6.3
$\Gamma_{Sato-Vartia,gt}$	-28.8	-7.1	-3.4	-0.9	1.2	4.0	41.5	-1.1	5.6
$\Gamma_{Jevons,gt}$	-24.0	-5.8	-2.8	-0.6	1.3	3.6	42.8	-0.7	4.8
$\Gamma_{Fisher,gt}$	-28.9	-7.1	-3.4	-0.9	1.2	4.0	41.5	-1.1	5.6
$\Gamma_{Laspeyres,gt}$	-27.0	-6.3	-2.9	-0.6	1.6	4.5	41.8	-0.5	5.6

There is a wide dispersion of inflation across product groups for all indexes. This is not surprising. Product groups are very narrowly defined and inflation can therefore be both largely negative or positive. We make the following observations. First, the distribution of the Sato-Vartia index and the Fisher index are very similar. Second, the mean product group inflation measured by the Laspeyres index is around 0.6 percentage points higher than the mean of the Fisher index, attesting to the upward substitution bias of the Laspeyres index. However, most noteworthy is the Γ_{gt} index which allows for taste changes. Inflation measured at the product group level is on average 1.3 percentage points lower than the Fisher index. As indicated in our theoretical discussion, taste changes tend to lower measured inflation rates.

Next, we are interested in the divergence between the inflation measured by various indexes and a superlative index. Table 2.3 shows summary statistics for the product group level difference between selected indexes and the Fisher index. We find that the difference between the Fisher index and the Sato-Vartia index is on average zero with a standard deviation of 0.4 percentage points. This variation is mostly attributable to a few outlier product groups, as our results show that for 50 percent of the product groups the difference is very small, between -0.02 and 0.01 percentage points. The Jevons and Laspeyres indexes are clearly upward biased relative to the Fisher index and, more importantly, the taste-adjusted Sato-Vartia index is on average 1.3 percentage points lower than the Fisher index, with a relatively large standard deviation of 3 percentage points. These results indicate that depending on the product group, taste changes can introduce a substantial deviation to the measured change in the price level compared to traditional price indexes.

Finally, we report the difference between inflation measured by the taste-adjusted and non-adjusted Sato-Vartia price index, which effectively captures the percentage change in the cost-of-living purely due to taste shifts, i.e. quantifies the effect of taste shocks. We find that the median effect is -0.4 percentage points, the mean effect is -1.3 percentage points with a standard deviation of 2.9 percentage points (again this is due to a few outlier product groups, for 50 percent of the product groups taste changes reduce cost-of-living between 1.2 and 0.1 percentage points).

Table 2.3: Difference between Fisher and selected indexes

Variable	**min**	**p10**	**p25**	**p50**	**p75**	**p90**	**max**	**mean**	**sd**
$\Gamma_{Fisher,gt} - \Gamma_{gt}$	-4.1	0.0	0.1	0.4	1.2	3.0	46.8	1.3	3.0
$\Gamma_{Fisher,gt} - \Gamma_{Sato-Vartia,gt}$	-6.7	-0.09	-0.02	0.0	0.01	0.07	5.8	0.0	0.4
$\Gamma_{Fisher,gt} - \Gamma_{Jevons,gt}$	-18.81	-3.3	-1.5	-0.2	0.9	2.3	21.6	-0.4	2.9
$\Gamma_{Fisher,gt} - \Gamma_{Laspeyres,gt}$	-19.5	-1.5	-0.7	-0.3	-0.05	0.04	12.3	-0.5	1.2

Note: Results are shown in percentage points.

Table 2.4: Summary statistics for the difference between the taste-adjusted and non-adjusted Sato-Vartia price index

Variable	**min**	**p10**	**p25**	**p50**	**p75**	**p90**	**max**	**mean**	**sd**
$\Gamma_{Sato-Vartia,gt}$ - Γ_{gt}	-42.0	-3.1	-1.2	-0.4	-0.1	0.0	2.2	-1.3	2.9

Note: Results are shown in percentage points.

2.4.3 Country level aggregate price indexes

In this section we present aggregate, country level results. Country level indexes are constructed by aggregating across product group price indexes. This aggregation is performed for all 10 countries in our sample. Results are shown in Table 2.5 that reports both the taste-adjusted Sato-Vartia index (Γ_t) and the standard non-adjusted Sato-Vartia index ($\Gamma_{Sato-Vartia,t}$) at the aggregate level. We report the distribution of annual inflation rates calculated for all 12 months over the year 2010. We find that upon aggregation, the national cost-of-living indexes measured by the taste-adjusted Sato-Vartia index and the Sato-Vartia index are similarly volatile. More importantly, for all 10 countries, the average rate of measured inflation is lower for the taste-adjusted Sato-Vartia index than for the Sato-Vartia index. These results confirm empirically our theoretical arguments described earlier in this chapter. Pure taste changes lower the cost of living and we find that the average reduction across countries in the inflation rate when allowing for taste changes is 1.1 percentage points.

Table 2.5: National cost-of-living indexes

Country	**Index**	**min**	**mean**	**max**	**sd**
AT	Γ_t	-3.6	-2.4	-1.4	0.8
	$\Gamma_{Sato-Vartia,t}$	-2.0	-1.1	-0.2	0.7
BE	Γ_t	-2.1	-1.0	-0.4	0.5
	$\Gamma_{Sato-Vartia,t}$	-1.7	-0.5	0.1	0.5
DE	Γ_t	-3.8	-2.1	0.2	1.3
	$\Gamma_{Sato-Vartia,t}$	-2.7	-1.0	1.1	1.3
ES	Γ_t	-3.2	-2.4	-1.2	0.7
	$\Gamma_{Sato-Vartia,t}$	-2.0	-1.2	-0.2	0.6
FR	Γ_t	-0.9	0.1	1.3	0.8
	$\Gamma_{Sato-Vartia,t}$	-0.6	0.5	1.7	0.8
GR	Γ_t	-5.4	-1.1	1.0	1.9
	$\Gamma_{Sato-Vartia,t}$	-4.6	-0.2	1.8	2.0
IE	Γ_t	-10.5	-7.6	-3.5	2.3
	$\Gamma_{Sato-Vartia,t}$	-9.1	-6.6	-2.4	2.3
IT	Γ_t	-3.5	-2.6	-1.5	0.6
	$\Gamma_{Sato-Vartia,t}$	-2.9	-2.0	-1.1	0.6
NL	Γ_t	-3.1	-0.3	1.5	1.7
	$\Gamma_{Sato-Vartia,t}$	-2.1	0.4	2.0	1.5
PT	Γ_t	0.0	1.1	1.8	0.5
	$\Gamma_{Sato-Vartia,t}$	1.1	2.2	2.9	0.5

Note: Results are shown in percentage points.

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2.5 Conclusions

We have shown empirically that introducing preference shifts in a nested Cobb-Douglas-CES utility framework has important implications for cost-of-living measurement. The proposed theoretical cost-of-living index under CES preferences is a taste-adjusted Sato-Vartia index. Although the theoretical discussion of taste changes in the theory of price indexes goes back at least as far as Fisher and Shell (1972), actual practice of inflation measurement has lagged behind. This can be partly attributed to the data requirements for estimating a theoretically consistent cost-of-living index, such as the taste-adjusted Sato-Vartia index, as it requires price and quantity information for a broad set of products.

However, the data requirements are fulfilled in the presence of barcode level data. One can then estimate the elasticity of substitution for a large set of product groups and use prices and market share jointly with the elasticity of substitution to measure the taste parameters of the utility surface of the consumer. This finally leads to a taste-adjusted Sato-Vartia index which can be used to measure cost of living.

Our empirical results are based on a large, multidimensional, barcode level dataset of consumer prices and expenditures across 311 product groups and 10 countries. Comparing a taste-adjusted Sato-Vartia index with the traditional Sato-Vartia index (which is the theoretical cost-of-living index under fixed preferences) leads to an annual inflation that is on average 1.1 percentage points lower. The upward bias of ignoring taste changes can therefore be large and our results point towards an important gap in cost-of-living measurement and a potentially significant source of bias in traditional price indexes.

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CHAPTER 3
A MODEL OF TRADE IN USED DURABLE GOODS

3.1 Introduction

Durable goods are an important component of consumption expenditures and show a strong co-movement with business cycle fluctuations. Since durables together with capital goods represent a significant share of internationally traded goods, volatility in their consumption and production will generate large fluctuations in international trade. Through trade linkages, fluctuations in trade contribute to spreading shocks between trading partners and affect aggregate economic activity in other countries[1]. A prominent example is the Great Recession, where international trade was a key propagation channel for adverse shocks.

Bils and Klenow (1998) show that household consumption of durable goods and income elastic goods are more cyclical than other components of household consumption (see Figure 3.1). Engel and Wang (2011) document that trade in durables represents 70% of exports and imports in OECD countries. Therefore, an unexpected shock will affect almost all trade flows and also cross-border economic activity[2]. Studies on the fluctuations in aggregate economic activity have long recognized the role of durable goods trade but focused on the role of net exports (Engel and Wang, 2011). The large drop in international trade flows during the 2008-2009 global economic slowdown (see Appendix C.1 Figure C.1) has spurred a more general interest in the behaviour of exports and imports during the business cycle. It has been documented that economic downturns are associated with substantial movements in international trade and volatility in exports and imports is significantly larger than that of GDP (Baldwin, 2009; Baldwin and Evenett, 2009; Freund, 2009). With regards to the Great Recession, Eaton et al. (2016) report that the decline in international trade in 2008 was disproportionately large for durable goods and Alessandria et al. (2010) document that the decline in trade was most pronounced in the automobile industry.

The goal of this chapter is to better understand fluctuations in durable goods[3] trade with a special focus on the interaction between the primary and secondary markets for durables. Durable goods are interesting because new goods become old and, as I will show, differences in how house-

[1]Baldwin (2009) for example document that despite the financial sector played a small role for the Japanese economy, it was severely affected by the US financial crisis. US imports from Japan declined by 40% (year-over-year) in the first quarter of 2009 and the Japanese GDP declined by 5.48% in 2009 compared to 2.54% in the US.

[2]Trade is a gross measure while GDP is a value added measure. Essays in Baldwin (2009) argue that this compositional effect helps explain why during the recent global recession world trade experienced a much more pronounced volatility than world GDP.

[3]The US Bureau of Economic Analysis defines durable goods as "Commodities, such as motor vehicles, that are purchased by consumers and are used repeatedly or continuously over a prolonged period."

holds value new relative to older vintages can influence cross-sectional dynamics.

Most important durable goods have an active secondary market (e.g. cars, household appliances, aircraft). This market is often very large. For example, the number of used car transactions is three times larger than the number of new cars sold in a given year in the US (Gavazza et al., 2014) and Germany[4]. Due to durability, buying and selling decisions in the primary (secondary markets) can have a first-order effect on the secondary (primary) market. Gavazza and Lanteri (2018) for example document for the US that the share of households who replaced old vehicles with new ones, among all households who acquired new cars, was around 50% before the financial crisis and declined sharply during the crisis. In the presence of secondary markets, demand for durable goods may change not only because the desired level of stock changes but also because the desired age composition of the stock changes (Oh, 2019). This chapter argues that taking into account the interaction between primary and secondary markets provides a better understanding of fluctuations in international trade. Studies that explicitly consider secondary markets, mainly focus on aggregate dynamics in a domestic context. Gavazza and Lanteri (2018) show how through the interaction between the primary and secondary national car market, negative credit supply shocks can be transmitted between markets, leading to large adjustments in consumer durable goods purchases. Oh (2019) shows that incorporating replacement trade into a business-cycle model with consumer durables improves the model's fit to the data, in particular to the volatility observed in durables spending and helps resolve the "comovement puzzle"[5]. I contribute to this literature by adding an international dimension to the role of secondary markets in generating volatile trade flows. Thus, this chapter connects with the literature that studies volatility in international trade flows (Baldwin, 2009; Engel and Wang, 2011; Petropoulou and Soo, 2011; Eaton et al., 2016).

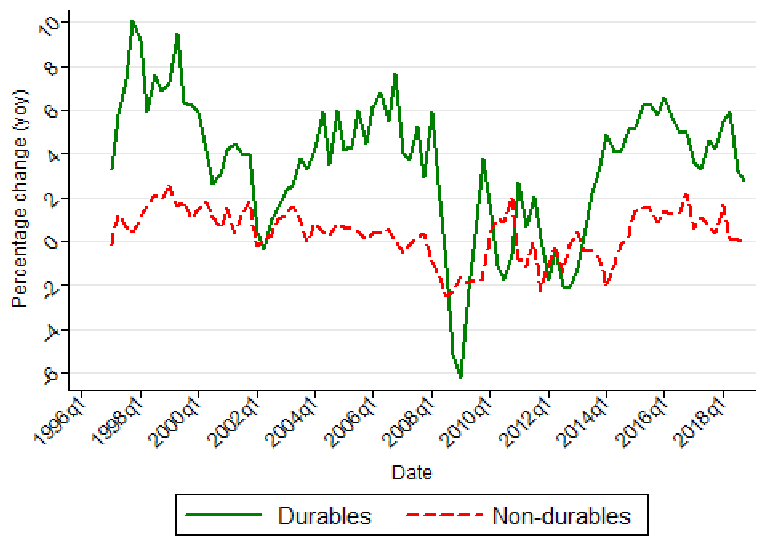
I consider the car market and argue that a substantial share in international trade fluctuations is generated from trade in cars. Further, I report empirical patterns in the European car market and develop a theoretical model which explains how stock adjustments can cause large swings in trade flows. In terms of the patterns documented in the data, a paper closely related to mine is Head and Mayer (2019) who study offshoring in the car industry, when firms relocate the production of home brands the new assembly sites. While the latter paper focuses on the patterns and determinants of offshoring in the car industry and do not account for secondary markets, I am interested in the

[4]Own calculations based on statistics obtained from the website of Kraftfahrt Bundesamt (KBA), Germany. It is important to note that secondary markets only contribute to value added GDP if goods are sold through dealers who operate with non-zero price margins. Oh (2019) documents that US data do not support the standard assumption in the macroeconomics literature that secondary markets have no value-added role when goods are sold back to households. The author reports that the value-added share of the second-hand market in the US is high because the number of used vehicle transactions through dealers is large and finds that the dealers' margins on used cars was above 20% of the total value-added expenditures on automobiles in recent years.

[5]The "comovement puzzle" is from Barsky et al. (2007). The authors conclude that a standard new Keynesian model with durables goods does not generate comovement of durable and nondurable consumption expenditures in response to a monetary shock.

demand side when international secondary markets are allowed. The chapter's second contribution is theoretical. Using a simple two-country general-equilibrium model in which trading partners are allowed to trade in various vintages of the same durable good, the model shows that international secondary markets introduce additional dynamics in international trade fluctuations.

Figure 3.1: Final consumption expenditure durable vs. non-durable in the EU

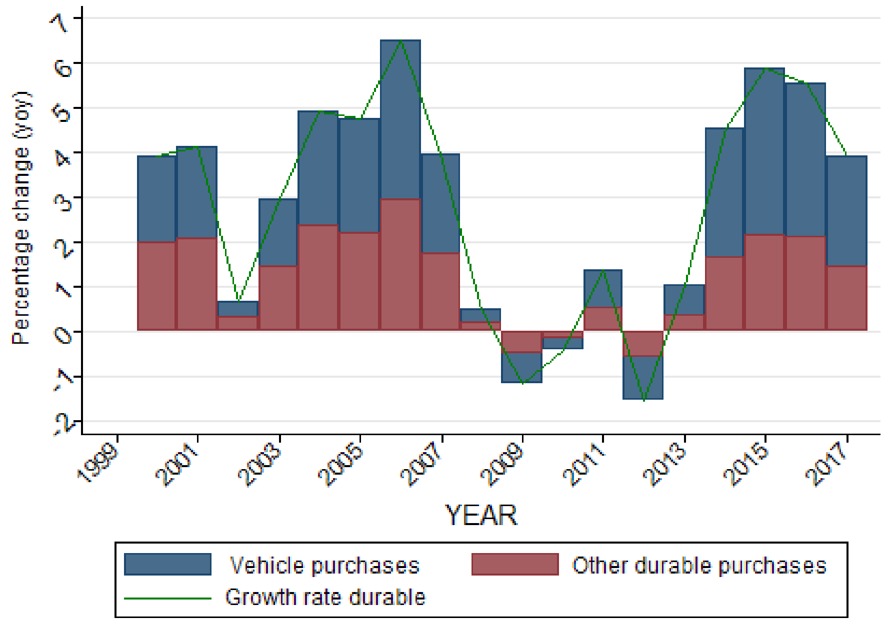


Note: Data on final consumption aggregates for EU countries are from EUROSTAT, the European Commission's official statistical institute.

I focus on international trade in vehicles. However, the key insights from my analysis should apply in general to consumer durables with an active international secondary market. The car market is a natural candidate for such an analysis. Cars can be consumed repeatedly over time, have an active secondary market and are also the most important consumer durables. Further, car sales are the most volatile component of households' durable purchases, and play a significant role in business cycle fluctuations. Figure 3.2 shows that vehicle purchases are pro-cyclical and that changes in durable goods' purchases are in a large part driven by vehicle purchases.

In addition to the work cited above, this paper is also related to the literature on trade in used durables in that it considers what gives rise to international trade in secondhand goods and what are the patterns of trade. The earlier literature focused on gains from trade and trade patterns in secondhand machinery. Several papers conclude that the pattern of trade should be one in which old capital is traded from high-income countries to low-income countries (Sen, 1962; Rust, 1985; Anderson and Ginsburgh, 1994; Schwartz, 1973; Mainwaring, 1986). In these models the pattern of trade relies on cross-country heterogeneity in factor prices. As equipment gets older, it requires higher maintenance costs. It becomes less desirable in high-income countries and more desirable

Figure 3.2: Vehicle purchases' contribution to the change in durable goods consumption in the EU



Note: Data on vehicle purchases, final consumption aggregates for EU countries are from Eurostat, the European Commission's official statistical institute.

in labor-abundant low-income countries where wage rates are lower and interest rates are higher. This argument is extended by other studies that suggest that factors, such as transportation costs, technological factors, skill constraints, and fuel economy standards are also relevant (Gruenspecht, 1982; Navaretti, Soloaga, and Takacs, 2000). Grubel (1980) is the first paper to explore gains from trade in secondhand vehicles. The author concludes that it is lower-income countries that would benefit most from a liberalization of trade in secondhand cars as long as their demand is relatively low compared to the supply of advanced economies and attributes this welfare improvement to the differential depreciate rates of cars between low-income countries and high-income countries. Although there is extensive research on trade in secondhand cars in the national markets, only few studies characterize the international markets for used vehicles. An exception is Clerides (2008). This paper suggests that gains from trade can also arise because international secondary markets broaden the range of product varieties that are available to households. Davis and Kahn (2010) study the environmental consequences of international trade in used vehicles and document large volume of used car exports to Mexico in the immediate aftermath of the deregulation of the US-Mexico trade following NAFTA which they attribute to operating cost differences and income effects.

Trade models with non-homothetic preferences imply similar patterns of trade (Fieler, 2011;

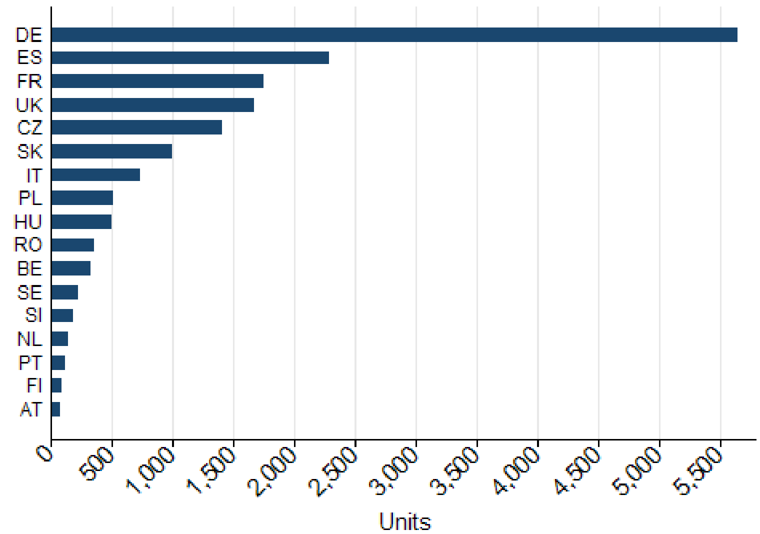
Markusen, 2013; Fajgelbaum and Khandelwal, 2016). With non-homothetic preferences demand for quality increases with per capita income. As newer cars have higher-quality than older ones, rich countries prefer newer cars. As these get older, their quality decreases and will be traded to poor countries where used cars are relatively more desirable.

The paper's contribution is twofold. First, it reports empirical patterns in cross-country trade in new and used cars. To this end, it documents that official trade statistics for the internal EU market will bias downward trade volumes in cars between EU Member States. Second, it develops a two-country general equilibrium model of trade in durable goods vintages, with a focus on cars. In my model the world is populated by two countries and households derive utility from the consumption of the various vintages of cars and other consumption. New cars become older over time and households in the two countries differ in that they have different tastes for new cars versus older vintages. This will imply that the representative household that dislikes older cars relatively less, will shift its consumption toward older cars when free trade is allowed. Countries are both car producers, and car production may grow at a different rate in the two countries[6]. The model predicts that the country with a high growth rate in new car production will have comparative advantage in new cars and becomes a new car exporter. Intuitively, a high growth rate in new car production increases new car supply relatively more than the supply of older vintages increases over time. This will make new cars relatively cheaper. Durability implies that older vintages can not be produced. Therefore, if the current stock is different from the optimally desired one, the only margin of adjustment is trade. In the model, motives for trade arise due to comparative advantages. Trade allows the representative household to adjust the level and age composition of its car stock to its desired level. The model also predicts that a sudden shock to new car production will trigger stock adjustment that will generate large immediate responses in trade flows.

The remainder of the chapter is organized as follows. Subsection 3.2.2 presents the empirical patterns that motivate my analysis. In subsection 3.3 I will state and discuss the model assumptions and this same subsection formulates a model of international trade in new and used durable goods. Subsection 3.4 analyzes the equilibrium of the closed economy. A general discussion about the immediate aftermath of trade liberalization and the long-run free trade equilibrium follows in subsection 3.5, and subsection 3.6 formulates the results for the small open economy equilibrium. Subsection 3.7 present the calibration of the model parameters that have been used in the numerical simulations and subsection 3.8 concludes.

[6]I model how households value used versus new cars. My focus is the demand side and the model is admittedly stylized on the supply side. I model the supply of new cars as an exogeneous endowment process and abstract away from relevant supply side decisions important for the car industry, for example supply chain considerations. For an excellent discussion on this see Sturgeon and Van Biesebroeck (2011)

Figure 3.3: Total passenger car production levels in 2017 (in 1,000 units)



Note: Data on the number of passenger cars produced in EU countries are obtained from the National Association of the Automobile Industry (ANFIA) and International Organization of Motor Vehicle Manufacturers.

3.2 Empirics

In this section I first discuss the data collection and then provide a broad picture of the automobile industry and trade patterns in the new and used passenger car markets for selected EU countries.

The case of the European Union is particularly appealing because it is the world's second largest producer of passenger cars behind China[7], and is characterized by a very active secondary market. To better understand international trade in cars, I will look at nine countries and exploit multiple data sources. My sample includes the Czech Republic, France, Germany, Hungary, Italy, Poland, Spain, Romania and Slovakia and this choice is motivated by three reasons. First, the selected countries are among the most important car producers in the EU (see Figure 3.3) and for each country the automobile industry plays a significant role for the domestic industrial production[8]. Together they cover 83% of the total number of cars manufactured in the EU in 2017. Second,

[7]According to data obtained from the website of the International Organization of Motor Vehicle Manufacturers China is the largest passenger car producer, followed by the EU and Japan.

[8]EU Member States are heterogeneous in terms of their production. Germany is the leading car producer in the EU, with more than 5 million cars manufactured in 2017 (for comparison, the USA produced $3{,}033{,}216$ units in 2017), more than double than that of Spain, that is the second largest car producer in the EU. Countries with an annual production exceeding 1 million units include France, the United Kingdom, the Czech Republic and Slovakia. The rest of the countries in my sample have an annual production of below 1 million units: Italy, Poland, Hungary and Romania. The United Kingdom is excluded from the sample because right-hand-drive cars typically purchased in the UK have only a very limited secondary market in the rest of the European Union.

all countries studied are Member States of the European Union and joined the Single Market at different points in time (the Czech Republic, Hungary, Poland and Slovakia joined the EU in 2004, and Romania in 2007). This allows me to discuss the allocative role of secondary markets in an international context following trade liberalization and adverse economic shocks. Finally, based on their GDP per capita, I can assign these nine countries to two income groups: high income (Germany, France, Spain, Italy) and low income (Romania, Hungary, the Czech Republic, Poland and Slovakia). This classification fits well with the theoretical part of the paper, where I model two countries, a relatively rich and a relatively poorer, that are trading with each other.

I proceed by first describing the data sources for aggregate trade data, and then report the empirical patterns found in cross-border trade between EU countries.

3.2.1 Data

Cross-border trade in Europe was affected by at least two major events in the last 15 years, the EU enlargement in 2004 and 2007 and the Great Recession. While the first represented an opening up to trade[9] and triggered an increase in trade volumes, the Great Recession was characterized by a sharp decline in trade flows. A systematic analysis of trade fluctuations over this period requires reliable data for the internal European market. In this subsection I document that such data are scarce because of a change in reporting requirements for Member States.

The scope of my data collection is limited to passenger cars. Further, the time period covered varies across countries and across statistics within a country. I collect publicly available data on annual country level car production, imports and exports of new and used vehicles, new car registrations, number of re-registrations (ownership changes) and country level overall car stock. The data were sourced from international and national sources and from extensive research of online newspaper articles.

Production data comes from the Italian National Association of the Automobile Industry (ANFIA) and for the most recent years from the International Organization of Motor Vehicle Manufacturers (OICA). Statistics on annual new car registrations are obtained from the French Central Register of Automobiles (Association Auxiliaire de l'Automobile). Note that in some cases countries report new car sales which can diverge from the number of new car registrations if not all new cars sold in a given year are also registered in the same year. New[10] car import and new car export statistics are from Eurostat, which is considered a reliable source of information for statistics referring to new goods[11]. Table 3.1 reports the data sources for the rest of the statistics.

[9] Note that there were active trade relationships between candidate countries and Member States already before joining the EU, but significant trade barriers were still in place.

[10] A car is new for VAT purposes if (a) it has been in use for no more than 6 months or (b) it has been driven for no more than 6000 kilometers when bought.

[11] And also for Extra-EU trade of used goods where customs declarations are still required.

The country-level overall car stock equals the total number of cars registered at the end of a given year. Import as export flows are defined as the total number of (used, new) cars imported from and exported to the rest of the world.

The data show that there is a substantial difference between official statistics on cross-country trade flows and the data based on own data collection. Eurostat, the Statistical Office of the European Commission collects detailed, product level information on the trading of goods between EU Member States and EU Member States and third countries. Disseminated in Eurostat's Comext database, this database serves as the reference point for statistics on import, export and trade balance of the EU. A distinctive feature of this data is that it differentiates between new and used (durable) goods, but the collected statistics underplay the role of international trade in older cars, mostly because they do not reflect trade flows between private persons. A country's EU accession removes customs formalities. This implies significant changes in statistics on trade, where private persons are not required to submit customs declarations anymore and countries can apply a so called reporting threshold for companies engaged in international trade, below which firms are either exempted from reporting or the extent of the information provided is significantly reduced. Table 3.2 shows how this affects data coverage. It compares official statistics and own data collection on used car import volumes and reports the share of used car import based on own data collection that is captured by Eurostat, for six countries and three points in time, one year before the EU accession, in the year of the accession and one year after. The effect of changes in reporting requirements is evident. The picture that emerges is the following. In the last year when customs declarations were still required, official statistics capture at least 46% of the import flows based on own data collection, this figure shrinks to around $2-4\%$ for four countries out of six, with import volumes almost being equal for the Czech Republic in the year after its EU accession. Figure 3.4 illustrates visually the large divergence between official statistics on used car import flows and own data collection for four countries, Romania, Poland, Hungary and the Czech Republic.

Table 3.1: Data sources

Country	Used import	Used export	Car stock	Re-registrations
CZ	Car Importers' Association (SDA)	Car Importers' Association (SDA)	CEBIA	Data reported in newspaper articles
DE	Petropoulou and Soo (2011)	Federal Environment Agency Germany), Umweltbundesamt (UBA)	Kraftfahrt Bundesamt (KBA)	Petropoulou and Soo (2011)
ES	Spanish Association of Automobile and Truck Manufacturers (Anfac)	Direccion General de Tráfico (DGT)	Spanish Association of Automobile and Truck Manufacturers (Anfac)	Spanish Association of Automobile and Truck Manufacturers (Anfac)
HU	Datahouse	Data reported in newspaper articles	Central Statistical Office (KSH)	Data reported in newspaper articles
FR	Petropoulou and Soo (2011)	Difference between deregistration (Petropoulou and Soo, 2011) and scrappage.	Ministère de l'Écologie, du Développement et de l'Aménagement durables	Ministère de l'Écologie, du Développement et de l'Aménagement durables
IT	Automobile Club d'Italia	Automobile Club d'Italia	Automobile Club d'Italia	Automobile Club d'Italia
PL	Central Statistical Office (PZPM)	n.a.	Central Statistical Office (PZPM)	Deported in newspaper articles
RO	Data reported in newspaper articles	Eurostat	Asociatia Producatorilor si Importatorilor de Automobile (APIA)	Data reported in newspaper articles
SK	Ministry of Interior of the Slovak Republic	n.a.	Ministry of Interior of the Slovak Republic	Ministry of Interior of the Slovak Republic

Note: To recover used car exports for Romania, I assume that Romania mainly exports its used cars to non-EU countries. Because the borders of Romania are the external borders of the EU, this is a plausible assumption. French data on re-registrations reflects re-registrations of French brands in a given year.

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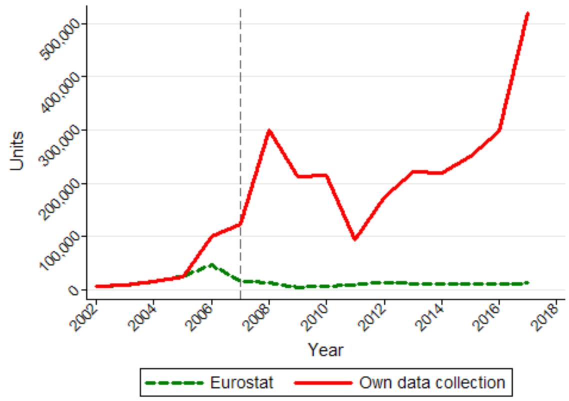
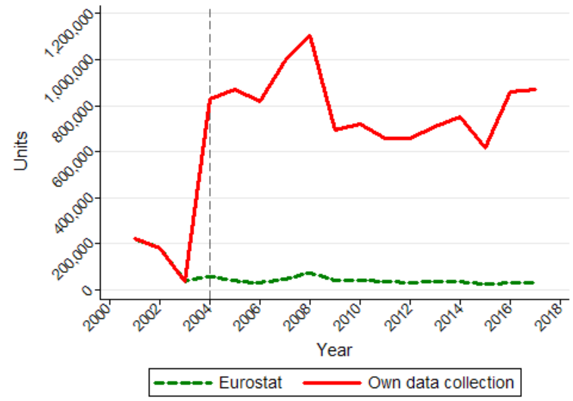
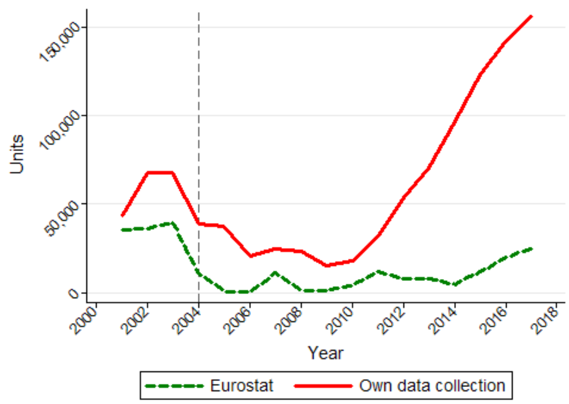
Figure 3.4: Official trade statistics underestimate import volumes in used cars



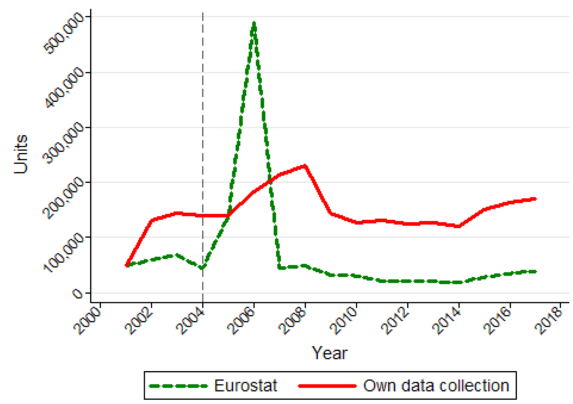
(a) Romania



(b) Poland



(c) Hungary



(d) Czech Republic

Note: Stock information are obtained from Papadimitriou et al. (2013) and the Hungarian Statistical Office. In 2004, just before its EU accession, Hungary introduced a registration tax for cars, that had a market regulatory effect, as it severely impeded the import of older cars. The registration tax was later reduced for older cars, in two stages, first in 2007 and later in 2012. Official statistics from Eurostat show a large spike in used car import volumes for 2006 in the Czech Republic. It could not be determined whether this is due to a measurement or reporting error in the data.

Table 3.2: Bias in Eurostat official statistics

Country	Year before EU accession	Accession year	Year after EU accession
BG	120	32	26
CZ	47	32	99
HU	58	27	2
PL	102	7	4
RO	46	13	4
SK	140	61	3

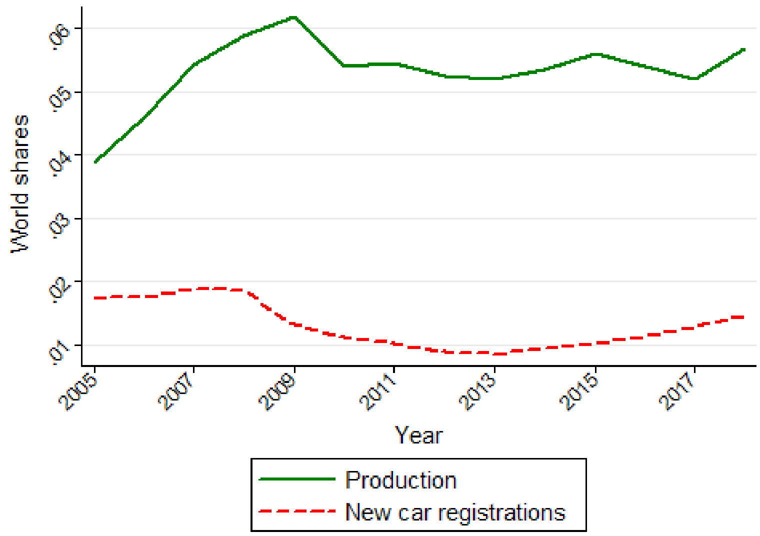
Note: The table shows the share of import trade flows captured by Eurostat compared to my own data collection at three different time periods: one year before the EU accession, the year of the EU accession and one year after the EU accession.

3.2.2 Empirical patterns

I begin by noting that after the EU expansion in 2004 and 2007, lower income new EU Member States play an increasingly relevant role in car manufacturing but a less pronounced one in new car consumption. Their total annual car production grows by 7.97% on average compared to 3.72% for world production[12]. This is illustrated by Figure 3.5 along with new Member States' share in world new car registration. In car-producing countries in the EU a large share of the production is exported. The mean export share for my sample in 2017 was 75% which also constitutes an important share of the overall manufacturing export performance. Haugh and Chatal (2010) study the car industry in OECD countries and estimate that automobile exports represent more than 20% of overall manufacturing exports in the Slovak Republic, Hungary and Spain. In complementary work Head and Mayer (2019) document a flourishing export of foreign brands in Eastern European countries and a rise of offshoring in the car industry between 2000-2016 (the authors find for example, the Tychy factory in Poland produces almost as many Fiat 500 models as the five biggest Fiat plants in Italy).

[12]Calculation is based on new passenger car production data over 2002-2018. Central and Eastern European countries included in the calculation are: Hungary, the Czech Republic, Poland, Slovakia, Slovenia, Latvia, Lithuania and Romania.

Figure 3.5: Producing to export



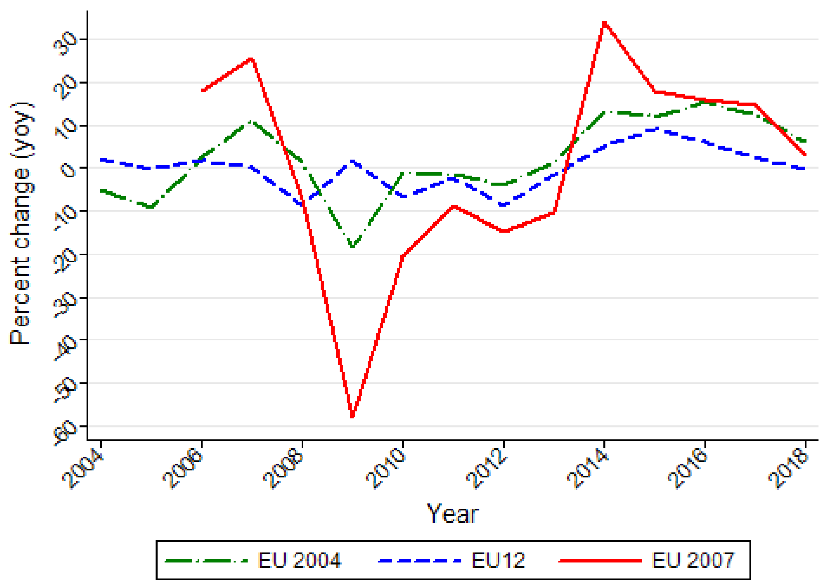
Note: Sample: Hungary, Slovakia, Poland, Latvia, Lithuania, Slovenia, Romania. Bulgaria is also a new Member State but is excluded from the sample as it produces cars since 2012 and it has a very low production level compared to the rest of the countries in the sample. Data on the number of annual passenger car production and annual new car registrations (sales) are obtained from the website of the International Organization of Motor Vehicle Manufacturers and the European Automobile Manufacturers' Association. Graph motivated by Head and Mayer (2019).

New car registrations, new and used car import are highly volatile, new car registrations and new car import are also procyclical. Figure 3.6 shows the evolution of new car registrations between 2004-2018 for three country groups (for further graphs see Figures C.2 and C.3). This period is characterized by the large fluctuations generated by the EU enlargement in 2004 and 2007 and the recession caused by the recent financial crisis. Several countries in the EU experienced a double-dip recession between 2008-2013 and while new car registrations, new and used car import all decreased during the first recession[13], used car import increased over the second recession between 2011-2013. It is also evident that not all countries reacted the same way to the economic downturn. New car registrations dropped sharply in new EU Member States at the end of 2008 and in 2009. The decrease was even more pronounced for the two countries that joined the EU in 2007 and have the lowest GDP per capita among the 28 EU Member States. In comparison, new car registrations grew in richer Western European countries that form the EU12 group between 2008 and 2009. This growth was supported by government actions aimed at stimulating car demand and that took

[13]While used car sales typically went up during economic downturns in the past, Oh (2019) also document for the US that used car sales dropped significantly during the Great Recession.

place in several European countries in 2009 and 2010. There is some evidence that due to the large import share of new car demand, this surge in new car registrations in advanced economies might have benefited car production elsewhere, such as in Poland, the Slovak Republic, France, Italy (Haugh and Chatal, 2010) and the Czech Republic (OECD, 2011). A decrease in demand for new cars may occure during recessions because of a drop in the desired level of stock (purchases are postponable) and due to adjustments in the desired age composition of the car stock (interaction between new and used car market) (Oh, 2019).

Figure 3.6: Annual growth in new passenger car registrations over time



*Note:*Countries that joined the EU in 2004: Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Slovakia, Slovenia; EU12 includes the first 12 Member States of the European Union: BE, DK, DE, EL, ES, FR, IE, IT, LU, NL, AT, PT, FI, SE, UK.Countries that joined the EU in 2007: Romania and Bulgaria.

Import in used cars is characterised by higher volatility than import in new cars. This is shown on Figure 3.7 that plots the year on year percentage change in total annual imports of new and used cars of three countries: Hungary, Poland and the Czech Republic. Figure 3.7a shows the change also around the EU accession and Figure 3.7b zooms in on the period between 2005-2017.

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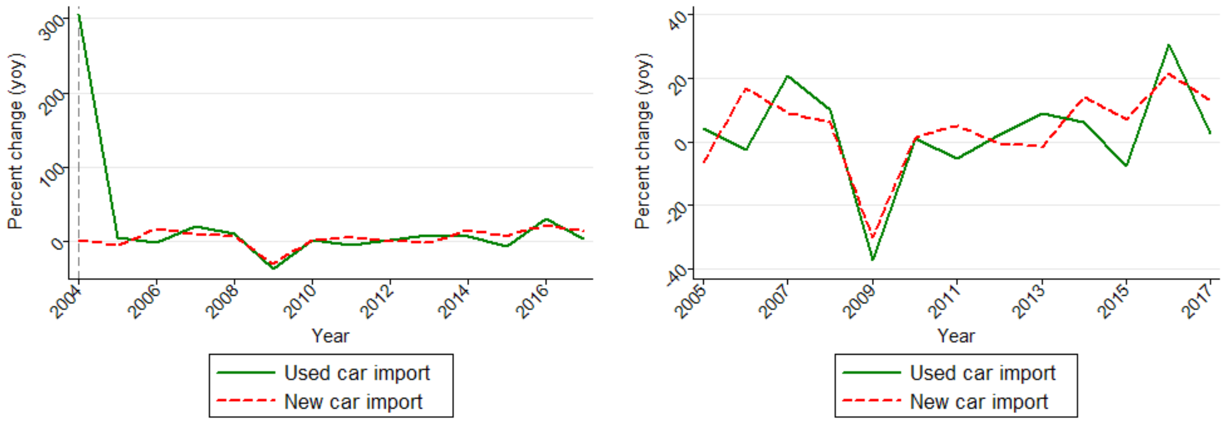
Figure 3.7: Annual growth in new and used car import over time



(a) With the effect of the EU enlargement in 2004 (b) Without the effect of the EU enlargement in 2004

Note: The sample includes: Hungary, Poland and the Czech Republic. Data for new car import volumes are obtained from Eurostat's COMEXT database. Used car import volumes are obtained from government organizations.

New car registrations ultimately determine new car stock in a given year and as cars get older, they will shape the age composition of the future car stock. Figure 3.8 zooms in on Hungary and illustrates the spillover effect of the sudden decline in new car registrations in 2009 on the stock of used cars of various ages since then. Each line in this figure shows the evolution of a car vintage over time. Red lines correspond to vintage 2009 and newer. Green lines correspond to vintages 2008 and older. The plunge in new car registrations between 2008 and 2009 is illustrated by the large wedge at age 0, between the solid green line and the solid red line, corresponding to vintage 2008 and 2009. Further, the graph shows that the large drop in the new car stock in 2009 affects strongly the stock of 1 year old cars in 2010, the stock of 2 year old cars in 2011 and that of older cars later on as well. For example, in 2010 (when the 2009 vintage was 1 year old) the stock of one year old cars is larger than the new car stock in 2009, which is attributable to import flows in 1 year old cars in 2010, but significantly lower than the stock of 1 year old cars in 2009 (solid green line, age 1). Due to the steep decline in new car registrations, certain vintages of popular car models are virtually non-existent in the Hungarian market. By 2014, if a household wanted to buy a 5 year old car, the domestic stock available was around 25% of the stock of 5 year old cars to choose from in 2009. Figure 3.8 reveals that if stocks are not adjusted through the import of used cars, a sudden decrease in new car registrations in a given year, can have a persistent impact on domestic car stock over time.

Access to international secondary car markets and the interaction between the new and used car markets broadens households' options and facilitates adjustment in car consumption during economic booms and busts. A useful measure that quantifies the importance of the used car market,

Figure 3.8: The evolution of car vintages over time in Hungary

Note: Stock information is collected from Papadimitriou et al. (2013) and the Hungarian Statistical Office. Each line shows the evolution of a car vintage over time. The difference between the number of new cars registered in 2009 versus 2008 is illustrated by the distance between vintage 2008 and 2009 at age 0. The difference between the stock of 1 year old cars in 2009 and 2010 is the distance between the two lines at age 1.

is the fraction of used cars in the total annual car registrations[14]. Figure 3.9a plots this share and shows that it is large in every year and especially in recent years. Secondary markets play an important role in the car market in both poorer and wealthier nations, with used cars enjoying a more than 50% share in total annual car registrations following 2004 and a rapid growth in the aftermath of the recent financial crisis[15]. Together with Figure 3.9b it becomes clear that used car import is an increasingly relevant source of used car consumption in poorer countries.

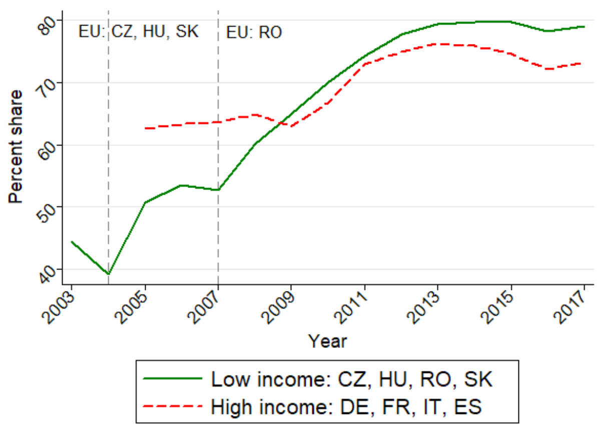
The allocative role of secondary markets is reinforced by domestic policy changes with an effect on households' incentives. Such policy changes may affect the composition of international trade. Further, due to international secondary markets, implications of policy changes will be exported to trading partners and have a spillover effect in these countries. A recent prominent example is the 'Dieselgate' emissions scandal and the ban of Diesel cars from certain German city centers. Anecdotal evidence from the national press suggests that poorer Central and Eastern European

[14]Total annual car registrations is the sum of new car registrations in a given year, number of re-registrations due to ownership changes and used car import

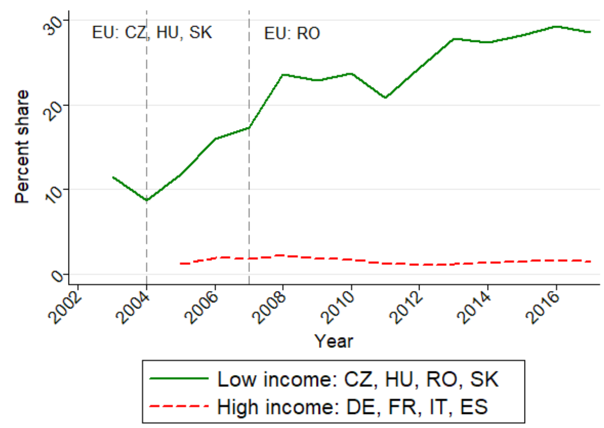
[15]Oh (2019) report that the value-added expenditure share of used vehicles out of total vehicle expenditure is above 25%.

countries soaked up the sudden large supply of used diesel cars when German car owners tried to get rid of their cars affected by the scandal or driving restrictions. Previous studies have mainly emphasized secondary markets' allocative role between poorer and wealthier households in the context of domestic markets (Gavazza et al., 2014). The empirical patterns presented in this section and the theoretical model detailed later in the paper, are suggestive that international secondary markets fulfill a similar role between poorer and wealthier nations as well.

Figure 3.9: Used share in annual car registrations



(a) Used share in total annual car registration

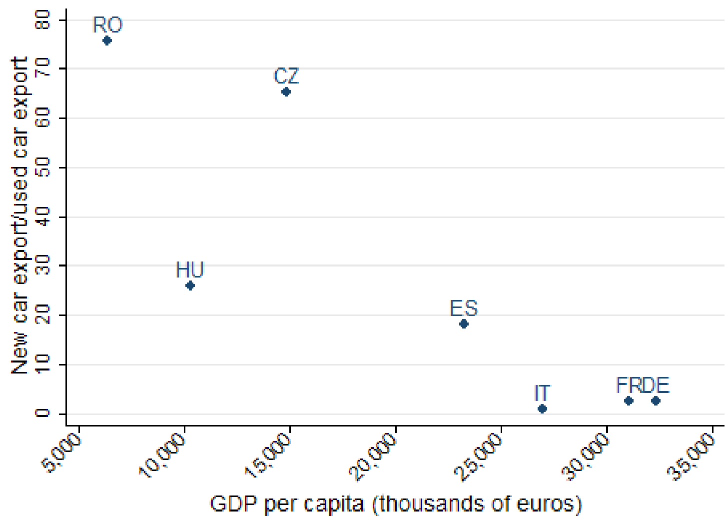


(b) From this imported

Note: Calculations take into account the number of domestic re-registrations. Values are means across countries. Composition changes over time. The period covered for the Czech Republic for this figure is 2012-2017, for Germany 2005-2010, for Spain 2005-2010, for France 2005-2010, for Hungary 2002-2017, for Italy 2010-2017, for Romania 2003-2017, and for Slovakia 2005-2017. Data used are based on own data collection with the exception of the period 2002-2005 for Romania, where information on used car import flows stem from Eurostat's COMEXT database. As this period precedes Romania's EU accession, when customs declarations were still in place, it is considered reliable in this context.

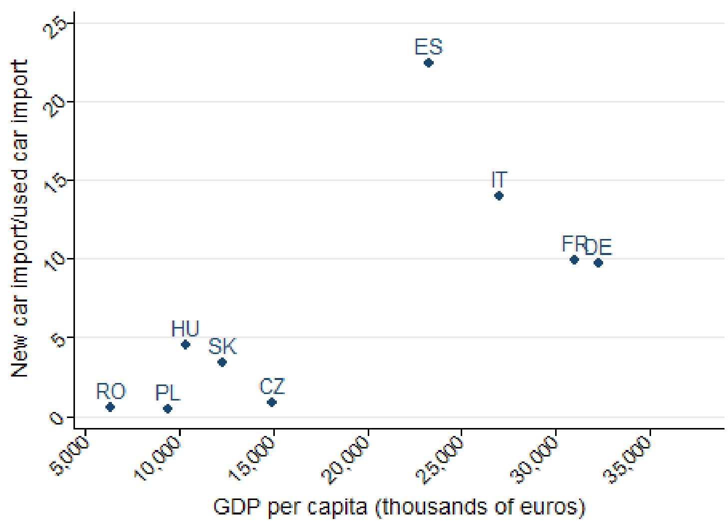
Developing countries in my sample, with a relatively low GDP per capita, typically export significantly more new cars than used cars and import around as much used cars as new cars. High GDP per capita countries on the other hand are large new and used car exporters but import considerably more new cars than used cars. This is illustrated by Figure 3.10 and 3.11, where Figure 3.10 compares the total number of new cars exported with the total number of used cars exported for several countries and shows systematic differences. For example, new car export in Romania is about 80 times higher than its used car export, whereas the same number is around 2 in Germany. Figure 3.11 zooms in on imports and illustrates that older cars have a dominant role in poorer countries' import and used car import is less relevant in richer countries.

Figure 3.10: Number of new cars exported relative to number of used cars exported



Note: GDP per capita is from Eurostat sdg_08_10 dataset. The horizontal axis shows mean values calculated over 2002-2018.

Figure 3.11: Number of new cars imported relative to number of used cars imported



Note: GDP per capita is from Eurostat sdg_08_10 dataset. The horizontal axis shows mean values calculated over 2002-2018.

3.3 Theoretical framework

This section formalizes a model of trade in used durable goods. I consider a world of two countries, Home (H) and Foreign (F). Consumers within a country have identical preferences and can be described by a representative consumer that draws utility from the consumption of all available vintages of a durable good, and the outside good. In what follows, I think of durable goods as being passenger cars. Cars in the representative consumer's choice set are homogeneous in all aspects but their age, denoted by a, and have an infinite lifespan, with $a \in [0, +\infty)$. I will use the term "new cars" to refer to age 0 cars. Income is exogeneous, consumers in country $n = H, F$ receive each period an endowment from new cars and the outside good. I first describe the properties of the equilibrium in the context of a closed economy. Then, trade is introduced and countries can trade freely in all goods. I use this framework to study how durability influences what countries consume when they are characterized by different tastes and growth rates in new car production. Further, I am interested in how these asymmetries affect the volatility in international trade when countries are hit by a major supply shock in the car industry. To study these questions, I construct a parsimonious model of trade that focuses on the demand side.

The representative consumer in country $n = H, F$ has a period utility flow of U_{nt} from the consumption of cars and other consumption. Preferences are described by a Cobb-Douglas utility function over the CES aggregate of car stocks and the outside good. I use the CES functional form to provide a richer characterisation of the demand side and to bring theory closer to the empirically observed data. The age distribution of a country's car stock reveals that households consume a large number of vintages and aggregate car holdings vary across vintages. Pooling together all older cars as used would hide important heterogeneity present in the data. Cars are non-perishable in the sense that they can be stored from one period to the next but consumers only care about the current period utility from owning cars[16].

$$U_{nt} = Q_{nt}^{\alpha} q_{nt}^{1-\alpha} \tag{3.1}$$

$$Q_{nt} = \left(\sum_{a=0}^{\infty} \lambda_{na} C_{nat}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{3.2}$$

with $n = H, F$. θ is the elasticity of substitution, which is the same in the two countries and λ_{na} are taste shifters, constant for a country-vintage pair over time. C_{nat} denotes the total number of cars of age a consumed by the representative consumer at time t in country n and q_{nt} is the per period consumption of the outside good. Intuitively, C_{nat} is the overall stock of age a cars held by households in a country in a given period. Vehicle age can be interpreted as a quality attribute as

[16] I abstract from the dynamic considerations in consumers' purchase decision.

in Gavazza and Lanteri (2018) and λ_{na} as consumers' taste for this attribute. Due to depreciation car quality decreases over time, which makes car maintenance becomes expensive. As a result older cars are less desirable for households. Cars of various vintages become imperfect substitutes. Foreign and Home vehicles of the same age are perfect substitutes. At the beginning of each period t, the representative consumer receives an exogenous endowment E_{nqt} from the outside good and Z_{n0t} from new cars, where Z_{n0t} is the period t new car production and is faced with a car stock S_{nat}, that is the depreciated car stock it owned in $t-1$. Then, consumers decide how many cars to consume C_{nat} for cars of all ages, $a \geq 0$ and from the outside good. The representative consumer can adjust its vintage structure to its desired level, C_{nat} by exporting or importing cars. My focus is not consumers' replacement decision, rather the aggregate market behaviour, and therefore the model features no frictions in the car market. More formally, the following equations define the law of motion:

$$\begin{aligned} q_{nt} &= E_{nqt} - X_{nqt} \\ C_{n0t} &= Z_{n0t} - X_{nat} \\ C_{nat} &= (1-\delta)C_{na-1t-1} - X_{nat} \\ S_{nat} &= (1-\delta)C_{na-1t-1} \end{aligned} \tag{3.3}$$

where δ denotes the rate of depreciation. I do not elaborate on scrapping in this model and assume that depreciation rate is identical in the two countries and age independent. The representative consumer's new car stock at time $t = 0$ is equal to the difference between that period's new car production and net car export, $Q_{n0} = Z_{n0} - X_{n0t}$. The vehicle stock of age a at time t equals the stock of vehicles age $a-1$ from period $t-1$ after depreciation $(1-\delta)S_{na-1t-1}$, minus net export, X_{nat} of vehicles of age a if countries trade with each other. Only new cars can be produced, world supply from new cars is given by that period's total production, and for age $a > 0$ it is determined by period $t-a$ new car production and the depreciation between $t-a$ and t. This implies, that when trade is allowed, domestic car stock in older cars can be adjusted by means of international trade only. Equations in (3.3) establish that in this two-country economy the total number of cars is deterministically given in any period t and every vintage a. Up to this point, endowment in the outside good and cars, the age composition of the car stock and differences in taste explain divergence between the two country's demand functions. The representative consumer maximizes its consumption utility subject to the prices that it faces in country n. The per period budget constraint is:

$$p_{nqt}X_{q0t} + \sum_{a=0}^{\infty} p_{nat}X_{nat} = 0 \tag{3.4}$$

$$p_{nqt}q_{nt} + \sum_{a=0}^{\infty} p_{nat}C_{nat} = p_{nqt}E_{nqt} + p_{n0t}Z_{n0t} + (1-\delta)\sum_{a=1}^{\infty} p_{nat}C_{na-1t-1} \tag{3.5}$$

$$p_{nqt}q_{nt} + \sum_{a=0}^{\infty} p_{nat}C_{nat} = W_{nt} \tag{3.6}$$

where W_{nt} denotes the right hand side of equation (3.5) and is the sum of the value of the overall car stock and other consumption in period t in country $n = H, F$. I will refer to it as wealth. Intuitively, equation (3.4) says that net exports have to be zero because of balanced trade. Following substitutions for the corresponding terms, the right hand side of equation (3.5) defines wealth because the right hand side is the stock that a country can sell, while the left hand side is the stock a country can buy. The budget constraint says that every period the representative consumer adjusts its desired car stock and also its age composition and spends all its wealth on the outside good and on cars. There is no saving and there is no borrowing. First, the representative consumer chooses, how much to spend on the aggregate car stock and on the outside good. Then, it chooses how to allocate its car expenditure on cars of various ages. The autarky equilibrium requires that all new cars produced in a given period and all the already existing car stock be consumed. Equilibrium in free trade requires that world demand equals world supply of cars and that the two country's trade be balanced at prevailing world prices. Car prices represent prevailing asset values in any period t. The numeraire will be the new car price. $p_{n0t}Z_{n0t}$ is the period t value of new car production. In the analysis what follows I rely on the following assumption.

Assumption 1. The representative household prefers newer cars to older ones. Formally, this relationship is governed by λ_{na} which is defined as an exponentially decreasing function of age.

$$\lambda_{na} = \gamma_n^a \text{ where } \gamma_n < 1 \tag{3.7}$$

This assumption is similar to Gavazza and Lanteri (2018) and Gavazza et al. (2014), where households have different willingness to pay for cars of different qualities, with younger cars being of higher quality. If γ_n differs in the two countries, then the exponential decay in taste implies for example that the average consumer in the richer country prefers newer cars to older ones more than the average consumer in the poorer country. The lower γ_n is in the richer country the more will newer cars be preferred to older ones in this economy. In what follows I solve the representative consumer's optimization problem and derive an expression for demand for cars of age a as a function of prices, wealth and model parameters. The Lagrangian takes the form:

$$max\, q_{nt}^{1-\alpha}\Big(\sum_{a=0}^{\infty}\lambda_{na}C_{nat}^{\frac{\theta-1}{\theta}}\Big)^{\frac{\alpha\theta}{\theta-1}}+\zeta\left(W_{nt}-\sum_{a}p_{nat}C_{nat}-p_{nqt}q_{nt}\right)$$

where ζ is the Lagrangian multiplier associated with the representative consumer's budget constraint in country $n=H,F$. The necessary first-order conditions of the consumer maximization problem are equations (3.3), (3.4) and with respect to vintage a:

$$q_{nt}^{1-\alpha}\alpha\left(\sum_{a}\lambda_{na}C_{nat}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta(\alpha-1)+1}{\theta-1}}\lambda_{na}C_{nat}^{-\frac{1}{\theta}}=\zeta p_{nat} \tag{3.8}$$

$$(1-\alpha)q_{nt}^{-\alpha}\Big(\sum_{a=0}^{\infty}\lambda_{na}C_{nat}^{\frac{\theta-1}{\theta}}\Big)^{\frac{\alpha\theta}{\theta-1}}=\zeta p_{nqt} \tag{3.9}$$

These first order conditions are fairly standard, except for the fact that the representative consumer has to allocate its per period wealth and not its per period income. As a first step, I exploit that the utility function implies that the representative consumer that faces price index P_{nt} in the car sector will choose to consume cars and the outside good such that their wealth expenditure share is constant:

$$Q_{nt}=\alpha\frac{W_{nt}}{P_{nt}} \tag{3.10}$$

$$q_{nt}=(1-\alpha)\frac{W_{nt}}{p_{nqt}} \tag{3.11}$$

The above equations define the demand for the composite aggregate in cars and the outside good. The next steps follow the derivation of the well-known CES demand function. Eq. (3.8) must hold for all $a\in[0,+\infty)$, therefore, for two arbitrary vintages a_1 and a_2 I can write:

$$q_{nt}^{1-\alpha}\alpha\left(\sum_{a}\lambda_{na_1}C_{na_1t}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta(\alpha-1)+1}{\theta-1}}\lambda_{na_1}C_{na_1t}^{-\frac{1}{\theta}}=p_{na_1t} \tag{3.12}$$

$$q_{nt}^{1-\alpha}\alpha\left(\sum_{a}\lambda_{na_1}C_{na_1t}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta(\alpha-1)+1}{\theta-1}}\lambda_{na_1}C_{na_1t}^{-\frac{1}{\theta}}=p_{na_2t} \tag{3.13}$$

I divide the two first order conditions to derive a relationship between the relative stocks consumed from good a_1 and a_2 and their relative prices.

$$\frac{C_{na_1t}}{C_{na2t}} = \left(\frac{\lambda_{na_1}}{\lambda_{na_2}}\right)^{\theta}\left(\frac{p_{na_1t}}{p_{na_2t}}\right)^{-\theta}$$

$$C_{na_1t} = C_{na_2t}\left(\frac{\lambda_{na_1}}{\lambda_{na_2}}\right)^{\theta}\left(\frac{p_{na_1t}}{p_{na_2t}}\right)^{-\theta} \tag{3.14}$$

In a similar way, every good in the representative consumers' choice set can be expressed in terms of good a_2. I use this observation and combine the budget constraint and the first order optimality conditions to derive demand for good a_2:

$$\sum_a p_{nat}C_{na_2t}\left(\frac{\lambda_{na}}{\lambda_{na_2}}\right)^{\theta}\left(\frac{p_{nat}}{p_{na_2t}}\right)^{-\theta} = \alpha W_{nt}$$

$$C_{na_2t} = \frac{\lambda^{\theta}_{na_2t}(p_{na_2t})^{-\theta}}{\sum_a \lambda^{\theta}_{na}(p_{nat})^{1-\theta}}\alpha W_{nt} \tag{3.15}$$

More generally, the demand for the vehicle stock of age a is:

$$C_{nat} = \frac{\lambda^{\theta}_{na}p^{-\theta}_{nat}}{P^{1-\theta}_{nt}}\alpha W_{nt} \tag{3.16}$$

where P_{nt} is the CES price index defined as:

$$P_{nt} = \left(\sum_a \lambda^{\theta}_{na}p^{1-\theta}_{nat}\right)^{\frac{1}{1-\theta}} = \left(\sum_a \gamma^{a\theta}_n p^{1-\theta}_{nat}\right)^{\frac{1}{1-\theta}} \tag{3.17}$$

Demand is a function of prices, wealth, the elasticity of substitution and taste. Further, knowing the price index, the expenditure on cars of age a is:

$$p_{nat}C_{nat} = \left(\frac{p_{nat}}{P_{nt}}\right)^{1-\theta}\lambda^{\theta}_{na}\alpha W_{nt} \tag{3.18}$$

3.4 Autarky balanced growth equilibrium

Assumption 2. New car production grows exponentially, each period at rate $\eta_n > 1$, such that $Z = \eta Z(-1)$.

This assumption formulates the exogeneous growth assumption.

Assumption 3. Endowment in the outside good grows at the same rate κ in the two countries

The first two assumptions are sufficient conditions for the autarky equilibrium results. Together with Assumption 3 they ensure the existence of the small open economy balanced growth equilibrium.

In this section I study the equilibrium in the context of a single country when no trade takes place. Market clearing in each period obtains as follows. Consumers demand new and used durables in accordance with the preferences outlined above. Demand is a function of the corresponding prices, and wealth measured as the sum of the value of its car stock and endowment in the outside good. Car supply is deterministically given and relative car supply pins down relative car prices. Because car production is exogeneous, and the representative consumer wants to consume all existing cars, the price of the outside good will adjust in order to clear the car market for cars of all ages and the market for the outside good. The utility function implies that the autarky balanced growth equilibrium does not depend on the outside good endowment. The equilibrium relative price of the outside good will ensure that total wealth equals $W_{nt} = \alpha^{-1} \sum_{a=0}^{\infty} p_{nat} C_{nat}$. In the remaining of this subsection I first lay out the definition of the autarky balanced growth equilibrium, then show that such an equilibrium indeed exists and present its properties.

Definition 1. *(Autarky balanced growth equilibrium.) The autarky balanced growth equilibrium is defined by a set of quantities* $\{C_{nat}, S_{nat}, q_{nt}, E_{nqt}\}_{t,n=H,F}$*, and prices* $\{p_{nat}, p_{nqt}\}_t$ *such that:*

1. *The representative consumer chooses* $\{C_{nat}, q_{nt}\}_{t,n=H,F}$ *to maximize utility (3.2), subject to the law of motion* (3.3)*, and the budget constraint (3.4).*

2. *Goods markets clear for every vintage* $a \in [0, \infty)$ *and the outside good.*

3. *All quantities, consumption of cars,* C_{nat}*, car stock* S_{nat} *and wealth,* W_{nt} *for each vintage a grow at a constant rate.*

Proposition 1. If new car production grows exponentially at constant rate $\eta_n > 1$ (Assumption 2 holds), an autarky balanced growth equilibrium exists and quantities, such as car consumption, C_{nat}, car stock, S_{nat} and wealth, W_{nt} grow by the same rate η_n.

Proof (Proposition 1) In autarky, by definition, trade flows are zero in every period. Thus, $X_{nat} = 0$ for all $a \geq 0$ and the outside good as well. Supply of new cars at time t is given by the per period new car production Z_{n0t}, for cars of age $a > 0$, it is the depreciated new car stock from period $t-a$, equal to $S_{n0t-a}(1-\delta)^a$. Equation (3.16) and (3.11) define demand in the autarky equilibrium. Market clearing is thus implied by equations (3.3). When markets clear, consumption of the outside good is equal to its period t endowment, consumption of new cars is equal to its exogeneously given production and consumption of older vintages equals the remaining stock after depreciation from the previous period:

$$q_{nt} = E_{nqt} \tag{3.19}$$

$$C_{nat} = S_{nat} \tag{3.20}$$

$$C_{nat} = S_{n0t-a}(1-\delta)^a \tag{3.21}$$

As a next step, I derive autarky equilibrium prices. By Assumption 1 and equation (3.21), the relative supply of good a at time t in country n takes the form:

$$\frac{S_{nat}}{S_{n0t}} = \left(\frac{1-\delta}{\eta_n}\right)^a \tag{3.22}$$

Relative supply in cars can be expressed as a function of model parameters only. Further, Equation (3.22) shows that the relative supply of cars aged a to new cars is constant over time. For this to hold, supply of age a cars S_{nat} has to grow at the same constant rate η_n as new car production. From equation (3.22) it is also clear that relative supply decreases exponentially in cars' age.

Next, in equilibrium, domestic goods markets have to clear for every $a \in [0, +\infty)$. With demand defined in equation (3.16), optimizing behaviour implies:

$$S_{nat} = \frac{\lambda_{na}^{\theta} p_{nat}^{-\theta}}{P_{nt}^{1-\theta}} \alpha W_{nt} \tag{3.23}$$

$$S_{n0t} = \frac{\lambda_{n0}^{\theta} p_{n0t}^{-\theta}}{P_{nt}^{1-\theta}} \alpha W_{nt} \tag{3.24}$$

I combine equation (3.23) and (3.24) and arrive at the equilibrium relationship between relative supply and relative demand for cars aged a.

$$\frac{S_{nat}}{S_{n0t}} = \gamma_n^{\theta a} (\frac{p_{nat}}{p_{n0t}})^{-\theta} \tag{3.25}$$

where I have used that $\lambda_{n0} = 1$ by definition and $\lambda_{na} = \gamma_n^a$. Equation (3.25) together with (3.22) define the autarky equilibrium relative prices:

$$\frac{p_{nat}}{p_{n0t}} = \left(\frac{1-\delta}{\eta_n}\right)^{-\frac{a}{\theta}} \gamma_n^a \tag{3.26}$$

Equilibrium prices are expressed in terms of the national numeraire. This corresponds to the unit price of the domestically produced new car. Autarky equilibrium relative prices are constant over time and a function of car age and model parameters only. [17] In autarky balanced growth equi-

[17] Note that although relative prices are constant, the CES price index will change over time as new vintages arrive.

librium, the new car stock grows over time at a constant rate and new cars become cheaper as their supply grows. Because relative prices are constant over time, the relative price of older cars grows. Further, the demand for the outside good as given by equation (3.11) and the market clearing condition for the outside good imply that the autarky equilibrium price of the outside good is:

$$p_{nqt} = (1-\alpha)\frac{W_H}{E_{nqt}} \tag{3.27}$$

This relationship simply shows that if country n is rich in the outside good, then its price will be low. Next, I want to show that consumption of cars and wealth both grow at the same rate as new car production. First, by Assumption 2, equation (3.20) and equation (3.22) it follows that the consumption of age a cars, C_{nat} will grow at rate η_n. Further, equality (3.10) and (3.11) imply that the relative expenditure share of cars is constant and equal to $\frac{\alpha}{1-\alpha}$. Because consumtion in cars for every vintage grows at rate η over time, but relative prices are constant, expenditure on cars $P_{nt}Q_{nt}$ also grows at rate η_n. This, together with the constant relative expenditure share imply that in autarky equilibrium, expenditure on the outside good $p_{nqt}E_{nqt}$ also has to grow at the constant rate η_n over time. In the special case when endowment in the outside good is constant, this would imply, that the price of the outside good relative to the new car price will adjust so that expenditure still grows at the rate of $\eta - n$. From (3.10) it follows, that wealth will also grow at the same rate as new car production. I have found a set of quantities $\{C_{nat}, S_{nat}, q_{nqt}\}_{n=H,F}$ and prices $\{p_{nat}, p_{nqt}\}_{n=H,F}$ that satisfy Definition 1, therefore I can conclude that an autarky balanced growth equilibrium does exist, and in this equilibrium all quantities grow at the same rate η_n. □

An important feature of the balanced growth equilibrium prices is that prices are exponentially decreasing in age and more importantly, decrease at a different rate in the two economies. I will rely on this result in the remaining sections.

3.5 Free trade patterns of trade

This section characterizes first the patterns of trade in the instant of opening up to trade and then lays out the definition and discusses the free-trade equilibrium.

Before opening up to trade, countries can be different in their tastes for new cars, country specific exogenous growth in the car sector, the age distribution of the aggregate car stock and the endowment in the outside good. These give rise to divergent demand and supply structures in the two closed economies and different equilibrium prices. Free trade equalizes prices in the two countries and patterns of trade are determined by comparative advantage. In equilibrium, every vintage will be traded. The model abstracts from horizontal differentiation and assumes that cars are not differentiated by country of origin either. This will imply in equilibrium that country $n = H, F$ will either export or import a vintage a. An important difference compared to the autarky

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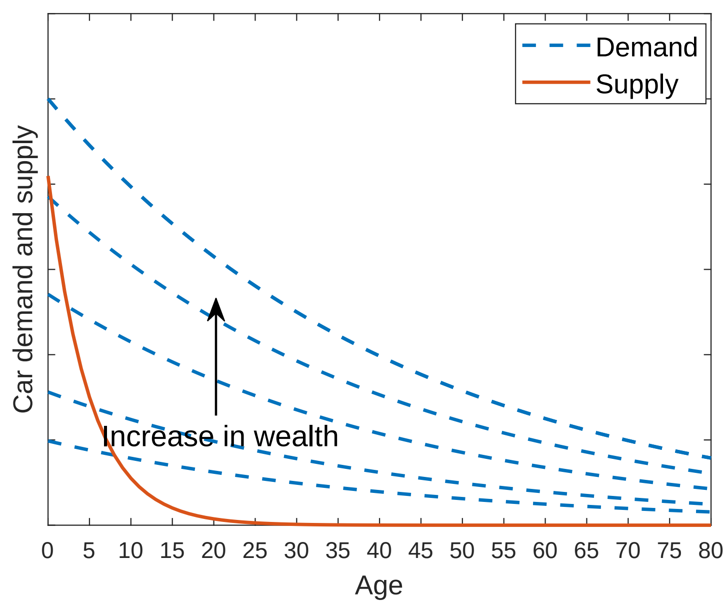
equilibrium is that whether a country is rich or poor in its outside good will play a significant role in determining whether it is an importer or exporter of vintage a cars.

Figure 3.12 is key for understanding the model's mechanism when trade is introduced. The red solid line illustrates car demand as a function of age, the blue dashed line shows car supply as a function of age. These curves were drawn to reflect that the demand and supply derived from the model are exponentially decreasing in cars' age. The graph shows that different wealth levels imply different demand curves, the following way. As a country gets wealthier, its demand for every vintage increases and its demand curve shifts up. This broadens the range of vintages a country imports and narrows the range of exported vintages. In the extreme, its domestic supply in every vintage will be lower than its demand. In such case a very rich country will import all vintages. The more interesting scenario is when one of the countries is a poor country because in free trade a poor country will export some vintages and will import other vintages. I will focus on this latter case.

Figure 3.12: Demand and supply for cars



Note: For illustration purposes. This figure shows scenarios in which the country has a comparative advantage in new cars. Supply is exogeneously given. Depending on the level of the outside good endowment, and the prevailing world prices, multiple scenarios are possible. As wealth rises, the range of vintages the country exports, decreases, ultimately, if the country becomes very rich, all vintages will be imported.

For the analysis what follows it is important to highlight the timing of actions. Before countries engage in trade the economies are determined by their country specific autarky balanced growth equilibrium. After opening up to trade, at the beginning of each period t, stocks depreciate from their $t-1$ level following the law of motion in equations in (3.3) and countries are endowed with their period t new car production that follows the exponential growth rule from Assumption 1. Then countries are allowed to trade with each other. End of period t prices and car stocks will emerge from the free trade equilibrium. When trade is allowed, by the law of comparative advantage as defined in Deardorff (1980), country n has comparative advantage in the good whose relative autarky price (compared to new cars) is lower than in the other country. The following propositions provide insights about which country will export new cars and import old cars.

Definition 2. *(Free trade equilibrium.) The free trade equilibrium is defined by a set of quantities* $\{C_{nat}, S_{nat}, q_{nt}, E_{nqt}\}_{t,n=H,F}$ *and world prices* $\{p_{at}, p_{qt}\}_t$ *such that:*

1. *The representative consumer chooses* $\{C_{nat}, q_{nt}\}_{t,n=H,F}$ *to maximize utility (3.2), subject to the law of motion (3.3), and the budget constraint (3.4).*
2. *World goods markets clear,* $C_{Fat}+C_{Hat}=S_{Fat}+S_{Hat}$ *for every good* $a\in[0,+\infty)$ *and* $q_{Ft}+q_{Ht}=E_{F0t}+E_{Hqt}$ for the outside good.
3. *Trade is balanced in each country n:* $\sum_a p_{at}(S_{nat}-C_{nat})+p_{nqt}(E_{nqt}-q_{nt})=0$.

As there are no frictions in this economy, world prices will be determined by world demand and world supply and markets will clear. To characterize the free trade equilibrium, I will first write international market clearing conditions for an arbitrary vintage a and new cars, and will use these relationships to express relative prices and then express the equilibrium price for the outside good using the market clearing condition in this market.

$$C_{Hat}+C_{Fat}=S_{Hat}+S_{Fat} \tag{3.28}$$

$$C_{H0t}+C_{F0t}=S_{H0t}+S_{F0t} \tag{3.29}$$

In the remaining of this section I will denote free trade equilibrium values by the superscript w. As a next step, I substitute in the corresponding expressions for demand and express world prices:

$$\frac{(p^w_{at})^{-\theta}\lambda^{\theta}_{Ha}}{(P^w_{Ht})^{1-\theta}}\alpha W^w_{Ht}+\frac{(p^w_{at})^{-\theta}\lambda^{\theta}_{Fat}}{(P^w_{Ft})^{1-\theta}}\alpha W^w_{Ft}=S_{Hat}+S_{Fat} \tag{3.30}$$

$$\frac{(p^w_{0t})^{-\theta}\lambda^{\theta}_{H0}}{(P^w_{Ht})^{1-\theta}}\alpha W^w_{Ht}+\frac{(p^w_{0t})^{-\theta}\lambda^{\theta}_{F0}}{(P^w_{Ft})^{1-\theta}}\alpha W^w_{Ft}=S_{H0t}+S_{F0t} \tag{3.31}$$

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From which I express prices for new cars and cars aged a:

$$p^w_{at} = \alpha(S_{Hat}+S_{Fat})^{-\frac{1}{\theta}} \left(\frac{\lambda^\theta_{Ha}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht} + \frac{\lambda^\theta_{Fa}}{(P^w_{Ft})^{1-\theta}} W^w_{Ft} \right)^{-\frac{1}{\theta}} \tag{3.32}$$

$$p^w_{0t} = \alpha(S_{H0t}+S_{F0t})^{-\frac{1}{\theta}} \left(\frac{\lambda^\theta_{H0}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht} + \frac{\lambda^\theta_{F0}}{(P^w_{Ft})^{1-\theta}} W^w_{Ft} \right)^{-\frac{1}{\theta}} \tag{3.33}$$

I divide the above two equilibrium conditions and arrive at a relationship between relative prices on the left hand side and relative supply and relative demand on the right hand side:

$$\frac{p^w_{at}}{p^w_{0t}} = \left(\frac{S_{Hat}+S_{Fat}}{S_{H0t}+S_{F0t}} \right)^{-\frac{1}{\theta}} \left(\frac{\frac{\lambda^\theta_{Ha}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht} + \frac{\lambda^\theta_{Fa}}{(P^w_{Ft})^{1-\theta}} W^w_{Ft}}{\frac{\lambda^\theta_{H0}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht} + \frac{\lambda^\theta_{F0}}{(P^w_{Ft})^{1-\theta}} W^w_{Ft}} \right)^{\frac{1}{\theta}} \tag{3.34}$$

As a next step, I use $\xi_t = \frac{\frac{\lambda^\theta_{H0}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht}}{\frac{\lambda^\theta_{H0}}{(P^w_{Ht})^{1-\theta}} W^w_{Ht} + \frac{\lambda^\theta_{F0}}{(P^w_{Ft})^{1-\theta}} W^w_{Ft}}$ to denote Home country's share in the overall demand for new cars and rewrite the above expression for free trade equilibrium relative prices as a function of the relative supply of cars aged a, taste parameters and demand shares.

$$\begin{aligned} \frac{p^w_{at}}{p^w_{0t}} &= \left(\frac{S_{Hat}+S_{Fat}}{S_{H0t}+S_{F0t}} \right)^{-\frac{1}{\theta}} \left(\frac{\lambda^\theta_{Ha}}{\lambda^\theta_{H0}} \xi_t + \frac{\lambda^\theta_{Fa}}{\lambda^\theta_{F0}} (1-\xi_t) \right)^{\frac{1}{\theta}} \\ &= \left(\frac{S_{Hat}+S_{Fat}}{S_{H0t}+S_{F0t}} \right)^{-\frac{1}{\theta}} \left(\gamma_H^{\theta a} \xi_t + \gamma_F^{\theta a} (1-\xi_t) \right)^{\frac{1}{\theta}} \end{aligned} \tag{3.35}$$

As the right hand side depends on all prices, not just vintage a, a closed form solution for free trade equilibrium prices can not be derived, but can be solved for by numerical optimization of the system of equations defined by (3.35). Equation (3.35) can be further manipulated to express world prices immediately after opening up to trade. This formulation reflects that in the instant of opening up to trade car stocks are still determined by autarky balanced growth equilibrium relationships[18].

$$\frac{p^w_{at}}{p^w_{0t}} = \left(\frac{S_{H0t}}{S_{H0t}+S_{F0t}} \eta_H^{-a} (1-\delta)^a + \frac{S_{F0t}}{S_{H0t}+S_{F0t}} \eta_F^{-a} (1-\delta)^a \right)^{-\frac{1}{\theta}} \left(\gamma_H^{\theta a} \xi_t + \gamma_F^{\theta a} (1-\xi_t) \right)^{-\frac{1}{\theta}} \tag{3.36}$$

A special case is when growth and taste parameters are the same in the two countries. Then, the

[18] I apply the relationship between stock of age a cars and the new car stock as defined by equation (3.22) and use that this relationship still holds in the instance of opening up to trade

only difference is due to their endowment. In this special case the equilibrium relative price formula takes the form:

$$\frac{p_a^w}{p_0^w} = \left(\frac{S_{Ha_t} + S_{Fa_t}}{S_{H0_t} + S_{F0_t}}\right)^{-\frac{1}{\theta}} \gamma^a \tag{3.37}$$

Further, the market clearing condition for the outside good implies:

$$q_{Ht} + q_{Ft} = E_{Hqt} + E_{Fqt} \tag{3.38}$$

I apply that equations (3.10) and (3.11) still hold in the free trade equilibrium and rewrite the above equation by substituting in the demand expression for the outside good at the prevailing free trade prices $q_{nt} = (1-\alpha)\frac{W_{nat}}{p_{qt}^w}$:

$$(1-\alpha)\frac{W_{Hat}^w}{p_{qt}^w} + (1-\alpha)\frac{W_{Fat}^w}{p_{qt}^w} = E_{Hqt} + E_{Fqt} \tag{3.39}$$

$$p_{qt}^w = (1-\alpha)\frac{W_{Hat}^w + W_{Fat}^w}{E_{Hqt} + E_{Fqt}} \tag{3.40}$$

Next, I am interested in how the free trade and the autarky equilibrium prices change with a car's age. To do so, I compute the first order derivative and use $\frac{\partial \log f(x)}{\partial x} = \frac{f'(x)}{f(x)}$. I perform these calculations to compare the rate at which free trade prices change with the change in autarky equilibrium prices.

$$\ln\frac{p_{at}^w}{p_{0t}^w} = -\frac{1}{\theta}\ln\left(\frac{S_{Hat} + S_{Fat}}{S_{H0t} + S_{F0t}}\right) + \frac{1}{\theta}\ln\left(\gamma_H^{\theta a}\xi_t + \gamma_F^{\theta a}(1-\xi_t)\right) \tag{3.41}$$

It then follows that the derivative with respect to a can be written as:

$$\frac{\partial \frac{p_{at}^w}{p_{0t}^w}}{\partial a} = -\frac{1}{\theta}\Big(\ln(1-\delta) - \frac{\eta_H^a\ln(\eta_H) + \eta_F^a\ln(\eta_F)}{\eta_H^a + \eta_F^a}\Big) + \frac{1}{\theta}\frac{(\gamma_H^{\theta a}\xi_t + \gamma_F^{\theta a}(1-\xi_t))'}{\gamma_H^{\theta a}\xi_t + \gamma_F^{\theta a}(1-\xi_t)} \tag{3.42}$$

$$= -\frac{1}{\theta}\ln(1-\delta) + \frac{1}{\theta}\Big(\omega_H\ln(\eta_H) + (1-\omega_H)\ln(\eta_F)\Big) + \frac{\gamma_H^{\theta a}\xi_t\ln(\gamma_H) + \gamma_F^{\theta a}(1-\xi_t)\ln(\gamma_F)}{\gamma_H^{\theta a}\xi_t + \gamma_F^{\theta a}(1-\xi_t)} \tag{3.43}$$

$$= -\frac{1}{\theta}\ln(1-\delta) + \frac{1}{\theta}\Big(\omega\ln(\eta_H) + (1-\omega)\ln(\eta_F)\Big) + \pi_H\ln(\gamma_H) + (1-\pi_H)\ln(\gamma_F) \tag{3.44}$$

with $\omega_H = \frac{\eta_H^a}{\eta_H^a + \eta_F^a}$ and $\pi_H = \frac{\gamma_H^{\theta a} \xi_t}{\gamma_H^{\theta a} \xi_t + \gamma_F^{\theta a}(1-\xi_t)}$. Similarly, for autarky equilibrium prices I get:

$$\frac{\partial \frac{p_{nat}}{p^n_{0t}}}{\partial a} = -\frac{1}{\theta}\ln(1-\delta) + \frac{1}{\theta}\ln(\eta_n) + \ln\gamma_n \tag{3.45}$$

The second and third terms in equation (3.44) are a convex combination of the second and third term in equation (3.45), respectively.

Lemma 1. The free trade equilibrium price decreases in cars' age at a faster rate than the Home autarky price and at a slower rate than the Foreign autarky price.

Proposition 2. Assume that the environment is such that there are two countries that grew in autarky balanced growth equilibrium until period $T-1$ and from period T, they can engage in frictionless trade. The country with higher $\eta_n \gamma_n^\theta$ will have comparative advantage in age 0 cars.

Proof (Proposition 2) Comparative advantage in new cars for country n compared to the other country n_* formally implies:

$$\frac{p_{n_*a}}{p_{n_*0}} < \frac{p_{na}}{p_{n0}} \tag{3.46}$$

$$\left(\frac{1-\delta}{\eta_{n*}}\right)^{-\frac{a}{\theta}} \gamma_{n_*}^a < \left(\frac{1-\delta}{\eta_n}\right)^{-\frac{a}{\theta}} \gamma_n^a \tag{3.47}$$

$$\eta_{n_*}\gamma_{n_*}^\theta < \eta_n \gamma_n^\theta \tag{3.48}$$

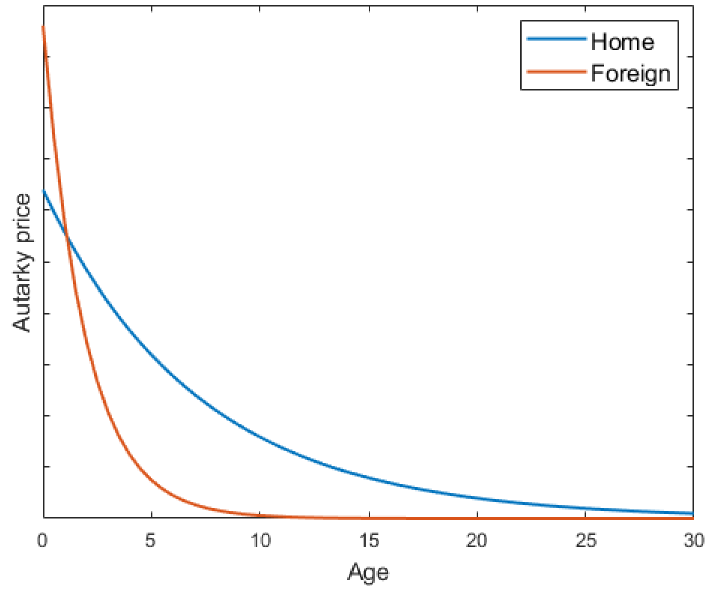
□

The above condition implies that Home will have comparative advantage in new cars if $\eta_F \gamma_F^\theta < \eta_H \gamma_H^\theta$. Intuitively, this means that Home will have comparative advantage if it has a large growth rate in new car production, which will make its new cars relatively cheaper compared to the other country. Home can also enjoy comparative advantage in new cars, if the representative consumer dislikes older cars significantly less than the representative consumer in the other country. The less households in a country dislike older vintages, the slower is the rate at which car prices in this country decrease in age. And it follows that older vintages will have relatively higher prices in Home than in Foreign.

Corollary 1. By Proposition 2, after opening up to trade, that country exports new cars that has relatively higher growth rate.

Proposition 3. Consider two countries that are in autarky balanced growth equilibrium until period T-1 and countries can engage in free trade in period T. Assume Home has comparative advantage in new cars. Then, by Lemma 1, there exists an $a^w \in [0, +\infty)$ for which in the free trade equilibrium Home will export cars with $a < a^w$ and will import cars with $a \geq a^w$.

Figure 3.13: Comparative advantage



Note: For illustration purposes. Distinct exponential decay in prices ensures that price curves cross only once.

Intuitively, the autarky balanced growth equilibrium prices in the two countries have different exponential decay as shown by Figure 3.13. This ensures that the two price curves cross exactly once. If Home has a comparative advantage in new cars, then the single crossing property ensures that Home will export new and relatively new cars and import older cars.

Free trade equalizes prices and changes the age composition of the durable stock in each country, with imported cars becoming cheaper and exported car becoming more expensive as prices converge. The free trade equilibrium does not satisfy the conditions of a balanced growth equilibrium. In the next section, I characterize the balanced growth equilibrium that describes trade patterns for a small open economy whose demand has no impact on prevailing equilibrium world prices but that is always met by world supply.

3.6 Small open economy balanced growth equilibrium

Assumption 4. Assume that world prices are exogenous for the Home country and equal to Foreign autarky balanced growth equilibrium prices $p^w_{at} = p_{Fat}$. Further, assume that Foreign is large enough to satisfy Home country's demand in every period.

This assumption is consistent with the standard modelling of a small open economy and implies internationally set prices for all goods and that the supply of cars is infinitely elastic. In the following I distinguish between the period of opening up to trade and the long-run equilibrium because in the first period when trade is allowed, car supply is still pinned down by the autarky equilibrium. Demand in the immediate aftermath of opening up to trade is then determined by the small open economy's endowment in the outside good and its autarky car stock, both evaluated at the prevailing world prices. Their total value defines the wealth that the small open economy can spend on its car and other consumption.

$$C_{Hat} = \frac{\lambda_{Ha}^{\theta}(p_{at}^{w})^{-\theta}}{\sum_a \lambda_{Ha}^{\theta}(p_{at}^{w})^{1-\theta}} W_{Ht}^{w} \tag{3.49}$$

$$q_{Ht} = (1-\alpha)\frac{W_{Ht}^{w}}{p_{qt}^{w}} \tag{3.50}$$

Equilibrium prices that prevailed in autarky diverge from world prices and this will generate an initial stock adjustment in cars which lasts for one period only, as I will show below. As before, patterns of trade are determined by the general law of comparative advantage. The utility function implies that, in equilibrium, expenditure on cars and the outside good will be a constant share of wealth:

$$\sum_{a=0}^{\infty} p_{at}^{w} C_{Hat} = \alpha W_{Ht}^{w} \tag{3.51}$$

$$p_{qt}^{w} q_{Ht} = \frac{1-\alpha}{\alpha} \sum_{a=0}^{\infty} p_{at}^{w} C_{nat} \tag{3.52}$$

In the first period when trade is introduced, the small open economy that grew in autarky balanced growth equilibrium will export cars aged a if demand at world prices C_{Hat}^{w} is lower than its domestic supply S_{Hat}: $C_{Hat}^{w} < S_{Hat}$. Appendix C.3.3 derives formally that the sufficient condition for exporting new cars is:

$$\frac{1-\gamma_F\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}}{1-\gamma_H\left(\frac{1-\delta}{\eta_H}\right)^{\frac{\theta-1}{\theta}}} < \frac{p_{Hqt}E_{Hqt} + Z_{H0t} + (1-\delta)\sum_{a=1}^{\infty}\left(\frac{1-\delta}{\eta_H}\right)^{-\frac{a}{\theta}}\gamma_H^{a} S_{Ha-1t-1}}{p_{wqt}E_{Hqt} + Z_{H0t} + (1-\delta)\sum_{a=1}^{\infty}\left(\frac{1-\delta}{\eta_w}\right)^{-\frac{a}{\theta}}\gamma_H^{a} S_{Ha-1t-1}} \tag{3.53}$$

The left hand side is Home demand for new cars evaluated at world prices, which in the moment of opening up to trade is constant and can be expressed as a function of model parameters. However, the right hand side depends on the endowment E_{Hqt} in the following way. A higher endowment E_{Hqt} will not affect the numerator, as p_{Hqt} is determined in equilibrium and adjusts such that $p_{Hqt}E_{Hqt}$ remains constant. But an increase in E_{Hqt} increases the denominator and decreases the right hand side of the inequality. Intuitively, this condition says that there exists an endowment in the outside good, below which the small open economy will export new cars. This condition focuses on the period of opening up to trade. Appendix C.3.3 discusses the condition for exporting vintage a in the small open economy balanced growth equilibrium.

Definition 3. *(Small open economy balanced growth equilibrium, SOEBGE.) The small open economy balanced growth equilibrium is defined by a set of quantities* $\{C_{Hat}, S_{Hat}, q_{nt}, E_{nqt}\}_t$ *such that:*

1. *The representative consumer chooses* $\{C_{Hat}, q_{Ht}\}_t$ *to maximize utility (3.2), subject to the law of motion (3.3), and the budget constraint (3.4) and takes world prices as given.*

2. *Trade is balanced,* $\sum_a p_{at}(S_{nat} - C_{nat}) + p_{nqt}(E_{nqt} - q_{nt}) = 0$ *for every good a.*

3. *All quantities, car stock,* S_{Hat}*, consumption,* C_{Hat}*, and wealth,* W_{Ht} *grow at a constant rate.*

Proposition 4. If Assumption 4 holds, a small open economy balanced growth equilibrium exists and if $\eta_H = \eta_F$, then all quantities, car stock, S_{Hat}, consumption, C_{Hat}, trade, X_{Hat}, and wealth, W_{Hat} grow at the same constant rate as new car production, η_H.

Proof (Proof of Proposition 4) Assume that Home can engage in trade in period $t-1$. Then, $S_{Hat} = (1-\delta)C_{Ha-1t-1}$ is the supply of cars aged a when trade occurs in period t. The representative consumer can adjust its stock by importing or exporting at the prevailing world prices p^w_{at} that it cannot influence. It follows from the utility maximization that the equilibrium consumption of cars and the outside good is:

$$C_{Hat} = \frac{\lambda^{\theta}_{Ha}(p^w_{at})^{-\theta}}{(P^w_t)^{1-\theta}} \alpha W^w_{Ht} \tag{3.54}$$

$$q_{Ht} = (1-\alpha)\frac{W^w_{Ht}}{p^w_{qt}} \tag{3.55}$$

with P^w_t and W^w_{Ht} being the price index and wealth in the small open economy evaluated at world prices[19]. Further, by the definition of the budget constraint in (3.6), the balanced trade condition always holds in equilibrium. To prove the last point in Definition 3, I first show that wealth grows at the constant rate η_H. In any period t, Home wealth is equal to the sum of its period t outside good endowment valued at world prices and its car stock also valued at prevailing world prices.

$$W^w_{Ht} = p^w_{qt} E_{Hqt} + Z_{H0t} + \sum_{a=1}^{\infty} (1-\delta) C_{a-1t-1} p^w_{at} \tag{3.56}$$

Here I have used that cars that were of age $a-1$ at time $t-1$ will become age a at time t and that in period $t-1$ the equilibrium stock of cars aged a equals their demand as defined by equation (3.54). Then, I substitute in the expression for demand, and rewrite Home wealth the following way:

[19] $P^w_t = (\sum_a \gamma^{a\theta}_H (p^w_{at})^{1-\theta})^{\frac{1}{1-\theta}}$ and $W^w_{Ht} = p^w_{qt} E_{Hqt} + p^w_{0t} Z_{H0t} + (1-\delta)\sum^{\infty}_{a=1} p^w_{at} S_{Ha-1t-1}$.

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$$W_{Ht}^{w} = p_{qt}^{w}E_{Hqt} + Z_{H0t} + (1-\delta)\frac{1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F}{1-\left((\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\gamma_F\right)^{\infty}}\alpha W_{Ht-1}^{w}\sum_{a=0}^{\infty}\gamma_H^{a\theta}p_{at}^{w\,1-\theta}\frac{p_{a+1t}^{w}}{p_{at}^{w}} \tag{3.57}$$

$$= p_{qt}^{w}E_{Hqt} + Z_{H0t} + (1-\delta)\frac{1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F}{1-\left((\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\gamma_F\right)^{\infty}}\alpha W_{Ht-1}^{w}\left(\frac{1-\delta}{\eta_F}\right)^{-\frac{1}{\theta}}\gamma_F\sum_{a=0}^{\infty}\gamma_H^{a\theta}(p_{at}^{w})^{1-\theta} \tag{3.58}$$

In the last equality I exploit that prices decrease exponentially in cars' age[20]. As a next step I substitute in for p_{at}^{w}. After further algebraic manipulations to wealth I get:

$$W_{Ht}^{w} = p_{qt}^{w}E_{Hqt} + Z_{H0t} + (1-\delta)\frac{1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F}{1-\left((\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\gamma_F\right)^{\infty}}\alpha W_{Ht-1}^{w}\left(\frac{1-\delta}{\eta_F}\right)^{-\frac{1}{\theta}}\gamma_F$$
$$\Bigg(1+\gamma_H^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F^{1-\theta}+\gamma_H^{2\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{2(\theta-1)}{\theta}}\gamma_F^{2(1-\theta)}+\gamma_H^{3\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{3(\theta-1)}{\theta}}\gamma_F^{3(1-\theta)}+\ldots$$
$$+\gamma_H^{a\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{a(\theta-1)}{\theta}}\gamma_F^{a(1-\theta)}+\ldots\Bigg) \tag{3.60}$$

$$W_{Ht}^{w} = p_{qt}^{w}E_{Hqt} + Z_{H0t}$$
$$+(1-\delta)\frac{1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F}{1-\left((\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\gamma_F\right)^{\infty}}\alpha W_{Ht-1}^{w}\left(\frac{1-\delta}{\eta_F}\right)^{-\frac{1}{\theta}}\gamma_F\frac{1-\left(\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F\right)^{\infty}}{1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F} \tag{3.61}$$

Next, I use that the price index converges to a constant to simplify the above expression (for derivation see Appendix C.3.4). I arrive at a tractable relationship that describes the evolution of Home wealth allocated to cars over time as a function of wealth at time $t-1$, period t new car production and endowment, and model parameters.

$$W_{Ht}^{w} = p_{qt}^{w}E_{Hqt} + Z_{H0t} + (1-\delta)\left(\frac{1-\delta}{\eta_F}\right)^{-\frac{1}{\theta}}\gamma_F\alpha W_{Ht-1}^{w} \tag{3.62}$$

[20]For $a > 0$ and any t the following equality holds:

$$\frac{p_{nat}}{p_{na-1t}} = \left(\frac{1-\delta}{\eta_n}\right)^{-\frac{1}{\theta}}\gamma_n \tag{3.59}$$

I want to show that if the first two terms in the above expression both grow at the rate of η_H, then, wealth also has to grow at the same rate. The proof to Proposition 1 establishes that in autarky balanced growth equilibrium, expenditure on the outside good grows at the same rate as new car production. Therefore $p_{Hqt}E_{Hqt}$ and $p_{Fqt}E_{Fqt}$ grow at rate η_H and η_F, respectively. By Assumption 3, if $\eta_H = \eta_F$, the first term in equation (3.62), $p_{qt}E_{Hqt}$ will grow at rate η_H. Further, the second term, new car production grows at rate η_H. Then, as model parameters are constant, wealth in Home country also has to grow at the same rate η_H.

$$W_{Ht} = p^w_{qt}E_{Hqt} + Z_{H0t} + cW_{Ht-1} \tag{3.63}$$

$$\frac{W_{Ht}}{W_{Ht-1}} = \eta_H \tag{3.64}$$

where $c = (1-\delta)\gamma_H^\theta \left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}} \gamma_F^{1-\theta}\alpha$ is a constant. Next, I show that consumption in good a also grows at rate η_H. From equations (3.54), (C.11) and the convergence condition:

$$C_{Hat} = \gamma_H^{a\theta}\left(\frac{\left((\frac{1-\delta}{\eta_F})^{-\frac{a}{\theta}}\gamma_F^a\right)^{-\theta}}{\sum_a \gamma_H^{a\theta}\left((\frac{1-\delta}{\eta_F})^{-\frac{a}{\theta}}\gamma_F^a\right)^{1-\theta}}\right)\alpha W^w_{Ht} \tag{3.65}$$

$$= \left(\frac{\gamma_H}{\gamma_F}\right)^{a\theta}\left(\frac{1-\delta}{\eta_F}\right)^a \frac{1-\left(\frac{\gamma_H}{\gamma_F}\right)^\theta \left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F}{1-\left((\frac{\gamma_H}{\gamma_F})^\theta(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\gamma_F\right)^{t+1}}\alpha W^w_{Ht} \tag{3.66}$$

$$= \left(\frac{\gamma_H}{\gamma_F}\right)^{a\theta}\left(\frac{1-\delta}{\eta_F}\right)^a \left(1-\left(\frac{\gamma_H}{\gamma_F}\right)^\theta\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F\right)\alpha W^w_{Ht} \tag{3.67}$$

By the above discussion, the right hand side of equation (3.67) grows at rate η_H and this implies that consumption of cars aged a also grows at rate η_H. Equation (3.67) together with (3.64), and equation (3.3) imply that consumption, car stock and trade all grow exponentially at rate η_H. □

Proposition 5. Let the environment be such that Assumption 4 holds, and the two countries grew in autarky balanced growth equilibrium. If countries can engage in costless trade in period T, then starting from period $T+1$ the small open economy will be in SOEBGE.

Proof (Proposition 5) By the proof of Proposition 4, the economy is in SOEBGE in period t whenever it was in free trade in period $t-1$. This implies that if the small open economy was in free trade in period T, it will be in SOEBGE starting from period $T+1$ and Proposition 5 is true. This condition does not hold for period T, because the small open economy was in autarky in period $T-1$. □

Proposition 5 says that after opening up to trade, transition lasts for one period only. The set of car vintages that the small open economy exports and imports during the transition period is different from the vintages exported and imported in the SOEBGE. This causes a whiplash effect. In the period of opening up to trade, older cars will also be exported, but starting from the second free trade period, the direction of trade reverses for these vintages and they will be imported instead.

Proposition 6. Let the environment be such that Assumption 4 holds, the two countries grew in autarky balanced growth equilibrium and can engage in costless trade. The small open economy will export only new cars if $\gamma_H^\theta \eta_H > \gamma_F^\theta \eta_F$ (for proof see Appendix C.3.3).

This proposition states that Home will export the goods in which it has comparative advantage. This result resembles Verhoogen (2008) who builds a model in which the quality of a poor country's export goods is higher than that of the goods it consumes.

3.6.1 Supply shock

Proposition 7. Let Home be in SOEBGE and let Home's new car stock decrease. Then, in period T Home country will import new cars affected by the supply shock and export all other car vintages. Starting from period $T+1$, Home will be in a new SOEBGE.

Proof By the proof of Proposition 4, Home can engage in frictionless trade in period $T+1$. Starting from this period, Definition 3 and Proposition 4 will hold and Home will be in SOEBGE, but as I explain below, this will be a new SOEBGE. The immediate effect of the supply shock is that it changes the vintage structure in the small open economy, thereby moving Home from its original SOEBGE. As there are no trade frictions in this economy, as before, Home can freely adjust its stocks through trade. A second effect is that Home becomes poorer. This implies that, in the new SOEBGE, Home can not afford to adjust its stocks to the same vintage structure that was desired before the shock. Therefore, it can not be in the same SOEBGE as before the supply shock. □

3.7 Numerical illustration

In this section I describe the parameter choices underlying the simulation results presented in the next subsections.

α is calibrated to the German ratio of the value of all registered cars and the sum of the value of all durable holdings, including home and expenditure on non-durables[21]. Based on data collected for 2017, I find that the total value of the German car stock is 4.6% of its households' total durable holdings and non-durable consumption expenditure in 2017. The total value of household holdings of passenger cars is €328.754x10^9, the value of family holdings of residential property at the end of

[21] $\alpha = \frac{value\,of\,all\,registered\,cars}{value\,of\,all\,durable\,holdings + expenditure\,on\,non-durables}$ in Germany in 2017.

2017 is €$5,155.668$x10^9, holdings of durable goods[22] is €$1,074.276$x10^9, and final consumption expenditure of households at current prices on non-durables[23] equals €303.383x10^9.

I calibrate Home and Foreign to match statistics about Hungary and Germany, respectively. Hungary's former experience as a closed economy, its later EU accession, and the extensive trade linkages Germany, the biggest car producing country in the EU, make them natural candidates for the numerical illustration. In the simulation exercises initial car stock in Foreign will be 10 times larger than car stock in Home. This choice is supported by the fact that Hungary's economy is smaller than that of Germany and Germany's new car production was around 10 times bigger than new car production in Hungary before the Global Recession. Endowments in the outside good and cars are set such that Foreign represents a large and rich country and Home a small and low-income country.

Further, I choose the depreciation rate to be the same in the two countries and set it to 5% to match the average scrapping rate in Hungary between 2005-2010, for which data is available from Papadimitriou et al. (2013).

Because my model features a single elasticity in preferences between all product varieties, independently from their origin, Home or Foreign, I follow Dekle et al. (2007) and Dekle et al. (2008) and set the elasticity of substitution to $\theta = 4$, a value that lies between the values considered in these papers. Growth rate is set to match the average annual change in passenger car production over 1960-2016 for Germany and 2000-2016 for Hungary. Production statistics are from Eurostat and Kraftfahrt-Bundesamt in Germany.

I use equation (3.26) to calculate country specific taste parameters. I set γ_H and γ_F to match the average price depreciation of 5 year old cars as reported in Csernátony (2018) for Hungary and in ADAC (2016) for Germany[24]. An average 5 year old car is still worth 48% of its original value in Hungary but only 38% in Germany. Information about the age distribution of the aggregate vehicle

[22]Data are collected from the website of the German Statistical Institute (DESTATIS) and correspond to the stock of personal transport equipment at the end of the year in billion Euro; net stock of residential property in billion euro at the end of the year

[23]Final consumption expenditure on non-durables includes expenditure on food and non-alcoholic beverages, alcoholic beverages, tobacco and narcotics, clothing and footwear.

[24]Take German new and 5 year old car stocks in 2005 and use $p_5/p_0 = 0.38$ as in ADAC (2016). Similarly, take the Hungarian new and 5 year old car stocks in 2005 and use $p_5/p_0 = 0.48$ as reported in Csernátony (2018). Then, from the expression of the autarky balanced growth equilibrium prices we obtain the country specific taste parameters.

$$\gamma_F = \left(\frac{2,779,378}{3,060,105} (0.38)^4 \right)^{\frac{1}{20}} = 0.82$$

$$\gamma_H = \left(\frac{263,863}{234,832} (0.48)^4 \right)^{\frac{1}{20}} = 0.87$$

Table 3.3: Parameter Values

Parameter	Value Home	Value Foreign
α	0.046	0.046
θ	4	4
δ	0.05	0.05
η	1.106	1.027
γ	0.87	0.82
$S_{0,2005}$	3060105	234832
$S_{5,2005}$	2779378	263863

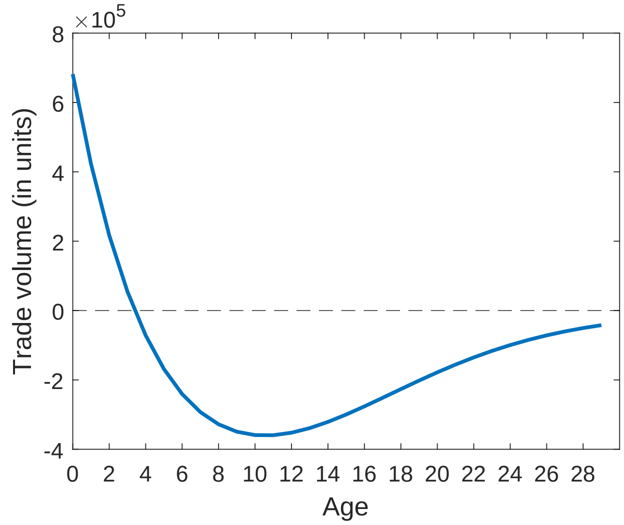
stock stem from the transport data collected for the Papadimitriou et al. (2013) EMISIA project, the Hungarian Statistical Institute and the German Kraftfahrt-Bundesamt. Table 3.3 provides an overview about the calibrated model parameters, stock levels and their values for the two countries.

3.7.1 Free trade

For the calibrated parameters it holds that $\eta_F \gamma_F^\theta < \eta_H \gamma_H^\theta$. Therefore, growth rate in new car production and taste for older cars together ensure that Home has comparative advantage in new cars. The differential decay in supply and demand for cars combined with the single crossing property from Proposition 3, will generate excess supply in new and relatively new cars, and excess demand in older cars in Home (when Home has comparative advantage in new cars). Figure 3.15 shows simulation results for trade volumes for Home in the first period when countries can engage in frictionless trade. Trade takes place in cars of all ages, Home will export new cars and relatively new cars and will import older cars (exports are shown with positive values, imports with negative values). Trade volumes decrease as cars get very old and this generates a J shape curve as shown in Figure 3.15. The initial stock adjustment lasts for one period only, after which further trade takes place, with trade flows increasing over time. This is the result of growing new car production, the excess supply of which will be exported to Foreign. As new cars are relatively more expensive than older vintages, Home can spend its income on a growing import of used cars. The model's prediction about the direction of new car export is similar to the case of "downward" offshoring in Head and Mayer (2019). The latter paper documents an increasing role of foreign production sites in serving the home country besides their traditional role of serving local markets[25].

[25] Head and Mayer (2019) find that "downward offshoring" occurs because sectoral cost competitiveness of the offshoring country and mismatch between product factor intensities and country factor abundances.

Figure 3.14: Trade volumes in the immediate aftermath of opening up to trade



Note: Assumes $a \in [0,29]$. The figure is constructed such that positive values denote Home exports, negative values denote Home imports.

3.7.2 Small open economy

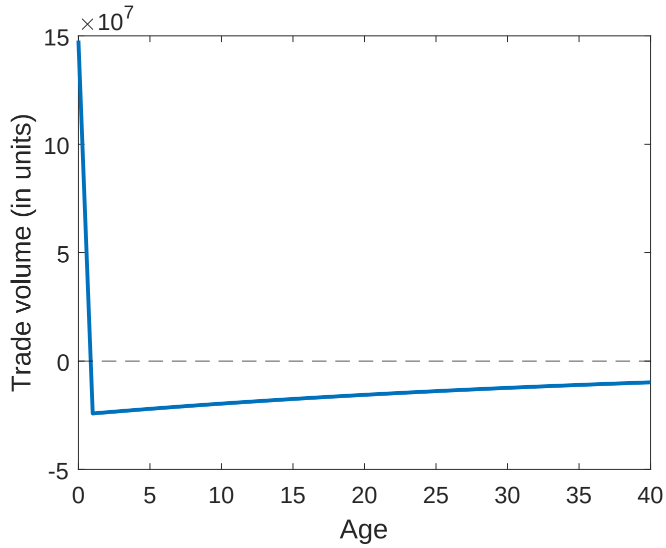
Starting from the second period in free trade, the small open economy will export only new vintages and import every other vintage. Formally this is derived in Appendix C.3.3. Intuitively, by the end of the first period when the small open economy can engage in free trade, relative supply equals relative demand at world prices and relative supply of consecutive vintages is also equal.

$$\frac{S_{Hat}}{S_{H0t}} = \gamma_H^{\theta a}(\frac{p^w_{at}}{p^w_{0t}})^{-\theta} \tag{3.68}$$

$$\frac{S_{H1t}}{S_{H0t}} = \frac{S_{H2t}}{S_{H1t}} = ... = \frac{S_{Hat}}{S_{Ha-1t}} \tag{3.69}$$

As new supply from cars aged 0 arrives, this equality will not hold anymore as there is excess supply from new cars. To restore equilibrium, the small open economy sells some of its new cars and buys older vintages in return.

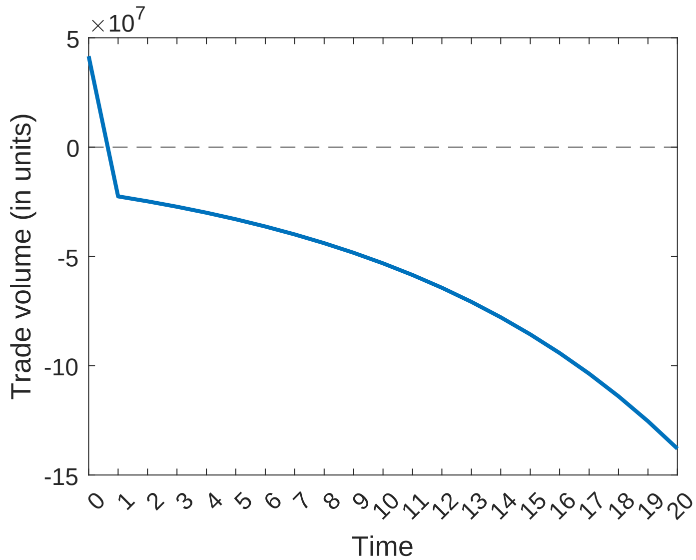
Figure 3.15: Trade volumes in the fifth period in free trade



Note: Assumes $a \in [0, 80]$ when opening up to trade. The figure is constructed such that positive values denote Home exports, negative values denote Home imports.

Figure 3.16 shows that the transition to SOEBGE generates volatile trade flows, as there are vintages for which direction of trade changes between the transition period following opening up to trade and SOEBGE. Starting from period 1, the small open economy will be in SOEBGE and trade volumes grow exponentially over time.

Figure 3.16: Trade volumes in cars aged 1 after opening up to trade

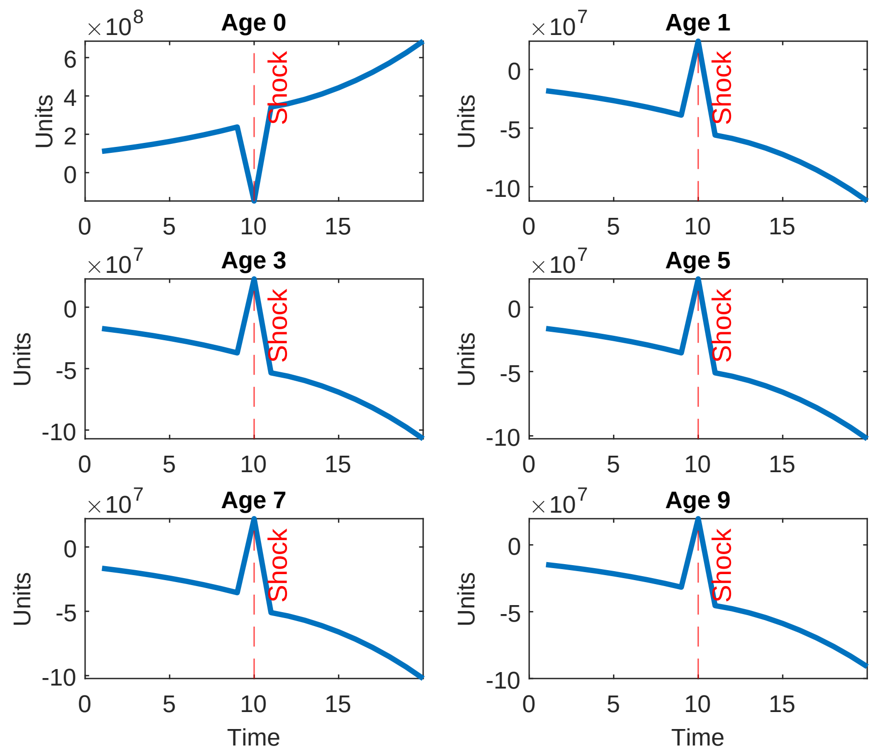


Note: The figure is constructed such that positive values denote Home exports, negative values denote Home imports.

Supply shock

Figure 3.17 plots the small open economy's response to a one-time negative shock that affects its domestic new car market. I model this shock as a 50% decrease in its period $t = 10$ new car production. This shock does not influence prevailing world prices, but changes the stock composition in the small open economy. Before the shock occurs the small open economy is in SOEBGE, exports new cars and imports every other vintage. As there are no trade frictions, this lead to an immediate large response in trade flows following the shock to the car stock. The small open economy will adjust its stock to its desired level according to equation (3.54). The immediate response in trade flows is that Home will import new cars and export all other vintages. Adjustment lasts for one period only. Starting from the next period after the shock, the direction of trade reverses, new cars will be exported and all other vintages imported. The supply shock makes Home country poorer which will cause a drop in demand that will show up in trade volumes as well. Home is no longer in its original autarky balanced growth equilibrium.

Figure 3.17: Large swings in trade flows following a supply shock



Note: The figure is constructed such that positive values denote Home exports, negative values denote Home imports.

3.8 Conclusions

Durable goods represent an important component in household consumption and many important durable goods have an active secondary market. Access to international secondary markets beyond the domestic market enlarges households' choice set and allows households to consume more in line with their preferences. At the aggregate level, as adjustment in stock affects trade flows, a sudden shock will generate large trade fluctuations.

This chapter documented empirical patterns in the European car market for multiple countries and over several years and highlighted the difficulty to characterize within-EU international trade flows. I presented a model of durable goods markets where I introduced international trade in the various vintages of the same durable good. The model characterized the demand side and showed that varying tastes for new and old vintages across countries affect cross-country trade dynamics. When trade is allowed and countries adjust the desired level and age composition of their car stock, this generates fluctuations in trade flows. Finally, I provided a numerical example of the

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model's predictions using parameters calibrated to Hungary and Germany. My analysis extends our understanding about how sudden changes in durable stocks affect current and future stocks of various vintages of the same good. Shocks to new goods can have a prolonged effect on trade flows and through international trade, shocks in one country can be transmitted elsewhere.

APPENDIX A
ECONOMIC POLICY UNCERTAINTY AND STOCK MARKET PARTICIPATION

A.1 Results

Table A.1: Descriptive Statistics and Correlations for Variables

Panel A: Descriptive Statistics			
	Mean	Median	St. Dev.
Word recall score	5.50	6.00	1.77
Numeracy score	3.71	4.00	1.65
No memory difficulties (interviewer)	0.93		0.25
Adequate understanding (interviewer)	0.94		0.24
Household size	2.00	2.00	1.11
Number of ADLs facing limitations with	0.29	0.00	0.81
Health fair or bad (self-reported)	0.25		0.43
Feeling depressed	0.13		0.33
Working	0.34		0.47
Retired	0.53		0.50
Know neighbors	0.72		0.45
Engage in voluntary activities	0.37		0.48
Expect to leave a bequest	0.90		0.30
Familiar with Internet	0.52		0.50
Non-capital total household income	55,070	30,400	431,780
Net total non-stock wealth	339,492	151,550	702,829

Panel B: Correlations			
	Mean	Median	St. Dev.
Hours reading newspapers (from paper and online)	19.2	12.0	18.2
Hours reading books	13.6	4.0	20.4
Hours using the PC	33.0	8.0	48.6
Hours watching programs or movies/ videos on TV	80.1	68.0	59.9
Hours working	56.2	0.0	78.2
Hours socializing with friends	53.3	38.0	51.0
Hours participating in voluntary/ religious activities	7.0	3.0	11.1
Hours entertaining	5.4	2.0	9.0
Hours sleeping	186.9	200.0	64.5

Table A.2: EPU and stock ownership

	(1)	(2)	(3)	(4)	(5)
log (EPU) × log (hours reading newspapers)	-0.0183***	-0.0182***	-0.0196**	-0.0196**	-0.0239**
	(0.0068)	(0.0069)	(0.0075)	(0.0075)	(0.0115)
log (hours reading newspapers)	0.0907***	0.0904***	0.0966***	0.0965***	0.1233**
	(0.0322)	(0.0324)	(0.0351)	(0.0351)	(0.0542)
Expected stock market up					0.0005***
					(0.0001)
Cognitive indicators					
Word recall score		0.0038**	0.0036*	0.0035*	0.0046
		(0.0018)	(0.0019)	(0.0019)	(0.0028)
Numeracy score		-0.0027	-0.0024	-0.0023	-0.0006
		(0.0021)	(0.0023)	(0.0023)	(0.0031)
No memory difficulties (interviewer)		-0.0076	-0.0096	-0.0095	0.0029
		(0.0087)	(0.0098)	(0.0097)	(0.0161)
Adequate understanding (interviewer)		-0.0021	-0.0050	-0.0047	-0.0033
		(0.0090)	(0.0101)	(0.0101)	(0.0152)
Income/wealth quartiles					
2nd Income Quartile				-0.0062	-0.0080
				(0.0081)	(0.0119)
3rd Income Quartile				0.0003	0.0035
				(0.0113)	(0.0141)
4th Income Quartile				0.0205	0.0066
				(0.0137)	(0.0177)
2nd Wealth Quartile				0.0136*	0.0110
				(0.0077)	(0.0125)
3rd Wealth Quartile				0.0140	0.0057
				(0.0120)	(0.0189)
4th Wealth Quartile				0.0091	0.0013
				(0.0151)	(0.0231)
Demographics	NO	NO	YES	YES	YES
Region fixed effects	NO	NO	YES	YES	YES
Household fixed effects	YES	YES	YES	YES	YES
Month-Year fixed effects	YES	YES	YES	YES	YES
Number of observations	21,642	21,451	19,797	19,797	11,725
Adj. R-Square	0.59	0.59	0.60	0.60	0.60

Note: Stock ownership refers to stocks held directly or through mutual funds. EPU is the monthly average EPU between January of the main survey year and the month prior to every household interview, calculated as in Baker, Bloom, and Davis (2016). Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.3: Hours reading news interacted with various indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log (EPU)	-0.0215***	-0.0272*	-0.0186**	-0.0156**	-0.0189**	-0.0167**	-0.0200**	-0.0195**
× log (hours reading newspapers)	(0.0078)	(0.0151)	(0.0078)	(0.0076)	(0.0083)	(0.0077)	(0.0077)	(0.0075)
log (hours	0.2186**	0.1068***	0.1136**	0.1227***	0.0933**	0.0840**	0.1002***	0.0971
reading newspapers)	(0.0914)	(0.0404)	(0.0442)	(0.0367)	(0.0395)	(0.0358)	(0.0372)	(0.0727)
log (SP500) x	-0.0157							
log (Hours reading newspapers)	(0.0101)							
log (VIX) x log		0.0088						
(hours reading newspapers)		(0.0146)						
log			-0.0047					
(Prof_forecaster) x log (Hours reading newspapers)			(0.0082)					
log (Oil) x log				-0.0104**				
(Hours reading newspapers)				(0.0050)				
real GDP gr x					0.0002			
log (Hours reading newspapers)					(0.0008)			
log (int_rate)						0.0011		
x log (Hours reading newspapers)						(0.0015)		
log (CPI) x log							-0.0015	
(Hours reading newspapers)							(0.0046)	
log (EPU_SE) x								-0.0002
log (Hours reading newspapers)								(0.0163)
Cognitive indicators	YES	YES	YES	YES	YES	YES	YES	YES
Income/wealth quartiles	YES	YES	YES	YES	YES	YES	YES	YES
Demographics	YES	YES	YES	YES	YES	YES	YES	YES
Region fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Household fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Month-Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Number of observations	19,797	19,797	19,797	19,797	19,797	19,797	19,739	19,797
Adj. R-Square	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

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Table A.4: EPU interacted with hours spent in various activities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log (EPU) x log (Hours reading books)	-0.0034							
	(0.0067)							
log (EPU) x log (Hours using the PC)		-0.0041						
		(0.0046)						
log (EPU) x log (Hours watching programs or movies / videos on TV)			-0.0007					
			(0.0086)					
log (EPU) x log (Hours working)				-0.0067				
				(0.0045)				
log (EPU) x log (Hours socializing with friends)					0.0001			
					(0.0087)			
log (EPU) x log (Hours participating in voluntary/ religious activities)						0.0009		
						(0.0076)		
log (EPU) x log (Hours entertaining)							-0.0073	
							(0.0087)	
log (EPU) x log (Hours sleeping)								-0.0158
								(0.0114)
log (Hours reading newspapers)	0.0206	0.0230	-0.0003	0.0309	-0.0010	-0.0072	0.0288	0.0755
	(0.0315)	(0.0216)	(0.0405)	(0.0210)	(0.0410)	(0.0359)	(0.0414)	(0.0533)
Cognitive indicators	YES	YES	YES	YES	YES	YES	YES	YES
Income/wealth quartiles	YES	YES	YES	YES	YES	YES	YES	YES
Demographics	YES	YES	YES	YES	YES	YES	YES	YES
Region fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Household fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Month-Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Number of observations	19,737	19,799	19,741	19,910	19,396	19,392	19,647	19,748
Adj. R-Square	0.60	0.61	0.60	0.60	0.60	0.60	0.60	0.60

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.5: Additional time-varying covariates

	(1)	(2)	(3)	(4)	(5)
log (EPU) × log (hours reading newspapers)		-0.0225**	-0.0203***	-0.0201**	-0.0183**
		(0.0091)	(0.0075)	(0.0088)	(0.0078)
log (hours reading newspapers)		0.1107**	0.0990***	0.1010**	0.0902**
		(0.0430)	(0.0352)	(0.0413)	(0.0369)
Follow stock market					0.0442***
					(0.0069)
Willingness to take higher risks		0.0134			
		(0.0100)			
Charity donation			0.0179**		
			(0.0086)		
Life expectancy				0.0006*	
				(0.0003)	
Cognitive indicators	YES	YES	YES	YES	YES
Income/wealth quartiles	YES	YES	YES	YES	YES
Demographics	YES	YES	YES	YES	YES
Region fixed effects	YES	YES	YES	YES	YES
Household fixed effects	YES	YES	YES	YES	YES
Month-Year fixed effects	YES	YES	YES	YES	YES
Number of observations	18,979	14,941	19,651	12,021	18,979
Adj. R-Square	0.60	0.60	0.60	0.58	0.60

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.6: EPU and stock ownership: IV estimates

	(1)	(2)
log (EPU) × log(hours reading newspapers_lagged)	-0.0202**	
	(0.0088)	
log(hours reading newspapers_lagged)	0.0989**	
	(0.0416)	
log (EPU_lagged) × log (hours reading newspapers)		0.0008
		(0.0091)
log (hours reading newspapers)		0.0001
		(0.0432)
Cognitive indicators	YES	YES
Income/wealth quartiles	YES	YES
Demographics	YES	YES
Region fixed effects	YES	YES
Household fixed effects	YES	YES
Month-Year fixed effects	YES	YES
Number of observations	13,553	13,732
Adj. R-Square	0.62	0.62

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.7: Lagged Hours reading news and lagged EPU

	(1)	(2)
log (EPU) × log(hours reading newspapers_lagged)	-0.0202**	
	(0.0088)	
log(hours reading newspapers_lagged)	0.0989**	
	(0.0416)	
log (EPU_lagged) × log (hours reading newspapers)		0.0008
		(0.0091)
log (hours reading newspapers)		0.0001
		(0.0432)
Cognitive indicators	YES	YES
Income/wealth quartiles	YES	YES
Demographics	YES	YES
Region fixed effects	YES	YES
Household fixed effects	YES	YES
Month-Year fixed effects	YES	YES
Number of observations	13,553	13,732
Adj. R-Square	0.62	0.62

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.8: EPU and ownership of various financial asset categories

	(1) Stock IRAs	(2) Government bonds	(3) Corporate bonds
log (EPU) × log (hours reading newspapers)	-0.0007	-0.0114	-0.0109**
	(0.0073)	(0.0074)	(0.0043)
log (hours reading newspapers)	0.0024	0.0510	0.0493**
	(0.0346)	(0.0345)	(0.0203)
Cognitive indicators	YES	YES	YES
Income/wealth quartiles	YES	YES	YES
Demographics	YES	YES	YES
Region fixed effects	YES	YES	YES
Household fixed effects	YES	YES	YES
Month-Year fixed effects	YES	YES	YES
Number of observations	19,797	19,797	19,797
Adj. R-Square	0.60	0.49	0.43

Note: Stock IRAs refer to stocks held through IRAs. Government bonds refer to CDs, government savings bonds and T-bills. Corporate bonds refer to corporate, municipal, government or foreign bonds, or any other bond funds. See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

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Figure A.1: HRS and CAMS timeline

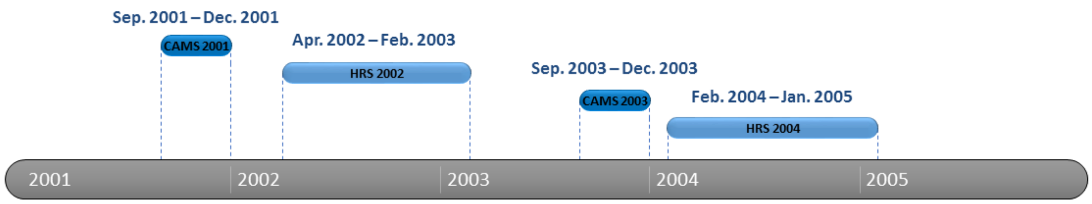
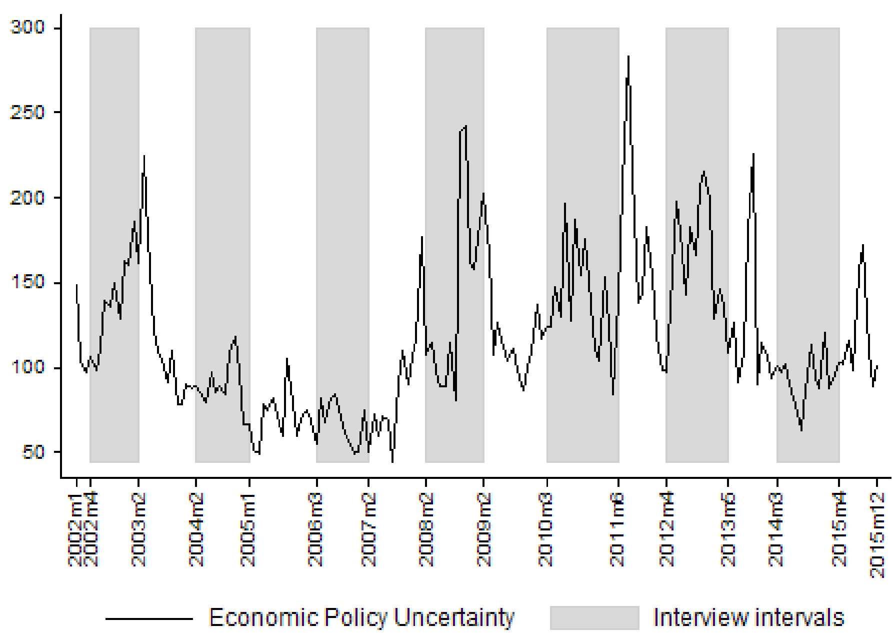


Figure A.2: EPU and interviews



Note: Shaded areas denote interview phases.

A.2 Robustness results

Table A.9: Stock ownership and transition rates

Wave	In	Out	Enter	Exit
2002-2004	0.26	0.56	0.09	0.09
2004-2006	0.25	0.59	0.06	0.11
2006-2008	0.23	0.61	0.07	0.09
2008-2010	0.22	0.64	0.07	0.08
2010-2012	0.21	0.65	0.05	0.09
2012-2014	0.20	0.67	0.06	0.07

Note: Stock ownership refers to stocks held directly or through mutual funds. Transition rates show ownership (In) and non-ownership (Out) in both waves as well as switches from non-ownership to ownership (Enter) or ownership to non-ownership (Exit) in the two waves.

Table A.10: Distributions, January 2001 - April 2015

	N	min	p10	p25	p50	p75	p90	max	mean	sd
Panel A										
EPU, interview phase	92	49.6	67.81	86.09	110.09	150.69	185.59	241.77	120.32	44.87
EPU, no interview	80	44.78	69.76	87.26	107.82	137.61	181.49	283.67	118.07	49.79
Total	172	44.78	69.48	86.23	108.45	144.91	184.82	283.67	119.28	47.1
Panel B										
VIX, interview phase	92	10.82	12.3	14.02	17.29	22.31	32.22	62.64	20.42	10.19
VIX, no interview	80	11.05	12.78	14.82	20.23	24.98	31.96	44.8	20.94	7.23
Total	172	10.82	12.47	14.22	17.92	24.53	31.98	62.64	20.66	8.92

Note: N denotes the number months over which the distribution was calculated.

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Table A.11: EPU: different pre-interview periods

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
log (EPU_3m) × log	-0.0119**	-0.0118**	-0.0126**	-0.0124**	-0.0179*					
(hours reading newspapers)	(0.0058)	(0.0058)	(0.0062)	(0.0062)	(0.0097)					
log (EPU_1m) × log						-0.0091*	-0.0090*	-0.0100*	-0.0099*	-0.0175**
(hours reading newspapers)						(0.0049)	(0.0049)	(0.0054)	(0.0054)	(0.0083)
log (hours reading newspapers)	0.0612**	0.0608**	0.0639**	0.0631**	0.0952**	0.0479**	0.0475**	0.0517*	0.0510*	0.0931**
	(0.0276)	(0.0276)	(0.0295)	(0.0296)	(0.0464)	(0.0236)	(0.0236)	(0.0262)	(0.0262)	(0.0401)
Expected stock market up					0.0005***					0.0005***
					(0.0001)					(0.0001)
Cognitive indicators	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Income/wealth quartiles	NO	NO	NO	YES	YES	NO	NO	NO	YES	YES
Demographics	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Region fixed effects	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Household fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Month-Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Number of observations	21,642	21,451	19,797	19,797	11,725	21,642	21,451	19,797	19,797	11,725
Adj. R-Square	0.59	0.59	0.60	0.60	0.60	0.59	0.59	0.60	0.60	0.60

Note: See note in Table 2. Double clustered standard errors by household and interview month in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

Table A.12: Data sources

Variable	**Description**	**Source**
S&P500	S&P500 index, used from 4/2002 - 4/2015	SNP Real Time Price (ˆSP500TR). Currency in USD, retrieved from Yahoo Finance, March 1, 2017
VIX	Model free measure of the implied volatility of a weighted range of S&P 500 Index options. Compiled and calculated by the Chicago Board Options Exchange (CBOE) using puts and calls at a variety of different strike prices, it reflects the market's expectation of volatility of the next 30 days.	VOLATILITY S&P 500 (ˆVIX), Chicago Options Delayed Price, retrieved from Yahoo Finance, March 1, 2017.
Prof_forecaster	Forecaster disagreement about future CPI as developed by Baker et al. (2016)	www.policyuncertainty.com
Oil	Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma, Dollars per Barrel, Monthly, Not Seasonally Adjusted	U.S. Energy Information Administration, Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma (DCOILWTICO), retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/DCOILWTICO, March 29, 2017.
real GDP gr	Real Gross Domestic Product, Percent Change from Preceding Period, Quarterly, Seasonally Adjusted Annual Rate	U.S. Bureau of Economic Analysis, Real Gross Domestic Product (A191RL1Q225SBEA), retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/A191RL1Q225SBEA, April 6, 2017.
int_rate	Effective Federal Funds Rate, Percent, Monthly, Not Seasonally Adjusted	Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate (FEDFUNDS), retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/FEDFUNDS, March 29, 2017.
CPI	Consumer Price Index for All Urban Consumers: All Items, Percent Change from Year Ago, Monthly, Seasonally Adjusted	U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL), retrieved from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/CPIAUCSL, April 21, 2017.
EPU_SE	Economic policy uncertainty index for Sweden as developed by Armelius et al. (2017)	www.policyuncertainty.com

APPENDIX B
THE RELATIVE IMPORTANCE OF TASTE SHOCKS AND PRICE MOVEMENTS IN THE VARIATION OF COST OF LIVING: EVIDENCE FROM BARCODE DATA

B.1 The consumer optimization problem

B.1.1 Demand

The consumer maximizes utility given budget E_t. The utility function is given by a Cobb-Douglas aggregate of CES sub-utilities,

$$U_t = \prod_{g \in G} U_{gt}^{\alpha_g} \quad with \quad \sum_{g \in G} \alpha_g = 1 \tag{B.1}$$

and

$$U_{gt} = \Big(\sum_{i \in I_g} (\varphi_{igt} c_{igt})^{\frac{\sigma_g - 1}{\sigma_g}} \Big)^{\frac{\sigma_g}{\sigma_g - 1}} \tag{B.2}$$

where φ_{igt} is the taste parameter of item i in product group g at time t. Total expenditures are,

$$E_t = \sum_{g \in G} \sum_{i \in I_g} p_{igt} c_{igt} \tag{B.3}$$

The Lagrangian is:

$$L = U_t - \lambda \big(\sum_{g \in G} \sum_{i \in I_g} p_{igt} c_{igt} - E_t \big) \tag{B.4}$$

First order condition w.r.t. c_{igt} (using the chain rule)

$$-\lambda p_{igt} + \frac{\delta U_t}{\delta U_{gt}} \frac{\delta U_{gt}}{\delta c_{igt}} = 0 \tag{B.5}$$

We have that:

$$\frac{\delta U_t}{\delta U_{gt}} = \frac{\alpha_g \prod_{g \in G} U_{gt}^{\alpha_g}}{U_{gt}} \tag{B.6}$$

$$\frac{\delta U_{gt}}{\delta c_{igt}} = \varphi_{igt} \Big(\sum_{i \in I_g} (\varphi_{igt} c_{igt})^{\frac{\sigma_g - 1}{\sigma_g}} \Big)^{\frac{\sigma_g}{\sigma_g - 1} - 1} (\varphi_{igt} c_{igt})^{\frac{\sigma_g - 1}{\sigma_g} - 1} \tag{B.7}$$

The term (B.7) can be simplified to:

$$\frac{\delta U_{gt}}{\delta c_{igt}} = \varphi_{igt}\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{-\frac{1}{\sigma_g}} \tag{B.8}$$

We now combine the first order conditions for two items of the same product group. The first order conditions of different items of the same product group have the following common term: $\frac{\delta U_t}{\delta U_{gt}}$. Combine the first order conditions for item i and item j of the same product group:

$$\frac{\frac{\delta U_{gt}}{\delta c_{igt}}}{\frac{\delta U_{gt}}{\delta c_{jgt}}} = \frac{p_{igt}}{p_{jgt}} \tag{B.9}$$

$$\frac{\varphi_{igt}\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{\frac{-1}{\sigma_g}}}{\varphi_{jgt}\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}(\varphi_{jgt}C_{jgt})^{\frac{-1}{\sigma_g}}} = \frac{p_{igt}}{p_{jgt}} \tag{B.10}$$

The middle term cancels:

$$\frac{\varphi_{igt}(\varphi_{igt}C_{igt})^{\frac{-1}{\sigma_g}}}{\varphi_{jgt}(\varphi_{jgt}c_{jgt})^{\frac{-1}{\sigma_g}}} = \frac{p_{igt}}{p_{jgt}} \tag{B.11}$$

Combining factors:

$$\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{\frac{\sigma_g-1}{\sigma_g}}\left(\frac{c_{igt}}{c_{jgt}}\right)^{\frac{-1}{\sigma_g}} = \frac{p_{igt}}{p_{jgt}} \tag{B.12}$$

Multiply both sides by $\left(\frac{p_{igt}}{p_{jgt}}\right)^{-\frac{1}{\sigma_g}}$:

$$\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{\frac{\sigma_g-1}{\sigma_g}}\left(\frac{p_{igt}c_{igt}}{p_{jgt}c_{jgt}}\right)^{\frac{-1}{\sigma_g}} = \frac{p_{igt}}{p_{jgt}}^{\frac{\sigma_g-1}{\sigma_g}} \tag{B.13}$$

Raise to power $-\sigma_g$:

$$\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{1-\sigma_g}\left(\frac{p_{igt}c_{igt}}{p_{jgt}c_{jgt}}\right) = \left(\frac{p_{igt}}{p_{jgt}}\right)^{1-\sigma_g} \tag{B.14}$$

We denote total expenditure in product group g as $E_{gt} = \sum_{j\in I_g} p_{jgt}c_{jgt}$ and divide the above expression by total sales of the product group E_{gt}. Now let $s_{igt} = \frac{p_{igt}c_{igt}}{E_{gt}}$ denote expenditure share of item i in product group g, then we have:

$$\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{1-\sigma_g}\left(\frac{s_{igt}}{s_{jgt}}\right) = \left(\frac{p_{igt}}{p_{jgt}}\right)^{1-\sigma_g} \tag{B.15}$$

Take logs:

$$(1-\sigma_g)(\ln\varphi_{igt}-\ln\varphi_{jgt})+\ln s_{igt}-\ln s_{jgt}=(1-\sigma_g)(\ln p_{igt}-\ln p_{jgt}) \tag{B.16}$$

Take the same equation at time t-1 and take the time difference

$$(1-\sigma_g)(\Delta\ln\varphi_{igt}-\Delta\ln\varphi_{jgt})+\Delta\ln s_{igt}-\Delta\ln s_{igt}=(1-\sigma_g)(\Delta\ln p_{igt}-\Delta\ln p_{jgt}) \tag{B.17}$$

Let $\Delta^{i,t}$ denote the double difference across time and varieties. The we can express the double differenced expenditure share: Or

$$\Delta^{i,t}\ln s_{igt}=(1-\sigma_g)(\Delta^{i,t}\ln p_{igt})-(1-\sigma_g)(\Delta^{i,t}\ln\varphi_{igt}) \tag{B.18}$$

Demand for a particular item

The equation (B.14) can be used to derive the demand curve of the particular item i. First rewrite (B.14) to isolate the spending on item j.

$$p_{jgt}c_{jgt}=\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{1-\sigma_g}(p_{igt}c_{igt})\left(\frac{p_{jgt}}{p_{igt}}\right)^{1-\sigma_g} \tag{B.19}$$

Summing over all items within the product group:

$$E_{gt}=\sum_{j\in I_g}\left(\frac{\varphi_{igt}}{\varphi_{jgt}}\right)^{1-\sigma_g}(p_{igt}c_{igt})\left(\frac{p_{jgt}}{p_{igt}}\right)^{1-\sigma_g} \tag{B.20}$$

Which can be rewritten as:

$$E_{gt}=c_{igt}\varphi_{igt}^{1-\sigma_g}{p_{igt}}^{\sigma_g}\sum_{j\in I_g}\left(\frac{p_{jgt}}{\varphi_{jgt}}\right)^{1-\sigma_g} \tag{B.21}$$

Define the exact price aggregate of product group g at time t:

$$P_{gt}(\varphi_{gt})\equiv P_{gt}\equiv\left(\sum_{j\in I_g}\left(\frac{p_{jgt}}{\varphi_{jgt}}\right)^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}} \tag{B.22}$$

We will use the notation $P_{gt}(\varphi_{gt})$ when we want to stress the fact that P_{gt} depends on the tastes φ_{jgt}. The total expenditure on product group g becomes:

$$E_{gt}=c_{igt}\varphi_{igt}^{1-\sigma_g}{p_{igt}}^{\sigma_g}P_{gt}^{1-\sigma_g} \tag{B.23}$$

Which gives the demand for item i

$$c_{igt} = \varphi_{igt}^{\sigma_g - 1} E_{gt} P_{gt}^{\sigma_g - 1} {p_{igt}}^{-\sigma_g} \tag{B.24}$$

B.1.2 Expenditure share of item i

Above we defined, the expenditure share of item i of product group g at time t, as a share of total spending on group g.

$$s_{igt} = \frac{p_{igt} c_{igt}}{E_{gt}} \tag{B.25}$$

Then we can use equation (B.23) to substitute out E_{gt}

$$s_{igt} = \frac{p_{igt} c_{igt}}{c_{igt} \varphi_{igt}^{1-\sigma_g} {p_{igt}}^{\sigma_g} P_{gt}^{1-\sigma_g}} \tag{B.26}$$

Simplify to:

$$s_{igt} = \frac{(\frac{p_{igt}}{\varphi_{igt}})^{1-\sigma_g}}{P_{gt}^{1-\sigma_g}} \tag{B.27}$$

or using the exact price aggregate of product group g:

$$s_{igt} = \frac{(\frac{p_{igt}}{\varphi_{igt}})^{1-\sigma_g}}{\left(\sum_{j \in I_g} (\frac{p_{jgt}}{\varphi_{jgt}})^{1-\sigma_g}\right)} \tag{B.28}$$

After taking the first derivative of the price aggregate defined in equation (B.22) equation, we obtain that the elasticity of the price aggregate for product group g w.r.t. price of variety i, ε_{igt}:

$$\varepsilon_{igt} = \frac{dP_{gt}}{dp_{igt}} \frac{p_{igt}}{P_{gt}} \tag{B.29}$$

$$\varepsilon_{igt} = \frac{(\frac{p_{igt}}{\varphi_{igt}})^{1-\sigma_g}}{\left(\sum_{j \in I_g} (\frac{p_{jgt}}{\varphi_{jgt}})^{1-\sigma_g}\right)} \tag{B.30}$$

It follows that ε_{igt} equal to the expenditure share of item i in product group g, s_{igt} from equation (B.28):

$$\varepsilon_{igt} = s_{igt} \tag{B.31}$$

B.1.3 Elasticity of the exact price aggregate of product group g w.r.t the price of item i

We start by taking first derivative of demand w.r.t. price is:

$$\frac{dc_{igt}}{dp_{igt}} = -\sigma_g \frac{c_{igt}}{p_{igt}} + (\sigma_g - 1)\frac{\partial P_{gt}}{\partial p_{igt}}\frac{c_{igt}}{P_{gt}} \tag{B.32}$$

$$= -\sigma_g \frac{c_{igt}}{p_{igt}} + (\sigma_g - 1)\frac{\partial P_{gt}}{\partial p_{igt}}\frac{p_{igt}}{P_{gt}}\frac{c_{igt}}{p_{igt}} \tag{B.33}$$

or using the equality of expenditure share and price elasticity

$$\frac{dc_{igt}}{dp_{igt}} = -\sigma_g \frac{c_{igt}}{p_{igt}} + (\sigma_g - 1)s_{igt}\frac{c_{igt}}{p_{igt}} \tag{B.34}$$

B.2 The supply equation

B.2.1 Profit maximization and the markup

This section formally derives the firm level markup from equation (2.30) in the main text. As before, assume the firm faces variable cost shocks z_{igt} and total variable cost V_{igt}, such that

$$V_{igt}(c_{igt}) = z_{igt}c_{igt}^{1+\delta_g} \tag{B.35}$$

The producer's profit maximization problem is:

$$\Pi_{igt} = p_{igt}c_{igt} - V_{igt}(c_{igt}) - H_{gt} \tag{B.36}$$

such that

$$c_{igt} = \varphi_{igt}^{\sigma g-1} p_{igt}^{-\sigma_g} P_{gt}^{\sigma g-1} E_{gt} \tag{B.37}$$

The first order condition of profit maximization is:

$$c_{igt} + p_{igt}\frac{\partial c_{igt}}{\partial p_{igt}} - \frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}\frac{\partial c_{igt}}{\partial p_{igt}} = 0 \tag{B.38}$$

Using equation (B.34), we rewrite the first order condition the following way:

$$c_{igt} + p_{igt}(-\sigma_g)\frac{c_{igt}}{p_{igt}} + p_{igt}(\sigma_g - 1)s_{igt}\frac{c_{igt}}{p_{igt}} - \frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}(-\sigma_g)\frac{c_{igt}}{p_{igt}} \tag{B.39}$$

$$-\frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}(\sigma_g - 1)s_{igt}\frac{c_{igt}}{p_{igt}} = 0 \tag{B.40}$$

Simplify and divide by c_{igt}:

$$1+(-\sigma_g)+(\sigma_g-1)s_{igt}-\frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}(-\sigma_g)\frac{1}{p_{igt}}-\frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}(\sigma_g-1)s_{igt}\frac{1}{p_{igt}}=0$$

Let markup $\mu_{igt}=\frac{p_{igt}}{\frac{\partial V_{igt}(c_{igt})}{\partial c_{igt}}}$, then the above first order condition becomes:

$$1-\sigma_g+(\sigma_g-1)s_{igt}+\sigma_g\frac{1}{\mu_{igt}}-(\sigma_{gt}-1)s_{gt}\frac{1}{\mu_{igt}}=0 \tag{B.41}$$

From which we can express the firm level markup:

$$\mu_{igt}=\frac{(\sigma_g-1)s_{igt}-\sigma_g}{1+(\sigma_g-1)s_{igt}-\sigma_g} \tag{B.42}$$

The supply equation

In equilibrium the firm charges a price that is equal to the marginal cost multiplied by the firm specific markup:

$$p_{igt}=\mu_{igt}(1+\delta_g)z_{igt}c_{igt}^{\delta_g} \tag{B.43}$$

Consider this condition for item i and j of the same product group and divide:

$$\frac{p_{igt}}{p_{jgt}}=\frac{\mu_{igt}}{\mu_{jgt}}\frac{z_{igt}}{z_{jgt}}\frac{c_{igt}^{\delta_g}}{c_{jgt}^{\delta_g}} \tag{B.44}$$

Multiply both sides by $\left(\frac{p_{igt}}{p_{jgt}}\right)^{\delta_g}$

$$\left(\frac{p_{igt}}{p_{jgt}}\right)^{1+\delta_g}=\frac{\mu_{igt}}{\mu_{jgt}}\frac{z_{igt}}{z_{jgt}}\left(\frac{p_{igt}c_{igt}}{p_{jgt}c_{jgt}}\right)^{\delta_g} \tag{B.45}$$

By dividing both numerator and denominator in the last term by total sales of group g, we arrive at an expression in sales shares s_{igt} and s_{jgt}, from which we take logs:

$$(1+\delta_g)(\ln p_{igt}-\ln p_{jgt})=\ln\mu_{igt}z_{igt}-\ln\mu_{jgt}z_{jgt}+\delta_g(\ln s_{igt}-\ln s_{jgt}) \tag{B.46}$$

Now take the same equation at time t-1 and take the time difference:

$$(1+\delta_g)(\Delta\ln p_{igt}-\Delta\ln p_{jgt})=\Delta\ln\mu_{igt}z_{igt}-\Delta\ln\mu_{jgt}z_{jgt}+\delta_g(\Delta\ln s_{igt}-\Delta\ln s_{jgt}) \tag{B.47}$$

Using $\Delta^{i,t}$ as defined above as the joint time difference and across item difference, we can write the above as:

$$(1+\delta_g)\Delta^{i,t}\ln p_{igt} = \Delta\ln\mu_{igt}z_{igt} + \delta_g\Delta\ln s_{igt} \tag{B.48}$$

Rearrange to get:

$$\Delta^{i,t}\ln p_{igt} = \frac{\delta_g}{1+\delta_g}\Delta^{i,t}\ln s_{igt} + \frac{1}{1+\delta_g}\Delta^{i,t}\ln\mu_{igt}z_{igt} \tag{B.49}$$

Applying the notation $\kappa_{gt} = \frac{1}{1+\delta_g}\Delta^{i,t}\mu_{igt}z_{igt}$, the relative supply can be further rewritten to:

$$\Delta^{i,t}\ln p_{igt} = \frac{\delta_g}{1+\delta_g}\Delta^{i,t}\ln s_{igt} + \kappa_{igt} \tag{B.50}$$

B.3 The cost-of-living index

B.3.1 Derivation of the cost-of-living index

We start with solving the expenditure minimization problem at the product group level:

$$m(\boldsymbol{c_0},\boldsymbol{\varphi},\boldsymbol{p}) = \min_{\boldsymbol{c}}\{\boldsymbol{pc} : U(\boldsymbol{c},\boldsymbol{\varphi}) = U(\boldsymbol{c_0},\boldsymbol{\varphi})\} \tag{B.51}$$

where $U(\boldsymbol{c_0},\boldsymbol{\varphi})$ is the indirect utility function that results from plugging in the Marshallian demand from equation (B.24) into the product group level utility function. The Lagrangian of the minimization problem in the money metric function is:

$$L^* = \sum_{g\in G}\sum_{i\in I_g} p_{igt}c_{igt} - \lambda^*\big(U_t - U(\boldsymbol{c_0},\boldsymbol{\varphi})\big) \tag{B.52}$$

First order condition w.r.t. c_{igt} (using the chain rule):

$$p_{igt} - \lambda^*\frac{\delta U_t}{\delta U_{gt}}\frac{\delta U_{gt}}{\delta c_{igt}} = 0 \tag{B.53}$$

If we define $\lambda = \frac{1}{\lambda^*}$, we can rewrite the first order condition identical to the consumers utility maximization problem:

$$-\lambda p_{igt} + \frac{\delta U_t}{\delta U_{gt}}\frac{\delta U_{gt}}{\delta c_{igt}} = 0 \tag{B.54}$$

Divide by φ_{igt} and rearange:

$$\lambda\frac{p_{igt}}{\varphi_{igt}} = \frac{\delta U_t}{\delta U_{gt}}\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}} \tag{B.55}$$

Raise to power $1-\sigma_g$ and aggregate over all items in group g:

$$\sum_{i\in I_g}\Big(\lambda\frac{p_{igt}}{\varphi_{igt}}\Big)^{1-\sigma_g}=\Big(\frac{\delta U_t}{\delta U_{gt}}\Big)^{1-\sigma_g}\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g} \tag{B.56}$$

Raise to power $\frac{1}{1-\sigma_g}$:

$$\lambda\Big(\sum_{i\in I_g}\Big(\frac{p_{igt}}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}}=\Big(\frac{\delta U_t}{\delta U_{gt}}\Big)\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}} \tag{B.57}$$

The second term on the left hand side is the exact price aggregate over items in product group g. So we have,

$$\lambda P_{gt}=\Big(\frac{\delta U_t}{\delta U_{gt}}\Big)\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}} \tag{B.58}$$

Now we show that $\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}}$ is equal to 1. Use $\frac{\delta U_{gt}}{\delta c_{igt}}$ as above in (B.8). Then, we have:

$$\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}}=\Big(\sum_{i\in I_g}\Big(\varphi_{igt}\Big(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\Big)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{\frac{-1}{\sigma_g}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}} \tag{B.59}$$

Simplify:

$$\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}}=\Big(\sum_{i\in I_g}\Big(\Big(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\Big)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{\frac{-1}{\sigma_g}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}} \tag{B.60}$$

Simplify further:

$$\Big(\sum_{i\in I_g}\Big(\frac{\delta U_{gt}}{\delta c_{igt}}\frac{1}{\varphi_{igt}}\Big)^{1-\sigma_g}\Big)^{\frac{1}{1-\sigma_g}}=\Big(\sum_{i\in I_g}\Big(\Big(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\Big)^{-1}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\Big)\Big)^{\frac{1}{1-\sigma_g}} \tag{B.61}$$

Which is equal to 1. So we have shown that:

$$\lambda P_{gt}=\frac{\delta U_t}{\delta U_{gt}} \tag{B.62}$$

Now we show that total expenditure on product group g, $\sum_{i\in I_g}p_{igt}c_{igt}$ is equal to $P_{gt}U_{gt}$. We use what we have just shown above $\lambda P_{gt}=\frac{\delta U_t}{\delta U_{gt}}$ and plug it into the first order condition $-\lambda p_{igt}+\frac{\delta U_t}{\delta U_{gt}}\frac{\delta U_{gt}}{\delta c_{igt}}=0$, we get:

$$-\lambda p_{igt}+\lambda P_{gt}\frac{\delta U_{gt}}{\delta c_{igt}}=0 \tag{B.63}$$

Divide by λ,multiply by c_{igt}, sum over all i in g and rearange,

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}\sum_{i\in I_g} c_{igt}\frac{\delta U_{gt}}{\delta c_{igt}} \tag{B.64}$$

Again use equation (B.8),

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}\sum_{i\in I_g}\left(\varphi_{igt}c_{igt}\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{\frac{-1}{\sigma_g}}\right) \tag{B.65}$$

Simplify,

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}\sum_{i\in I_g}\left(\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right) \tag{B.66}$$

Simplify again, (bring sum out of the outer sum)

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}\left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{1}{\sigma_g-1}}\sum_{i\in I_g}\left((\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right) \tag{B.67}$$

Using the definition of U_{gt}

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}U_{gt}^{\frac{1}{\sigma_g}}U_{gt}^{\frac{\sigma_g-1}{\sigma_g}} \tag{B.68}$$

or

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}U_{gt} \tag{B.69}$$

with U_{gt} being the indirect utility function and c_{igt} the Marshallian demand, we arrive at the well-known identity for the CES utility function:

$$\sum_{i\in I_g} p_{igt}c_{igt} = P_{gt}C_{gt} \tag{B.70}$$

$$C_{gt} = \left(\sum_{i\in I_g}(\varphi_{igt}c_{igt})^{\frac{\sigma_g-1}{\sigma_g}}\right)^{\frac{\sigma_g}{\sigma_g-1}} \tag{B.71}$$

The Cobb-Douglas utility function at the upper level and CES utilities at the lower level imply that the total expenditure, aggregated over all product groups, at time t takes the form:

$$E_t = C(\boldsymbol{c_t},\boldsymbol{\varphi_t})P(\boldsymbol{p_t},\boldsymbol{\varphi_t}) \tag{B.72}$$

with

$$C(\boldsymbol{c_t}, \boldsymbol{\varphi_t}) = \prod_{g \in G} (C_{gt})^{\alpha_g} \tag{B.73}$$

$$P(\boldsymbol{p_t}, \boldsymbol{\varphi_t}) = \prod_{g \in G} (\frac{\alpha_g}{P_{gt}})^{\alpha_g} \tag{B.74}$$

where $\boldsymbol{c_t}$ is the vector for product group CES consumption aggregates, C_{gt}, further, $\boldsymbol{p_t}$ is the vector for product group price aggregates, P_{gt} and c_{igt} is the Marshallian demand. Further, as defined in the main text, the cost-of-living index, in the presence of taste changes, between period t and t-1 is:

$$P_N(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_t}, \boldsymbol{p_{t-1}}) = \frac{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_t})}{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}, \boldsymbol{p_{t-1}})} \tag{B.75}$$

Now the denominator denotes optimal expenditure in period t-1,

$$m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_t}) = C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}) P(\boldsymbol{p_{t-1}}, \boldsymbol{\varphi_{t-1}}) \tag{B.76}$$

The numerator measures minimum expenditure needed to reach the utility curve that goes through the base period basket under period t prices:

$$m(\boldsymbol{c}_{t-1}, \boldsymbol{\varphi_{t-1}}, \boldsymbol{p}_{t-1}) = C(\boldsymbol{c}_{t-1}, \boldsymbol{\varphi_t}) P(\boldsymbol{p_t}, \boldsymbol{\varphi_t}) \tag{B.77}$$

where $C(\boldsymbol{c}_t, \boldsymbol{\varphi_t})$ denotes the Cobb-Douglas consumption aggregator. The cost-of-living index at the aggregate level takes is:

$$P_N = \frac{C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}})} \frac{P(\boldsymbol{p_t}, \boldsymbol{\varphi_t})}{P(\boldsymbol{p_{t-1}}, \boldsymbol{\varphi_{t-1}})} \tag{B.78}$$

By equation (B.74), the cost-of-living index can be rewritten:

$$P_N = \frac{C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}})} \prod_{g \in G} \Big(\frac{P_g(\boldsymbol{p_{gt}}, \boldsymbol{\varphi_t})}{P_g(\boldsymbol{p_{gt-1}}, \boldsymbol{\varphi_{gt-1}})} \Big)^{\alpha_g} \tag{B.79}$$

B.3.2 Deriving the price change effect and taste change effect

The cost-of-living index under changing preferences can also be written as,

$$P_N = \frac{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_t})}{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_{t-1}})} \frac{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}, \boldsymbol{p_{t-1}})}{m(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}, \boldsymbol{p_{t-1}})} \tag{B.80}$$

where $\frac{m(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t},\boldsymbol{p_t})}{m(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t},\boldsymbol{p_{t-1}})}$ measures the price effect and $\frac{m(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t},\boldsymbol{p_{t-1}})}{m(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_{t-1}},\boldsymbol{p_{t-1}})}$ measures the taste change effect. Note that the denominator of the price effect is the minimum expenditure needed to obtain utility in period t at the base period basket at prices of $t-1$:

$$m(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t},\boldsymbol{p_{t-1}}) = C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t}) \tag{B.81}$$

Importantly, $P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})$ denotes the price aggregate at prices of period $t-1$ constructed using taste parameters of period t. So the cost of living index using our CES preferences becomes,

$$P_N = \frac{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_t},\boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}\frac{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_{t-1}})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_{t-1}})} \tag{B.82}$$

Which is equal to:

$$P_N = \frac{P(\boldsymbol{p_t},\boldsymbol{\varphi_t})}{P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}\frac{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_{t-1}})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_{t-1}})} \tag{B.83}$$

where the first term gives the price change effect $\frac{P(\boldsymbol{p_t},\boldsymbol{\varphi_t})}{P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}$ and the second term gives the taste change effect: $\frac{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_t})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_t})}{C(\boldsymbol{c_{t-1}},\boldsymbol{\varphi_{t-1}})P(\boldsymbol{p_{t-1}},\boldsymbol{\varphi_{t-1}})}$.

We show that $\frac{P_g(\boldsymbol{p_{gt}},\boldsymbol{\varphi_{gt}})}{P_g(\boldsymbol{p_{gt-1}},\boldsymbol{\varphi_{gt-1}})}$ can be written as a weighted geometric average of price ratios and taste parameter ratios. We start with the equation (B.27) given above,

$$s_{igt} = \frac{\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{1-\sigma_g}}{P_{gt}^{1-\sigma_g}} \tag{B.84}$$

from which we express the product group level price aggregate:

$$P_{gt} = s_{igt}^{\frac{-1}{1-\sigma_g}} p_{igt}\varphi_{igt}^{-1} \tag{B.85}$$

Divide by the same equation written for period $t-1$:

$$\frac{P_{gt}}{P_{gt-1}} = \left(\frac{s_{igt}}{s_{igt-1}}\right)^{\frac{-1}{1-\sigma_g}} \frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}} \tag{B.86}$$

Take logs:

$$\ln\frac{P_{gt}}{P_{gt-1}} = \ln\left(\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}}\right) - \frac{1}{(1-\sigma_g)}\ln\left(\frac{s_{igt}}{s_{igt-1}}\right) \tag{B.87}$$

Define log-change weights[1]:

$$w_{igt} = \frac{f(s_{igt},s_{igt-1})}{\sum_{i\in I_g} f(s_{igt},s_{igt-1})} \tag{B.88}$$

[1]Note that w_{igt} summed over all varieties in product group g is equal to 1.

Multiply both sides of equation (B.87) by the weights w_{igt}:

$$w_{igt}\ln\frac{P_{gt}}{P_{gt-1}}=w_{igt}\ln\left(\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)-\frac{1}{(1-\sigma_g)}w_{igt}\ln\left(\frac{s_{igt}}{s_{igt-1}}\right) \tag{B.89}$$

Use the definition of log-change weight:

$$w_{igt}\ln\frac{P_{gt}}{P_{gt-1}}=w_{igt}\ln\left(\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)-\frac{1}{(1-\sigma_g)}\frac{f(s_{igt},s_{igt-1})}{\sum_{i\in I_g}f(s_{igt},s_{igt-1})}\ln\left(\frac{s_{igt}}{s_{igt-1}}\right) \tag{B.90}$$

In the special case when $s_{igt}=s_{igt-1}$ the last term becomes zero, when shares vary over time, it becomes:

$$\frac{s_{igt}-s_{igt-1}}{\sum_{i\in I_g}f(s_{igt},s_{igt-1})} \tag{B.91}$$

Summing equation (B.90) over all varieties i in product group g, we get:

$$\ln\frac{P_{gt}}{P_{gt-1}}=\sum_{i\in I_g}w_{igt}\ln\left(\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}}\right) \tag{B.92}$$

From which we can express the Sato-Vartia index at the product group level (corrected for taste shocks).

$$\frac{P_{gt}}{P_{gt-1}}=\prod_{i\in I_g}\left(\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}}\right)^{w_{igt}} \tag{B.93}$$

B.3.3 Writing the taste-adjusted cost-of-living index as a ”common-goods price index”

In this section we show how $\frac{P_g(\boldsymbol{p_{gt}},\boldsymbol{\varphi_{gt}})}{P_g(\boldsymbol{p_{gt-1}},\boldsymbol{\varphi_{gt-1}})}$ can be written as a common-goods price index as in Redding and Weinstein (2016, 2019) (which is identical to their unified price index in the absence of changes in the number of varieties). Start from equation (B.86):

$$\frac{P_{gt}}{P_{gt-1}}=\left(\frac{s_{igt}}{s_{igt-1}}\right)^{\frac{-1}{1-\sigma_g}}\frac{p_{igt}}{p_{igt-1}}\frac{\varphi_{igt-1}}{\varphi_{igt}} \tag{B.94}$$

Take logs and sum over all $i\in I_g$.

$$\sum_{i\in I_g}\ln\frac{P_{gt}}{P_{gt-1}}=\sum_{i\in I_g}\ln\frac{p_{igt}}{p_{igt-1}}+\sum_{i\in I_g}\ln\frac{\varphi_{igt-1}}{\varphi_{igt}}-\frac{1}{1-\sigma_g}\sum_{i\in I_g}\ln\frac{s_{igt}}{s_{igt-1}} \tag{B.95}$$

Note that we have assumed that $\prod \varphi_{igt} = 1$ and $\prod \varphi_{igt-1} = 1$, from which assumption it follows that $\sum_{i \in I_g} \ln \frac{\varphi_{igt-1}}{\varphi_{igt}} = 0$. Then the above equation becomes:

$$N_g \ln \frac{P_{gt}}{P_{gt-1}} = \sum_{i \in I_g} \ln \frac{p_{igt}}{p_{igt-1}} - \frac{1}{1-\sigma_g} \sum_{i \in I_g} \ln \frac{s_{igt}}{s_{igt-1}} \tag{B.96}$$

Dividing by N_g, the number of product varieties in product group g, on both sides:

$$\ln \frac{P_{gt}}{P_{gt-1}} = \sum_{i \in I_g} \ln \left(\frac{p_{igt}}{p_{igt-1}} \right)^{\frac{1}{N_g}} - \frac{1}{1-\sigma_g} \sum_{i \in I_g} \ln \left(\frac{s_{igt}}{s_{igt-1}} \right)^{\frac{1}{N_g}} \tag{B.97}$$

or

$$\frac{P_{gt}}{P_{gt-1}} = \prod_{i \in I_g} \left(\frac{p_{igt}}{p_{igt-1}} \right)^{\frac{1}{N_g}} \left(\frac{s_{igt}}{s_{igt-1}} \right)^{\frac{1}{N_g} \frac{1}{\sigma_g - 1}} \tag{B.98}$$

Note that Redding and Weinstein (2016) define the common-goods price index or unified price index to be a cost-of-living index. They state '*Our objective in this paper is to allow for demand shifts for individual goods while still being able to make consistent comparisons of welfare over time. To be able to make such consistent welfare comparisons between a pair of time periods, one must obtain the same change in the cost of living whether one uses today's preferences for both periods, yesterday's preferences for both periods, of the preferences of each period (so that all three comparisons are consistent with one another)*. For this to be true they require *'demand-shocks that do not directly affect utility'*. So they start by expressing the change in the cost-of-living as the ratio between the unit expenditure functions in both periods $\frac{P_{gt}}{P_{gt-1}}$ (see their equation (4)). However the 'units' of expenditure are not comparable if tastes change. Following our theoretical definition of cost-of-living (which follows Bassmann et al. (1984) and Balk (1989) this ratio is not equal to a cost-of-living. It needs to be pre-multiplied by the ratio of indirect utilities in both periods.

B.3.4 Taste shocks

In this subsection, we derive a formula for taste shocks as a function of prices, expenditures shares and the elasticity of substitution. Start with equation (B.27) and raise it to power N_g:

$$s_{igt} = \frac{\left(\frac{p_{igt}}{\varphi_{igt}} \right)^{1-\sigma_g}}{\sum_{j \in I_g} \left(\frac{p_{jgt}}{\varphi_{jgt}} \right)^{1-\sigma_g}} \tag{B.99}$$

$$s_{igt}^{\frac{1}{N_g}} = \frac{\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{\frac{1-\sigma_g}{N_g}}}{\left(\sum_{j\in I_g}\left(\frac{p_{jgt}}{\varphi_{jgt}}\right)^{1-\sigma_g}\right)^{\frac{1}{N_g}}} \tag{B.100}$$

There is one such equation for every i in I_g and we multiply them:

$$\prod_{i\in I_g} s_{igt}^{\frac{1}{N_g}} = \frac{\prod_{i\in I_g}\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{\frac{1-\sigma_g}{N_g}}}{\sum_{j\in I_g}\left(\frac{p_{jgt}}{\varphi_{jgt}}\right)^{1-\sigma_g}} = \frac{\left(\prod\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{\frac{1}{N_g}}\right)^{1-\sigma_g}}{\sum_{j\in I}\left(\frac{p_{jt}}{\varphi_{jt}}\right)^{1-\sigma}} = \frac{\left(\frac{\prod p_{igt}^{\frac{1}{N_g}}}{\prod \varphi_{igt}^{\frac{1}{N_g}}}\right)^{1-\sigma_g}}{\sum_{j\in I_g}\left(\frac{p_{jgt}}{\varphi_{jgt}}\right)^{1-\sigma_g}} \tag{B.101}$$

Next, we divide equation (B.100) and (B.101):

$$\frac{s_{igt}}{\prod s_{igt}^{\frac{1}{N_g}}} = \frac{\left(\frac{p_{igt}}{\varphi_{igt}}\right)^{1-\sigma_g}}{\left(\frac{\prod p_{igt}^{\frac{1}{N_g}}}{\prod \varphi_{igt}^{\frac{1}{N_g}}}\right)^{1-\sigma_g}} \tag{B.102}$$

Raise to power $\frac{1}{1-\sigma_g}$

$$\frac{s_{igt}}{\prod s_{igt}^{\frac{1}{N_g}}}^{\frac{1}{1-\sigma_g}} = \frac{\frac{p_{igt}}{\varphi_{igt}}}{\prod p_{igt}^{\frac{1}{N_g}}} \prod \varphi_{igt}^{\frac{1}{N_g}} \tag{B.103}$$

From this we can express the taste parameter:

$$\varphi_{igt} = \left(\frac{p_{igt}}{\prod p_{igt}^{\frac{1}{N_g}}}\left(\frac{s_{igt}}{\prod s_{igt}^{\frac{1}{N_g}}}\right)^{-\frac{1}{1-\sigma_g}}\right)\prod \varphi_{igt}^{\frac{1}{N_g}} \tag{B.104}$$

Note that our normalisation assumption implies that $\prod_{i\in I_g}(\frac{\varphi_{igt-1}}{\varphi_{igt}})^{\frac{1}{N_g}} = 1$. It follows that the relative tastes between period t and $t-1$ can be written as:

$$\frac{\varphi_{igt-1}}{\varphi_{igt}} = \left(\frac{p_{igt-1}}{\prod p_{igt-1}^{\frac{1}{N_g}}}\left(\frac{s_{igt-1}}{\prod s_{it-1}^{\frac{1}{N_g}}}\right)^{-\frac{1}{1-\sigma_g}}\right)\left(\frac{p_{igt}}{\prod p_{igt}^{\frac{1}{N_g}}}\left(\frac{s_{igt}}{\prod s_{it}^{\frac{1}{N_g}}}\right)^{-\frac{1}{1-\sigma_g}}\right)^{-1} \tag{B.105}$$

B.3.5 An example of the cost-of-living index

In this section we give an example for the cost-of-living index for the simplest case of two goods. Utility at time t is:

$$U_t = \left((\varphi_{1t}c_{1t})^{\frac{\sigma-1}{\sigma}} + (\varphi_{2t}c_{2t})^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{B.106}$$

The exact price index at time t from equation (3.17) then becomes:

$$P_t = \left(\left(\frac{p_{1t}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{B.107}$$

The cost-of-living index from equation (B.80) becomes:

$$P^{Coli} = \frac{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_t})}{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_{t-1}})} \frac{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_{t-1}})}{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}), \boldsymbol{p_{t-1}})} \tag{B.108}$$

Whose elements are:

$$m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_t}) = C_t(\boldsymbol{c_{t-1}})P_t = \tag{B.109}$$

$$\left((\varphi_{1t}c_{1t-1})^{\frac{\sigma-1}{\sigma}} + (\varphi_{2t}c_{2t-1})^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \left(\left(\frac{p_{1t}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{B.110}$$

$$m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_{t-1}}) = C_t(\boldsymbol{c_{t-1}})P_{t-1} = \tag{B.111}$$

$$\left((\varphi_{1t}c_{1t-1})^{\frac{\sigma-1}{\sigma}} + (\varphi_{2t}c_{2t-1})^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \left(\left(\frac{p_{1t-1}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t-1}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{B.112}$$

Note that P_{t-1} has prices at time $t-1$ with taste parameters at time t.

$$m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}), \boldsymbol{p_{t-1}}) = C_{t-1}(\boldsymbol{c_{t-1}})P_{t-1} = \tag{B.113}$$

$$\left((\varphi_{1t-1}c_{1t-1})^{\frac{\sigma-1}{\sigma}} + (\varphi_{2t-1}c_{2t-1})^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \left(\left(\frac{p_{1t-1}}{\varphi_{1t-1}}\right)^{1-\sigma} + \left(\frac{p_{2t-1}}{\varphi_{2t-1}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{B.114}$$

P^{Coli} can then be written as the pure price change effect multiplied by the taste change effect:

$$\Gamma_p^{Coli} - \Gamma_\varphi^{Coli} = \frac{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_t})}{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_{t-1}})} = \frac{\left(\left(\frac{p_{1t}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{\left(\left(\frac{p_{1t-1}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t-1}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}} \tag{B.115}$$

Note that the price change effect captures the effect of a pure price change at constant taste (with base period t).

$$\Gamma_{\varphi}^{Coli} = \frac{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_t}), \boldsymbol{p_{t-1}})}{m(C(\boldsymbol{c_{t-1}}, \boldsymbol{\varphi_{t-1}}), \boldsymbol{p_{t-1}})} = \tag{B.116}$$

$$\frac{\left(\left(\varphi_{1t}c_{1t-1}\right)^{\frac{\sigma-1}{\sigma}} + \left(\varphi_{2t}c_{2t-1}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}}{\left(\left(\varphi_{1t-1}c_{1t-1}\right)^{\frac{\sigma-1}{\sigma}} + \left(\varphi_{2t-1}c_{2t-1}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}} \frac{\left(\left(\frac{p_{1t-1}}{\varphi_{1t}}\right)^{1-\sigma} + \left(\frac{p_{2t-1}}{\varphi_{2t}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{\left(\left(\frac{p_{1t-1}}{\varphi_{1t-1}}\right)^{1-\sigma} + \left(\frac{p_{2t-1}}{\varphi_{2t-1}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}} \tag{B.117}$$

Equation (B.117) shows the mechanism of a taste change. In particular, an increase in tastes decreases prices and increases the expenditure weight. It therefore has a similar effect on expenditures as a price change.

B.3.6 Prices index and quantity index

In this section we show how the expenditure change between two periods can be written as the product of a price index and a quantity index. Consider period 1 and 2 with nominal expenditures E_1 and E_2. We will derive P_N and Q_N as follows:

$$\frac{E_2}{E_1} = \frac{P_2}{P_1}\frac{Q_2}{Q_1} \tag{B.118}$$

Consumer optimization implies that:

$$\frac{E_2}{E_1} \equiv \frac{m(\boldsymbol{q_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})} \tag{B.119}$$

where $\boldsymbol{q_2}$ and $\boldsymbol{q_1}$ are the utility maximizing consumption baskets corresponding to period 1 and period 2. Then,

$$\frac{E_2}{E_1} \equiv \frac{m(\boldsymbol{q_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})}\frac{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})} \tag{B.120}$$

Rearange :

$$\frac{E_2}{E_1} \equiv \frac{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})}\frac{m(\boldsymbol{q_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})} \tag{B.121}$$

The first term is our price index under taste changes:

$$P_N = \frac{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_1}, \boldsymbol{p_1})} \tag{B.122}$$

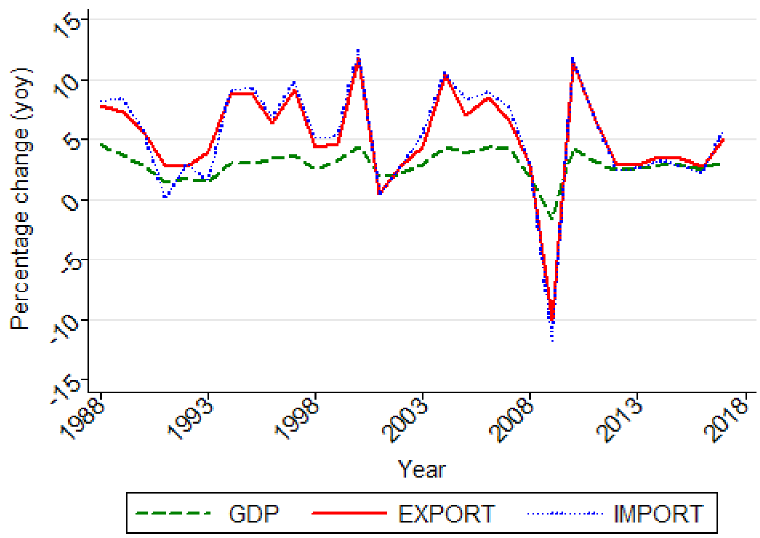
The second term is the quantity index.

$$Q_N = \frac{m(\boldsymbol{q_2}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})}{m(\boldsymbol{q_1}, \boldsymbol{\varphi_2}, \boldsymbol{p_2})} \tag{B.123}$$

APPENDIX C
A MODEL OF TRADE IN USED DURABLE GOODS

C.1 World trade

Figure C.1: World GDP, export and import

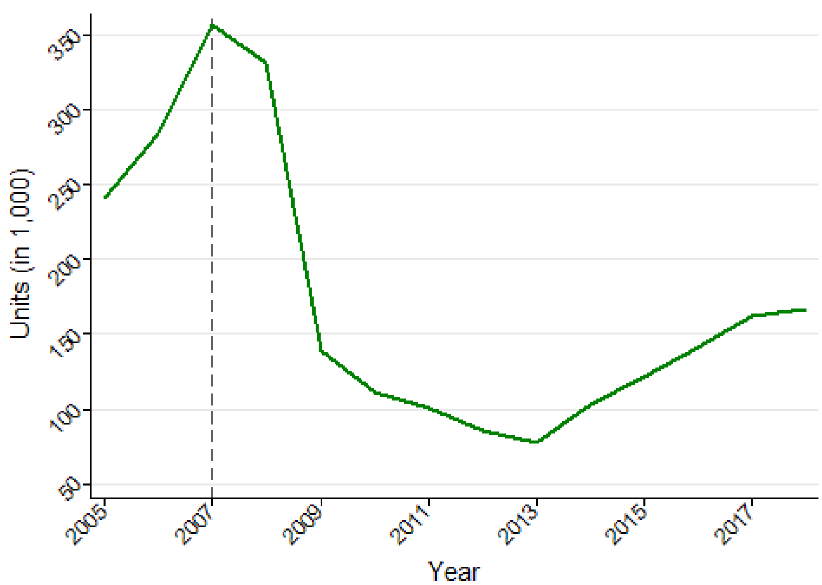


Note: Annual series on growth rate in world GDP, world export and import of goods and services come from the World Bank database on World Development Indicators.

Figure C.2: Evolution of overall new car registrations for Austria, Finland and Sweden

Note: Austria, Finland and Sweden joined the European Union in 1995.

Figure C.3: Evolution of overall new car registrations for Romania and Bulgaria



Note: Romania and Bulgaria joined the European Union in 2007.

C.2 Free trade equilibrium

C.2.1 Proof of Definition 2

Proof. (To be completed) Starting point for the derivation is the free trade equilibrium price.

$$\frac{p_a^*}{p_0^*} = \left(\frac{S_{Ha}+S_{Fa}}{S_{H0}+S_{F0}}\right)^{-\frac{1}{\theta}} \left(\frac{\frac{\lambda_{H0}^{\theta}}{(P_H^*)^{1-\theta}}W_H + \frac{\lambda_{F0}^{\theta}}{(P_F^*)^{1-\theta}}W_F}{\frac{\lambda_{Ha}^{\theta}}{(P_H^*)^{1-\theta}}W_H + \frac{\lambda_{Fa}^{\theta}}{(P_F^*)^{1-\theta}}W_F}\right)^{-\frac{1}{\theta}}$$

$$\frac{p_a^*}{p_0^*} = \left(\frac{S_{H0}}{S_{H0}+S_{F0}}\eta_H^{-a}(1-\delta)^a + \frac{S_{F0}}{S_{H0}+S_{F0}}\eta_F^{-a}(1-\delta)^a\right)^{-\frac{1}{\theta}} \left(\frac{\frac{\lambda_{H0}^{\theta}}{(P_H^*)^{1-\theta}}W_H + \frac{\lambda_{F0}^{\theta}}{(P_F^*)^{1-\theta}}W_F}{\frac{\lambda_{Ha}^{\theta}}{(P_H^*)^{1-\theta}}W_H + \frac{\lambda_{Fa}^{\theta}}{(P_F^*)^{1-\theta}}W_F}\right)^{-\frac{1}{\theta}}$$

$$\frac{p_a^*}{p_0^*} = \left(\frac{S_{H0}}{S_{H0}+S_{F0}}\eta_H^{-a}(1-\delta)^a + \frac{S_{F0}}{S_{H0}+S_{F0}}\eta_F^{-a}(1-\delta)^a\right)^{-\frac{1}{\theta}} \left(\frac{\frac{\lambda_{H0}^{\theta}}{(P_H^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{Ha} + \frac{\lambda_{F0}^{\theta}}{(P_F^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{Fa}}{\frac{\lambda_{Ha}^{\theta}}{(P_H^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{Ha} + \frac{\lambda_{Fa}^{\theta}}{(P_F^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{Fa}}\right)^{-\frac{1}{\theta}}$$

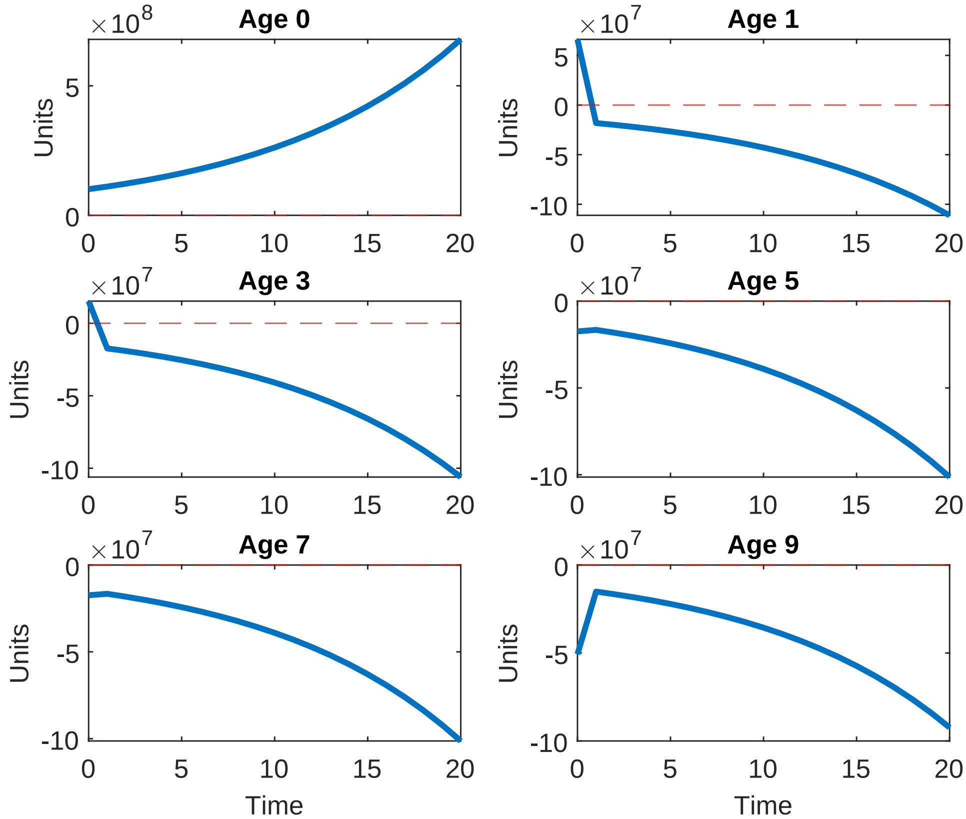
$$\frac{p_a^*}{p_0^*} = \left(\frac{S_{H0}}{S_{H0}+S_{F0}}\eta_H^{-a}(1-\delta)^a + \frac{S_{F0}}{S_{H0}+S_{F0}}\eta_F^{-a}(1-\delta)^a\right)^{-\frac{1}{\theta}}$$
$$* \left(\frac{\frac{\lambda_{H0}^{\theta}}{(P_H^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{H0}\eta_H^{-a}(1-\delta)^a + \frac{\lambda_{F0}^{\theta}}{(P_F^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{F0}\eta_F^{-a}(1-\delta)^a}{\frac{\lambda_{Ha}^{\theta}}{(P_H^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{H0}\eta_H^{-a}(1-\delta)^a + \frac{\lambda_{Fa}^{\theta}}{(P_F^*)^{1-\theta}}\sum_a \frac{p_a^*}{p_0^*}S_{F0}\eta_F^{-a}(1-\delta)^a}\right)^{-\frac{1}{\theta}}$$

$$\frac{p_a^*}{p_0^*} = \left(\frac{S_{H0}}{S_{H0}+S_{F0}}\eta_H^{-a}(1-\delta)^a + \frac{S_{F0}}{S_{H0}+S_{F0}}\eta_F^{-a}(1-\delta)^a\right)^{-\frac{1}{\theta}}$$
$$* \left(\frac{\frac{\lambda_{H0}^{\theta}}{(P_H^*)^{1-\theta}}S_{H0}\sum_a \frac{p_a^*}{p_0^*}\eta_H^{-a}(1-\delta)^a + \frac{\lambda_{F0}^{\theta}}{(P_F^*)^{1-\theta}}S_{F0}\sum_a \frac{p_a^*}{p_0^*}\eta_F^{-a}(1-\delta)^a}{\frac{\lambda_{Ha}^{\theta}}{(P_H^*)^{1-\theta}}S_{H0}\sum_a \frac{p_a^*}{p_0^*}\eta_H^{-a}(1-\delta)^a + \frac{\lambda_{Fa}^{\theta}}{(P_F^*)^{1-\theta}}S_{F0}\sum_a \frac{p_a^*}{p_0^*}\eta_F^{-a}(1-\delta)^a}\right)^{-\frac{1}{\theta}} \tag{C.1}$$

C.3 SOEBGE

C.3.1 Small open economy patterns of trade

Figure C.4: SOE opening up to trade and balanced growth



C.3.2 Demand for very old cars is zero

Proof In this subsection I want to prove that $\lim_{a\to\infty} C_{Hat} = 0$ if $\frac{1-\delta}{\eta_F} < \left(\frac{\gamma_F}{\gamma_H}\right)^{\theta}$. From equation (3.67) we have that the demand for vintage a in a small open economy balanced growth equilibrium is:

$$C_{Hat} = \left(\frac{\gamma_H}{\gamma_F}\right)^{a\theta}\left(\frac{1-\delta}{\eta_F}\right)^{a}\left(1-\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\gamma_F\right)\alpha W_{Ht}$$

As only the first two terms depend on age, we can write:

$$\lim_{a\to\infty} C_{Hat} = \lim_{a\to\infty}\left(\frac{\gamma_H}{\gamma_F}\right)^{a\theta}\left(\frac{1-\delta}{\eta_F}\right)^{a} = \lim_{a\to\infty}\frac{\left(\frac{1-\delta}{\eta_F}\right)^{a}}{\left(\frac{\gamma_F}{\gamma_H}\right)^{a\theta}} = \lim_{a\to\infty}\left(\frac{\frac{1-\delta}{\eta_F}}{\left(\frac{\gamma_F}{\gamma_H}\right)^{\theta}}\right)^{a} \tag{C.2}$$

Using the exponential function's monotone decreasing property on $(0,1)$, we have that $\lim_{a\to\infty} C_{Hat} = 0$ if $\frac{1-\delta}{\eta_F} < \left(\frac{\gamma_F}{\gamma_H}\right)^{\theta}$. □

C.3.3 Sufficient condition for SOE to be new car exporter

In this subsection I am interested in when the SOE that grew in ABGE will become a new car exporter. First, I focus on the instant of opening up to trade because in this period stocks are still determined by the autarky balanced growth equilibrium, then I move on the small open economy balanced growth equilibrium starting from period $T+1$, where period T denotes the time of opening up to trade. I do so to be able to compare two consecutive time periods in both of which the equilibrium prices are the world prices.

In period T the SOE that grew in ABGE will export cars aged $a=0$ if demand at world prices C^w_{Hat} is lower than its domestic supply S_{Hat}: $C^{SOE}_{Hat} < S^{autarky}_{Hat}$. This is equivalent to:

$$\begin{aligned}
\frac{\lambda^{\theta}_{Ha}(p^w_{at})^{-\theta}}{(\sum_a \lambda^{\theta}_{Ha} p^{w\,1-\theta}_{at})^{\frac{1}{1-\theta}}}\alpha\big(p^w_{qt}E_{Hqt}+\sum_a p^w_{at}S_{Hat}\big) &< \frac{\lambda^{\theta}_{Ha}p^{-\theta}_{Hat}}{(\sum_a \lambda^{\theta}_{Ha}p^{1-\theta}_{Hat})^{\frac{1}{1-\theta}}}\alpha\big(p_{Hqt}E_{Hqt}+\sum_a p_{Hat}S_{Hat}\big)\\
\frac{p^w_{qt}E_{Hqt}+\sum_a p^w_{at}S_{Hat}}{(\sum_a \lambda^{\theta}_{Ha}p^{w\,1-\theta}_{at})^{\frac{1}{1-\theta}}} &< \frac{p_{Hqt}E_{Hqt}+\sum_a p_{Hat}S_{Hat}}{(\sum_a \lambda^{\theta}_{Ha}p^{1-\theta}_{Hat})^{\frac{1}{1-\theta}}}\\
\left(\frac{P_{Ht}}{P^w_{Ht}}\right)^{1-\theta} &< \frac{W_{Ht}}{W^w_{Ht}}
\end{aligned} \tag{C.3}$$

Here I have used that new car price is the numeraire and that $\lambda^{\theta}_{Ha}=1$ for $a=0$. Then, by Assumption 5 from the main text and the convergence in the price index, I can rewrite the above inequality.

$$\frac{1-\gamma_F\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}}{1-\gamma_H\left(\frac{1-\delta}{\eta_H}\right)^{\frac{\theta-1}{\theta}}} < \frac{W_{Ht}}{W^w_{Ht}} \tag{C.4}$$

$$\frac{1-\gamma_F\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}}{1-\gamma_H\left(\frac{1-\delta}{\eta_H}\right)^{\frac{\theta-1}{\theta}}} < \frac{p_{Hqt}E_{Hqt}+Z_{H0t}+(1-\delta)\sum_{a=1}^{\infty}\left(\frac{1-\delta}{\eta_H}\right)^{-\frac{a}{\theta}}\gamma^a_H S_{Ha-1t-1}}{p_{wqt}E_{Hqt}+Z_{H0t}+(1-\delta)\sum_{a=1}^{\infty}\left(\frac{1-\delta}{\eta_w}\right)^{-\frac{a}{\theta}}\gamma^a_H S_{Ha-1t-1}} \tag{C.5}$$

In SOEBGE, the small open economy will export vintage a for which demand at time t at the prevailing word prices is smaller than its domestic stock, which in small open economy equilibrium equals the depreciated stock from the previous period, i.e. vintage a will be exported if $S_{Hat} - C_{Hat} > 0$. Before trade would take place, the period t stock of age $a>0$ cars is equal to the depreciated stock of age $a-1$ cars from period $t-1$, this is equivalent to:

$$(1-\delta)C_{Ha-1t-1} - C_{Hat} > 0 \tag{C.6}$$

$$(1-\delta)\frac{(p_{Fa-1t-1})^{-\theta}\lambda_{Ha-1}^{\theta}}{(P_{Ht-1}^{W})^{1-\theta}}\alpha W_{Ht-1}^{w} - \frac{(p_{Fat})^{-\theta}\lambda_{Ha}^{\theta}}{(P_{Ht}^{W})^{1-\theta}}\alpha W_{Ht}^{W} > 0 \tag{C.7}$$

$$\alpha W_{Ht-1}^{w}\Big((1-\delta)\frac{(p_{Fa-1t-1})^{-\theta}\gamma_H^{(a-1)\theta}}{(P_{Ht-1}^{w})^{1-\theta}} - \eta_H\frac{(p_{Fat})^{-\theta}\gamma_H^{a\theta}}{(P_{Ht}^{w})^{1-\theta}}\Big) > 0 \tag{C.8}$$

I use Assumption 5 and convergence in the price index to further simplify the left hand side of the above inequality condition:

$$\alpha W_{Ht-1}^{w}\frac{(p_{Fa-1t-1})^{-\theta}\gamma_H^{(a-1)\theta}}{(P_H^{w})^{1-\theta}}\Big((1-\delta) - \eta_H\gamma_H^{\theta}\frac{1-\delta}{\eta_F}\gamma_F^{-\theta}\Big) > 0 \tag{C.9}$$

$$\alpha W_{Ht-1}^{w}(1-\delta)\frac{(p_{Fa-1t-1})^{-\theta}\gamma_H^{(a-1)\theta}}{(P_H^{w})^{1-\theta}}\Big(1-\Big(\frac{\gamma_H}{\gamma_F}\Big)^{\theta}\frac{\eta_H}{\eta_F}\Big) > 0 \tag{C.10}$$

If $\gamma_H^{\theta}\eta_H > \gamma_F^{\theta}\eta_F$ holds, the above can not be satisfied for any $a \geq 1$. Therefore, if the two countries engage in trade, in small open economy balanced growth equilibrium, Home will only export new cars.

C.3.4 Convergence in the price index

This subsection derives a convergence condition for the price index when Assumption 4 holds and Home is a small open economy. I start by rewriting the expression for the price index and use that prevailing world prices equal Foreign autarky equilibrium prices.

$$\begin{aligned}
(P_t^{w})^{1-\theta} &= \sum_{a=0}^{\infty}\gamma_H^{a\theta}\Big(\Big(\frac{1-\delta}{\eta_F}\Big)^{-\frac{a}{\theta}}\gamma_F^{a}\Big)^{1-\theta} \\
&= \sum_{a=0}^{\infty}\gamma_F^{a}\Big(\frac{\gamma_H}{\gamma_F}\Big)^{a\theta}\Big(\frac{1-\delta}{\eta_F}\Big)^{\frac{a(\theta-1)}{\theta}} \\
&= \frac{1-\Big(\gamma_F(\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\Big)^{\infty}}{1-\gamma_F\Big(\frac{\gamma_H}{\gamma_F}\Big)^{\theta}\Big(\frac{1-\delta}{\eta_F}\Big)^{\frac{\theta-1}{\theta}}}
\end{aligned} \tag{C.11}$$

Assumption 5. Assume that the following condition holds: $\gamma_F\Big(\frac{\gamma_H}{\gamma_F}\Big)^{\theta}\Big(\frac{1-\delta}{\eta_F}\Big)^{\frac{\theta-1}{\theta}} < 1.$

Provided that assumption 5 holds, the small open economy balanced growth equilibrium price index converges to a constant[1], as a goes to infinity.

[1]**Proof** Using the properties of exponential functions, it is easy to see that if $\gamma_F\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}} < 1$ holds, then $\lim_{a\to\infty}\left(\gamma_F(\frac{\gamma_H}{\gamma_F})^{\theta}(\frac{1-\delta}{\eta_F})^{\frac{\theta-1}{\theta}}\right)^{a} = 0$. It follows, that $\lim_{a\to\infty}(P_t^w)^{1-\theta} = \left(1-\gamma_F\left(\frac{\gamma_H}{\gamma_F}\right)^{\theta}\left(\frac{1-\delta}{\eta_F}\right)^{\frac{\theta-1}{\theta}}\right)^{-1}$, which is constant and depends on model parameters only. $\square$

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