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IMPORT PENETRATION AND CONSUMPTION OF DOMESTIC AND FOREIGN VARIETIES

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Abstract: This paper analyses import penetration with a consumer demand approach that distinguishes domestically and foreign-produced varieties. Consistent aggregation leads to a macro-level import demand equation that faithfully reflects the underlying micro demands for foreign varieties. The approach avoids restrictive assumptions such as homotheticity and permits an array of hypothesis tests of functional form. We show how to estimate the model with a relative short time series -- important for countries with limited data -- and as an illustrative example, apply it to Australia. We find that income growth is largely responsible for the recent surge in imports into that country.

Keywords: Disaggregated import demand; Consumer demand; Estimating demand equations; Bootstrap simulation

JEL classifications: D12, F41

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1. Introduction

Over the last two decades, import penetration in Australia has risen substantially. Panel A of Figure 1.1 shows the evolution of the share of sales of food and agricultural products in Australia coming from imported sources. As can be seen, the share has increased from about 6 percent in 1996 to a little under 12 percent in 2017, so it has almost *doubled* over two decades. Similar large increases occur in the other seven groups in the figure, and imports in total have risen by more than 12 percentage points (panel I).

In this paper we use a consumer demand system for domestic and foreign varieties of a number of goods to analyse changes in import penetration. The paper extends prior research in several ways. A prominent approach is to break-up the problem into two steps – first allocate total expenditure to the broad groups and then, given that decision, split spending on each into domestic and foreign components. Our paper proposes an alternative one-step approach that treats both varieties for all goods simultaneously. This avoids issues related to endogeneity of group expenditures and the restrictive assumption of homotheticity. We show how our framework can be implemented with a short span of data, important for countries with limited data endowments, and how it permits an array of hypothesis tests pertaining to functional form. The paper also demonstrates how consistent aggregation over demand equations leads to a subsystem for each good, which is a convenient mechanism to study import penetration. Additionally, aggregating equations leads to a macro-level total demand for imports, reflecting the underlying micro demands for foreign varieties in a satisfactory manner. Thus, the elasticities of total imports are weighted averages of their micro counterparts. Finally, we show how our approach can be used for counter-factual simulations that isolate factors responsible for the rapid import growth.

There are two broad streams of literature dealing with import penetration. The first generation research starts directly with an import demand equation such as

$$\log q = \lambda_0 + \lambda_1 \log \frac{p}{P} + \lambda_2 \log y + \text{controls}.$$

Here, q is the volume of imports, $\frac{p}{P}$ the relative price, y real income, $\lambda_1 < 0$ the price elasticity and $\lambda_2 > 0$ the income elasticity. Regarding imports as the excess demand for the good, $q = q^d - q^s$, where q^d (q^s) is domestic demand (supply), and the price elasticity of imports is a simple function of the elasticity of domestic demand ($\eta^d < 0$) and supply ($\eta^s > 0$), that is, $\lambda_1 = \omega \eta^d + (1 - \omega) \eta^s$, where $\omega = q^d / q$. There is an extensive literature on this approach and surveys are available by, for example, Goldstein and Khan (1985), Hooper et al. (2000), Magee (1975), Marquez (1990, 1999, 2002) and Stern et al. (1976). A particularly influential paper in this stream is Houthakker and Magee (1969).

Second-generation research treats domestic and imported varieties of each good as two distinct goods, so rather than imports being the excess demand, now there is a separate demand function for these, as well as one for the domestically produced good. This approach makes explicit the substitution between the imported and domestic goods. As there are domestic and foreign varieties of each good, the number of demand equations equals twice the number of goods separately identified, which can be large even for only a modest number of goods. A common practice is to simplify the problem by dividing it into two steps. The first considers spending on each good from both foreign and domestic sources. Typically, this involves the split of total expenditure into spending on the broad aggregates such as food, clothing, housing, etc. This might be governed by a demand model such as the linear expenditure system (LES, Stone, 1954). The second step of this approach deals with the split of expenditure into domestic and foreign components. A popular choice for this purpose is the constant elasticity of substitution expenditure (CES) system.

The attractive features of the two-step approach include its comprehensive nature with the extensive commodity detail, as well as the clean analytic interpretation of the parameters of the LES and CES. There is also the key advantage of the reduced dimensionality of the

problem. With G broadly-defined groups of goods, there are $2G$ demands with a $2G \times 2G$ substitution matrix. This matrix contains $4G^2$ elements, which for $G = 10$, for example, is 400. This matrix is restricted to be symmetric negative semidefinite, but even then the number of free elements is still huge at $G(2G + 1)$, or 210 for $G = 10$. The LES involves $2G - 1$ free parameters (G subsistence parameters and $G - 1$ marginal shares), while the CES has $2G$ (G distribution parameters and G elasticities of substitution), a total of $4G - 1$ parameters. Reducing the $G(2G + 1)$ elements of the matrix to $4G - 1$ more basic parameters represents a major advantage; in fact, this reduction is crucial in making the approach computationally feasible.

Empirical research on the second approach described above was initiated by Armington (1969). The substitutability between domestic and foreign goods (or the so-called “Armington elasticity”) is one of the key parameters in much of computable general equilibrium (CGE) modelling. In a survey, Lloyd and Zhang (2006) identify a number of CGE models that use Armington elasticities, and they go so far as to emphasise that the Armington framework dominates CGE modelling of trade policy issues.² Contemporary major users of the Armington approach include the MONASH model (Dixon and Rimmer, 2002), the models of the Centre for International Economics (Stoeckel et al., 1990) and the Global Trade Analysis Project (GTAP, Hertel, 1997). It should also be noted that the Armington model plays a prominent role in modern numerical trade theory (Costinot and Rodríguez-Clare, 2014).

The LES is also used in several leading CGE models for the allocation of expenditure to the broad groups in the first step. There are some disadvantages of the LES-CES combination, however. The first is that these are based on separability. LES is derived from the

² Early examples include Sato (1968), Miller and Spencer (1977), Lloyd (1979a, 1979b), Deardorff and Stern (1981), Dixon et al. (1982) and Shoven and Whalley (1984).

Stone-Geary utility function which is additive with no interactions among groups, the strongest form of separability. The CES utility function is also separable, but not additive. When applied to domestic and foreign varieties of the same group, separability may not be too unreasonable when broad aggregates are used, as these are likely to exhibit limited utility interactions. The more serious issue with CES is that it is homothetic (income elasticities are all unitary). Suppose the foreign variety is more luxurious than the domestic counterpart (think: imported French champagne versus locally produced sparklingly wine). With the income elasticity of both varieties constrained to unity, CES cannot account for the frequently occurring phenomenon of surging imports of imported varieties when income rises. The two-step procedure can itself be another disadvantage. This decision hierarchy is usually justified by separability, but there can still be the problem of endogeneity of group expenditure in the allocation of the second step. “Fortunately”, as the income (that is, expenditure) elasticities of the CES are constrained to unity, the possibility of biased estimates is sidestepped.³

Two studies are more closely related to ours. Berner (1977) considers the demand for five groups of goods, each coming from three sources, domestic, the European Economic Community (EEC) and the rest of the world. Goods belonging to the same group, such as domestically produced food items and those imported from the EEC, are allowed to interact fully in generating utility. On the other hand, between-group interactions are more limited. For the allocation to groups, Berner uses two demand models, the S-branch system (Brown and

³ There is a related matter due to Gorman (1959), who considered the conditions required for a two-step approach to result in expenditure equations of the first step that contain well-defined indexes of the prices of the groups of goods. He showed this requires either separability or a stringent homogeneity condition on the group sub-utility functions, a condition satisfied by the CES as it is homothetic. Accordingly, while the CES is rigid because of its unitary expenditure elasticities, this very limitation gives it immunity from endogeneity and Gorman-type problems.

Heien, 1972) and the Rotterdam model (Barten, 1964; Theil, 1965). The estimates of the Rotterdam model seem to be more successful than those of the S-branch. The sample period (1954-70) was a time of relative economic tranquillity with limited variability of the data, possibly leading to imprecise estimates of the model. Although not clear from the paper, that could have been the reason for employing the mixed estimation procedure (that merges subjective prior distributions on the parameters with sample evidence) for the Rotterdam. Detailed results are presented for Germany only, but Berner notes that for two other countries, the Rotterdam sample estimates were not satisfactory.

The second closely related paper is Marquez (1993) who considers the demand for imports from several countries, as well as the demand for domestic goods. Thus, if there are n countries, there is a system of n demand equations for each country, $n - 1$ imports plus the demand for domestic goods. While Marquez also uses the Rotterdam model, in contrast to Berner, all types of imports from a given country are aggregated into one good. Marquez considers $n = 5$ countries of origin and estimates the model for each destination country, Canada, Japan and the US. All but one of the own-price effects are negative, but many of the cross-price effects are small and insignificant, and the substitution matrix is not negative semidefinite for Japan and the US.⁴

⁴ Both Berner (1977) and Marquez (1993) use the Rotterdam model, but there is a difference in the form of the model. Berner uses the “relative price version” (which holds constant the marginal utility of income), while Marquez uses the “absolute price version” (real income constant). The price responses of the absolute version combine the specific and general substitution effects; these responses are of the nature of reduced-form coefficients and cannot be used to identify utility interactions among goods. In another paper, Marquez (1999) estimates an import demand equation for Canada, Japan and the US. He uses the Rotterdam functional form again, but rather than an equation system, the demand for imports from all sources is treated as a single equation for each country.

Finally, there is related research that advocates disaggregation in import demand estimation. Estimating elasticities with disaggregated data and then aggregating up typically leads to substantial larger elasticities, as compared to those estimated directly with aggregated data. This work includes Freenstra et al. (2018), Imbs and Méjean (2015), Kee et al. (2008); see also Hummels and Lee (2018).

The remainder of this paper is structured as follows. Section 2 sets out the details of the demand system to be used, while Section 3 introduces a method of estimation that can be employed with modest-sized samples. The model is applied in Section 4 to Australian data of the last two decades with $G = 8$ groups, each with domestic and foreign varieties. A novel two-dimensional aggregation scheme is used in Section 5: (i) The demand equations are aggregated over the two varieties to give sub-models for each group that can be used for market analysis. (ii) The foreign-variety demands are aggregated over the 8 groups to give the demand for total imports. Surprisingly, Section 6 shows that the primary driver of the higher import penetration in Australia was not the lower prices of foreign goods associated with trade liberalisation. Many of these prices did indeed fall but when combined with low price elasticities, this was insufficient to account for the increased penetration. Higher incomes are shown to have been responsible for the increased imports -- higher incomes meant more spending on superior-quality varieties, and these were typically imported. Concluding comments are contained in Section 7.

2. Demand Equations

Let there be n goods purchased by the consumer in quantities $q_1, \dots, q_n$, at prices $p_1, \dots, p_n$. Spending on good i is $p_i q_i$, and so total expenditure is $\sum_{i=1}^n p_i q_i$, which plays the role of the budget constraint:

$$(2.1) \quad \sum_{i=1}^n p_i q_i = M.$$

This M is total expenditure, but as an abbreviation, it will be referred to as “income”. The share of income devoted to good i is $w_i = \frac{p_i q_i}{M}$, which is known as the budget share. Suppose we have annual observations indexed by $t = 0, 1, \dots, T$. Define $\bar{w}_{it} = \frac{1}{2}(w_{it} + w_{i,t-1})$ as the arithmetic average of the i^{th} budget share in years t and $t - 1$ and $Dq_{it} = \log q_{it} - \log q_{i,t-1}$ as the i^{th} quantity log-change. The Divisia volume index is then

$$(2.2) \quad DQ_t = \sum_{i=1}^n \bar{w}_{it} Dq_{it}.$$

This is a budget-share-weighted average of the growth in the n quantities consumed and is an index of the change in the consumer’s real income.

Next, define $\theta_i = \frac{\partial(p_i q_i)}{\partial M}$ as the i^{th} marginal share, the impact on spending on good i following a \$1-rise in income. As the increase in income is totally spent, these shares have a unit sum:

$$(2.3) \quad \sum_{i=1}^n \theta_i = 1.$$

The Frisch price index is a marginal-share weighted average of the changes in prices:

$$(2.4) \quad DP'_t = \sum_{i=1}^n \theta_i Dp_{it},$$

where $Dp_{it} = \log p_{it} - \log p_{i,t-1}$. These indexes are used in the Rotterdam model (Barten, 1964, Theil, 1965), which takes the form

$$(2.5) \quad \bar{w}_{it} Dq_{it} = \theta_i DQ_t + \sum_{j=1}^n v_{ij} (Dp_{jt} - DP'_t) + \varepsilon_{it}, \quad i = 1, \dots, n.$$

The term on the left-hand side is $\bar{w}_{it} Dq_{it}$, the change in the quantity demanded of good i weighted by its (average) budget share. As $\Delta w_i \approx \bar{w}_{it} Dp_{it} + \bar{w}_{it} Dq_{it} - \bar{w}_{it} DM_t$, where $DM_t = \log M_t - \log M_{t-1}$, the variable on the left of (2.5) is interpreted as the quantity component of the change in the i^{th} budget share, the endogenous part of the change. The first term on the right measures the effect of income changes and is the Divisia volume index, DQ_t , with coefficient θ_i , the marginal share of i . It is to be noted that DQ_t is the sum over $i = 1, \dots, n$ of the variable on the left of (2.5).

The second term on the right of (2.5), $\sum_{j=1}^n v_{ij} (Dp_{jt} - DP'_t)$, is a weighted sum of n relative price changes, which measures the substitution effects of price changes. These are relative price changes with the change in each nominal price, Dp_{jt} , deflated by the Frisch price index DP'_t . The price coefficients, v_{ij} , are symmetric in i and j :

$$(2.6) \quad v_{ij} = v_{ji}, \quad i, j = 1, \dots, n,$$

and satisfy

$$(2.7) \quad \sum_{j=1}^n v_{ij} = \phi \theta_i, \quad i = 1, \dots, n,$$

where $\phi < 0$ is the income flexibility, the reciprocal of the income elasticity of the marginal utility of income. Constraints (2.3) and (2.7) imply $\sum_{i=1}^n \sum_{j=1}^n v_{ij} = \phi$. The final term on the right of model (2.5) is the random disturbance ε_{it} , assumed to be zero mean and serially uncorrelated. Dividing both sides of (2.5) by $\bar{w}_{it}$, it can be seen that $\eta_i = \frac{\theta_i}{\bar{w}_{it}}$ is the income elasticity of good i and that $F_{ij} = \frac{v_{ij}}{\bar{w}_{it}}$ is the $(i, j)^{th}$ Frisch price elasticity, the elasticity of demand for i with respect to the Frisch-deflated price of j , which holds constant the marginal utility of income.

Equation (2.5) is the relative price version of the model. Substitution of (2.4) into (2.5) and using (2.7), gives the absolute-price version:

$$(2.8) \quad \bar{w}_{it} Dq_{it} = \theta_i DQ_t + \sum_{j=1}^n \pi_{ij} Dp_{jt} + \varepsilon_{it},$$

where $\pi_{ij} = v_{ij} - \phi \theta_i \theta_j$ is a Slutsky coefficient. These coefficients measure the total substitution effects and satisfy symmetry, $\pi_{ij} = \pi_{ji}$, $i, j = 1, \dots, n$, and homogeneity, $\sum_{j=1}^n \pi_{ij} = 0$, $i = 1, \dots, n$. The $(i, j)^{th}$ Slutsky elasticity is $S_{ij} = F_{ij} - \phi \eta_i \theta_j$, while the corresponding Marshallian elasticity (measuring the income and substitution effects combined) is $M_{ij} = S_{ij} - \eta_i \bar{w}_{jt}$.

Model (2.8) can be derived from the familiar Marshallian demand equation, $q_i = q_i(M, p_1, \dots, p_n)$, in differential form. Thus, $dq_i = \frac{\partial q_i}{\partial M} dM + \sum_{j=1}^n \frac{\partial q_i}{\partial p_j} dp_j$, or using $\frac{dx}{x} = d \log x$ and multiplying through by w_i , $w_i d \log q_i = \frac{\partial p_i q_i}{\partial M} d \log M + \sum_{j=1}^n \frac{p_j}{M} \frac{\partial q_i}{\partial p_j} d \log p_j$. Using the Slutsky decomposition, $\frac{\partial q_i}{\partial p_j} = s_{ij}^* - q_j \frac{\partial q_i}{\partial M}$, where s_{ij}^* is the (symmetric) substitution effect, we have

$$(2.9) \quad w_i d \log q_i = \left(\frac{\partial p_i q_i}{\partial M} \right) d \log M + \sum_{j=1}^n \left(\frac{p_j s_{ij}^*}{M} \right) d \log p_j,$$

where $d \log M - \sum_{j=1}^n w_j d \log p_j = \sum_{j=1}^n w_j d \log q_j$, which follows from the total differential of (2.1). The absolute price version (2.8) is a finite-change version of (2.9) with $\theta_i = \frac{\partial(p_i q_i)}{\partial M}$ and $\pi_{ij} = \frac{p_j s_{ij}^*}{M}$. Using $\pi_{ij} + \phi \theta_i \theta_j = v_{ij}$, the relative price version (2.5) can be obtained from (2.8).

To deal with domestic and foreign varieties, divide the n goods into $G < n$ groups denoted by $\mathbf{S}_1, \dots, \mathbf{S}_G$, such that each good belongs to one group only. Goods within each group are taken to be reasonably close substitutes, while there is limited substitution between varieties belonging to different groups. If groups are strongly separable, then the utility function is of the form $\sum_{g=1}^G u_g(\mathbf{q}_g)$, where $u_g(\mathbf{q}_g)$ is the sub-utility function for g and $\mathbf{q}_g$ are the quantities belonging to $\mathbf{S}_g$. This implies the following restrictions on the price coefficients of model (2.5):

$$v_{ij} \begin{cases} \neq 0 & i, j \in \mathbf{S}_g, \quad g = 1, \dots, G \\ = 0 & i \in \mathbf{S}_g, j \in \mathbf{S}_h, \quad g \neq h, g, h = 1, \dots, G, \end{cases}$$

so that the demand for $i \in \mathbf{S}_g$ is

$$(2.10) \quad \bar{w}_{it} Dq_{it} = \theta_i DQ_t + \sum_{j \in \mathbf{S}_g} v_{ij} (Dp_{jt} - DP'_t) + \varepsilon_{it}.$$

Now the prices affecting the consumption of good i are only those of goods belonging to the same group as the good in question, so there is an appealing unification between the structure of the utility function and the demand equations.

Suppose there are two varieties of each good, those from domestic and foreign sources, and the two varieties of each good form a separable group. Thus, we shall denote varieties by the subscript i , with $i = 1, 2$ for domestic and foreign varieties, and indicate the group by the superscript g , as set out in Table 2.1. With this notation system, the demands for the domestic and foreign varieties are

$$(2.11) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t^g) + \varepsilon_{it}^g, i = 1, 2; g = 1, \dots, G.$$

Here, $DQ_t = \sum_{g=1}^G \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$ and $DP_t^g = \sum_{i=1}^2 \theta_i^g Dp_{it}^g$.

According to Equation (2.11), the demand for the domestically (foreign) produced variety of a good in group g is affected by income, its own relative price and that of the foreign (domestic) variety. From (2.6) and (2.7), the price coefficients now satisfy

$$(2.12) \quad v_{12}^g = v_{21}^g, g = 1, \dots, G,$$

$$(2.13) \quad \sum_{j=1}^2 v_{ij}^g = \phi \theta_i^g, i = 1, 2, g = 1, \dots, G.$$

For $g, h = 1, \dots, G$, the $(i, j)^{th}$ Frisch, Slutsky and Marshallian price elasticities are,

respectively, $F_{ij}^{gh} = \delta_{gh} \frac{v_{ij}^g}{\bar{w}_{it}^g}$, where δ_{gh} is the Kronecker delta; $S_{ij}^{gh} = F_{ij}^{gh} - \phi \eta_i^g \theta_j^h$, where

$\eta_i^g = \frac{\theta_i^g}{\bar{w}_{it}^g}$ is the income elasticity of $i \in \mathbf{S}_g$; and $M_{ij}^{gh} = S_{ij}^{gh} - \eta_i^g \bar{w}_{jt}^h$.

3. Estimation

To estimate model (2.11) subject to constraints (2.12) and (2.13), several complexities need to be addressed.

The Constraints and Dimensionality

The constraints can be substituted out in the manner suggested by Theil (1975/76). For each group g , constraint (2.13) can be used to eliminate the diagonal elements of the 2×2 matrix of price coefficients $[v_{ij}^g]$. Define $A_{it}^g(\boldsymbol{\theta}) = \theta_i^g (Dp_{it}^g - \sum_{g=1}^G \sum_{k=1}^2 \theta_k^g Dp_{kt}^g)$, with $\boldsymbol{\theta} = [\theta_k^g]$, a vector of all the marginal shares, and the price difference $\Delta p_{ij,t}^g = Dp_{it}^g - Dp_{jt}^g, i \neq j$,

which satisfies $\Delta p_{ij,t}^g = -\Delta p_{ji,t}^g$. Then, using symmetry, $v_{21}^g = v_{12}^g$, the price term of (2.11) can be written for $i = 1, 2$ as:

$$\begin{bmatrix} \sum_{j=1}^2 v_{1j}^g (Dp_{jt}^g - DP_t') \\ \sum_{j=1}^2 v_{2j}^g (Dp_{jt}^g - DP_t') \end{bmatrix} = \begin{bmatrix} A_{1t}^g(\boldsymbol{\theta}) & \Delta p_{21,t}^g \\ A_{2t}^g(\boldsymbol{\theta}) & -\Delta p_{21,t}^g \end{bmatrix} \begin{bmatrix} \phi \\ v_{12}^g \end{bmatrix}.$$

This vector form highlights the cross-equation constraints. Thus, model (2.11) becomes

$$(3.1) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi A_{it}^g(\boldsymbol{\theta}) + v_{12}^g [2\gamma(i) - 1] \Delta p_{21,t}^g + \varepsilon_{it}^g; \quad i = 1, 2; g = 1, \dots, G,$$

where $\gamma(i)$ denotes an indicator variable that equals 1 when $i = 1$ and zero when $i = 2$.

For each group, now there are 2 marginal shares and one off-diagonal price coefficient and with G groups, the total number of free parameters is $3G$. There is also the income flexibility ϕ , which is common to each equation. As the marginal shares have a unit sum, one of these is constrained, leaving the number of free parameters for the system at $3G$. There are two item indexes in system (3.1), $i = 1, 2$ for the domestic and foreign varieties of goods within a group, and $g = 1, \dots, G$ for groups. It is convenient to provisionally consolidate the two indexes into one, $k = 1, \dots, 2G$, and express (3.1) as

$$(3.2) \quad \bar{w}_{kt} Dq_{kt} = \theta_k DQ_t + \text{price terms} + \varepsilon_{kt}; \quad k = 1, \dots, 2G.$$

The disturbance terms, ε_{kt} , are assumed to have zero means with variances and covariances denoted by $\sigma_{kl} = E(\varepsilon_{kt}\varepsilon_{lt})$. The $2G \times 2G$ covariance matrix $[\sigma_{kl}]$ contains $G(2G + 1)$ distinct elements, which for $G = 8$ amounts to 136. Our data with $T = 22$ years (see below) are insufficient to estimate with any precision these 136 elements together with the $3G = 24$ coefficients.⁵

⁵ On the problems of estimating systems when the sample size is small relative to the number of goods, see Appendix A2.

The Covariance Matrix

To make the problem tractable, we initially ignore the dependence of $A_{it}^g(\boldsymbol{\theta})$ on $\boldsymbol{\theta}$ by treating the term as known, and assume $\sigma_{kl} = \sigma^2 w_k (\delta_{kl} - w_l)$, where w_k is now interpreted as the sample mean of $\bar{w}_{kt}$. This is the covariance structure associated with the multinomial distribution with probabilities $w_1, \dots, w_{2G}$. We write Equation (3.1) for a given year t in vector form by stacking each commodity one on top of the other to give $\mathbf{y}_t = \mathbf{X}_t \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$. The $2G \times 2G$ disturbance covariance matrix $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t')$ takes the form $\boldsymbol{\Sigma} = \sigma^2(\mathbf{W} - \mathbf{w}\mathbf{w}')$, where $\mathbf{W} = \text{diag}[\mathbf{w}]$ and $\mathbf{w} = [w_1, \dots, w_{2G}]$. This matrix is singular ($\boldsymbol{\Sigma}\mathbf{1} = \mathbf{0}$, as $\mathbf{w}'\mathbf{1} = 1$ where $\mathbf{1}$ is a vector of unit elements) since model (3.1) is a budget allocation system, implying $\boldsymbol{\varepsilon}_t'\mathbf{1} = 0$. One equation is redundant and the solution is to drop one and the results are invariant to which equation is chosen (Barten, 1969). Delete the last equation and define $\tilde{\boldsymbol{\Sigma}} = \sigma^2(\tilde{\mathbf{W}} - \tilde{\mathbf{w}}\tilde{\mathbf{w}}')$ as the covariance matrix of the reduced system, where $\tilde{\mathbf{W}} = \text{diag}[\tilde{\mathbf{w}}]$ with $\tilde{\mathbf{w}}$ the vector of the remaining $2G - 1$ budget shares. Then, the inverse of this covariance matrix is

$$(3.3) \quad \tilde{\boldsymbol{\Sigma}}^{-1} = \frac{1}{\sigma^2} \left(\tilde{\mathbf{W}}^{-1} + \frac{1}{w_{2G}} \mathbf{u}' \right),$$

where w_{2G} is the share of the omitted good.⁶

Let $\mathbf{e}_t = [e_{1t}, \dots, e_{2G-1,t}, e_{2G,t}]'$ be the vector of the $2G$ residuals of the full system and $\tilde{\mathbf{e}}_t = [\tilde{e}_{1t}, \dots, \tilde{e}_{2G-1,t}]'$ be the vector of the $2G - 1$ residuals of the reduced system. It follows from $\boldsymbol{\varepsilon}_t'\mathbf{1} = 0$ that $\mathbf{e}_t'\mathbf{1} = 0$ and $\tilde{\mathbf{e}}_t'\mathbf{1} = -e_{2G,t}$. Using GLS, we minimise the sum over $t = 1, \dots, T$ of the quadratic form of the latter residuals with weight matrix the inverse covariance matrix $\tilde{\boldsymbol{\Sigma}}^{-1}$. It follows from Equation (3.3) that this sum is

$$(3.4) \quad \sum_{t=1}^T \tilde{\mathbf{e}}_t' \tilde{\boldsymbol{\Sigma}}^{-1} \tilde{\mathbf{e}}_t = \frac{1}{\sigma^2} \sum_{t=1}^T \tilde{\mathbf{e}}_t' \left(\tilde{\mathbf{W}}^{-1} + \frac{1}{w_{2G}} \mathbf{u}' \right) \tilde{\mathbf{e}}_t = \frac{1}{\sigma^2} \sum_{k=1}^{2G} \sum_{t=1}^T \left(\frac{e_{kt}}{\sqrt{w_k}} \right)^2,$$

⁶ For more on the stacked form of the model, see Appendix A1. For a justification of the multinomial approach and further details of the above, see Appendix A2.

where the second step is based on $\mathbf{t}'\tilde{\mathbf{e}}_t = -e_{2G,t}$. The quadratic form for the reduced system involves the weighted squares and cross-products of the residuals, but from the far-right side of (3.4), the counterpart for the full system has no cross-product terms. That is, the GLS criterion is equivalent to the weighted sum of squares of the full system with weights the reciprocals of the square roots of the budget shares. As commodities with larger budget shares tend to have a larger dispersion, this can be viewed as a variance-stabilising weighting scheme.

The multinomial approach transforms what would have been a large-scale SURE-type problem into a more-manageable single-equation one: After multiplying through by $\frac{1}{\sqrt{w_k}}$, Equation (3.2) -- the full model -- can be estimated as a single equation by OLS using all $2G \times T$ observations:

$$\frac{\bar{w}_{kt}Dq_{kt}}{\sqrt{w_k}} = \theta_k \frac{DQ_t}{\sqrt{w_k}} + \frac{\text{price terms}}{\sqrt{w_k}} + \frac{\varepsilon_{kt}}{\sqrt{w_k}}, k = 1, \dots, 2G; t = 1, \dots, T.$$

This is a pooled OLS approach. Let $\sqrt{\mathbf{W}^{-1}}$ denote the $2G \times 2G$ diagonal matrix with the reciprocals of the square roots of the budget shares on the diagonal, and define the transforms $\mathbf{y}_t^* = \sqrt{\mathbf{W}^{-1}}\mathbf{y}_t$, $\mathbf{X}_t^* = \sqrt{\mathbf{W}^{-1}}\mathbf{X}_t$, $\boldsymbol{\varepsilon}_t^* = \sqrt{\mathbf{W}^{-1}}\boldsymbol{\varepsilon}_t$. Multiplying both sides of $\mathbf{y}_t = \mathbf{X}_t\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$ by $\sqrt{\mathbf{W}^{-1}}$ gives $\mathbf{y}_t^* = \mathbf{X}_t^*\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t^*$, and the BLU estimator of the coefficient vector $\boldsymbol{\beta}$ is $\hat{\boldsymbol{\beta}} = (\sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{X}_t^*)^{-1} \sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{y}_t^*$, which is equal to $(\sum_{t=1}^T \mathbf{X}_t' \boldsymbol{\Sigma}^{-1} \mathbf{X}_t)^{-1} \sum_{t=1}^T \mathbf{X}_t' \boldsymbol{\Sigma}^{-1} \mathbf{y}_t$.

The multinomial approach is somewhat restrictive, as all covariances are negative and do not allow for specific interdependencies between individual pairs of goods. But the approach avoids the problem of having to estimate a large number of elements of the unrestricted disturbance covariance matrix, and so leads to a considerable simplification of a complex estimation problem. Moreover, Monte Carlo studies point to the robust performance of this approach (Selvanathan, 1991; Theil, 1987).

There are two additional issues that need to be mentioned. First, model (3.1) is nonlinear in the parameters due to the term $A_{it}^g(\boldsymbol{\theta})$, but this was ignored above by treating the vector of

marginal shares, θ , as known. We deal with the nonlinearity with an iterative procedure. Secondly, to avoid relying on asymptotics, we use a bootstrap procedure for standard errors. Details of these procedures are provided in Appendix A3.

4. Application

We start with data for 20 sectors in Australia over the period 1996 – 2017 and then aggregate into $G = 8$ broader groups, each with two varieties -- domestic and foreign. For details, see Appendix A4. The budget shares of Table 4.1 indicate the importance of food and energy, which between them more than 40 percent of the total. And in both cases, the domestic variety dominates. By contrast, several of the other groups have substantial foreign components – in the case of machinery and equipment, expenditure on the foreign variety exceeds the domestic counterpart. Figure 4.1 plots quantities against prices and in most instances, the regression line has a noticeable negative slope, giving informal support to the law of demand.⁷

We estimate model (3.1) using the approach described above and columns 4 – 6 of Table 4.2 contain the results. The marginal shares are all positive and the majority significant. All own-price coefficients are negative, but many imprecisely estimated with quite high standard errors. From the final row of this table, the estimate of the income flexibility is -0.506 , which is significant and agrees with prior estimates.⁸ A number of the cross-price coefficients appear insignificant – the only such coefficient more than twice its standard error is for “Wood and Paper Products”. Looking at column 2 of panel B of Table 4.3, it can be seen that on the basis of univariate “t-tests”, the hypothesis $H_0: \nu_{ij}^g = 0, i \neq j$ cannot be rejected for any group. An “F-test” of the joint hypothesis of zero cross-price coefficients for all groups is

⁷ Appendix A4 presents the Divisia moments, which reveal (i) for the majority of observations, quantities are more dispersed than prices; and (ii) the cross-commodity price-quantity correlations are negative. These results agree with prior studies as summarised by Clements (2019).

⁸ For surveys, see Brown and Deaton (1972, p. 1206), Clements (2019) and Clements and Zhao (2009).

rejected at the 5-percent level of significance, but not at the 1-percent, as shown in column 3 of row 1 of panel A. Could the domestic and foreign-produced varieties of the *same* good really be independent and not interact in the generation of utility? On the face of it, this would seem to stretch creditability, but there can be plausible explanations. Although all care has been exercised in constructing the data, it is still possible that the difficulty in matching varieties of some goods has led to measurement error. Alternatively, there could simply be insufficient price variation to precisely measure subtle interactions between varieties. A third explanation is that our tests could be faulty, although this would seem unlikely with the robust bootstrap approach used.⁹

In any event, on the basis of Occam's razor it is useful to examine the implications of reformulating the model in the simpler preference-independent form whereby all the cross-price coefficients are zero. Under preference independence (PI), model (2.11) becomes:

$$(4.1) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + v_{ii}^g (Dp_{it}^g - DP_t') + \varepsilon_{it}^g, \quad i = 1, 2; g = 1, \dots, 8.$$

As shown in Appendix A10, the estimated marginal share for domestic "Wood and Paper Products" (hereafter, wood) is negative, which although insignificant, is inadmissible under PI. Interestingly, as noted above for the preference dependence model, wood was the only group for which the cross-price coefficient was more than twice its standard error. Therefore, it would seem appropriate to use the less-restricted version that allows this group to have interactions, that is, $v_{ij}^5 \neq 0, i \neq j$. In a format similar to (3.1), this model can be expressed as:

$$(4.2) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi A_{it}^g(\boldsymbol{\theta}) + \delta(g)[2\gamma(i) - 1]v_{12}^g \Delta p_{21,t}^g + \varepsilon_{it}^g, \quad i = 1, 2; g = 1, \dots, 8,$$

⁹ As shown in Appendix A10, adding intercepts to the model (which allow for residual trends) does not change the estimates appreciably.

where $\delta(g)$ is an indicator variable equal to 1 when $g = 5$ (for wood) and zero when $g \neq 5$, and as before, $\gamma(i)$ is an indicator variable that equals 1 when $i = 1$ and zero otherwise. This will be referred to as the “partial preference independence” (PPI) model.

We shall use model (4.2) subsequently as it is parsimonious and as shown in Table 4.4, all marginal shares are now positive. These estimates can be compared to those of the preference dependent model given in Table 4.2. First, the marginal shares, and their standard errors, are very similar. Second, regarding the domestic own-price coefficients, those of Table 4.4 are all absolutely lower (except for group 5, where the coefficient is slightly higher), and all their standard errors are lower. Third, the foreign own-price coefficients and their standard errors tend to fall. Fourth, the cross-price coefficient for wood is significantly positive and close to the Table 4.2 value; the positive value means the two varieties of the good are substitutes, which is plausible. Fifth, the changes in the price coefficients lead to a noticeable drop in the income flexibility from -0.51 to -0.36 , while its standard error falls by almost one-half. All in all, there is a reduced substitutability. From panel A, row 1, column 2 of Table 4.3, model (4.2) is acceptable at the 1-percent level, but not at the 1-percent level.¹⁰

There is considerable diversity among the income elasticities of column 7 of Table 4.4, and in all cases, the foreign-variety elasticity exceeds that of the domestic one. Foreign goods are evidently regarded as more luxurious than their domestic counterparts, agreeing with the idea that overseas-varieties tend to be more expensive and prized for their quality. From column 3 of panel B of Table 4.3, the hypothesis that the foreign income elasticities exceed the domestic ones cannot be rejected, as expected. As the income elasticities are less than unity, food is a necessity, in accordance with Engel’s law (although the foreign variety is close to the cut-off value of unity). There is not a great deal of substitution as the price elasticities of

¹⁰ For further implications of the estimates in Table 4.4, see Appendix A10.

columns 8 and 9 are reasonably low, reflecting the broad nature of the goods involved. Finally, as shown by column 4, panel A of Table 4.3, completely ignoring the role of prices by setting all price coefficients to zero would be unwise, as expected. All in all, the estimates of Table 4.4 seem not unreasonable.

5. The Macro Aggregates and Micro Elements

The linear structure of the model means that consistent aggregates can be obtained by summing over subsets of goods. Taking imports as an example, denote the set of all foreign-variety goods (other than wood, to be treated separately) by V_2 . The budget and marginal shares of imports of all goods are $\bar{W}_{2t} = \sum_{g \in V_2} \bar{w}_{2t}^g$, $\Theta_2 = \sum_{g \in V_2} \theta_2^g$, so that $\bar{w}_{2t}^g / \bar{W}_{2t}$ and θ_2^g / Θ_2 are the shares of good g within imports, or the conditional shares. The corresponding conditional Divisia volume and Frisch price indexes use these shares as weights:

$$DQ_{2t} = \sum_{g \in V_2} \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} Dq_{2t}^g, \quad DP'_{2t} = \sum_{g \in V_2} \frac{\theta_2^g}{\Theta_2} Dp_{2t}^g.$$

The demand for total imports is given by summing over $g \in V_2$ both sides of the preference independent demand equation, Equation (4.1) for $i = 2$ and with $\phi\theta_2^g$ substituted for v_{ii}^g :

$$\sum_{g \in V_2} \bar{w}_{2t}^g Dq_{2t}^g = \sum_{g \in V_2} \theta_2^g DQ_t + \sum_{g \in V_2} \phi\theta_2^g (Dp_{2t}^g - DP'_t),$$

which can be expressed as (see Appendix A7 for details)

$$(5.1) \quad \bar{W}_{2t} DQ_{2t} = \Theta_2 DQ_t + \phi\Theta_2 (DP'_{2t} - DP'_t),$$

where, for simplicity, the disturbance has been omitted. This is the demand for all imports, or the group demand equation; thus, imports depend on the changes in real income, DQ_t , and their relative price, $DP'_{2t} - DP'_t$.

Dividing both sides of Equation (5.1) by $\bar{W}_{2t}$ shows that $\frac{\Theta_2}{\bar{W}_{2t}}$ and $\phi \frac{\Theta_2}{\bar{W}_{2t}}$ are the income and price elasticities of demand for V_2 . Since $\frac{\Theta_2}{\bar{W}_{2t}} = \sum_{g \in V_2} \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} \frac{\theta_2^g}{\bar{w}_{2t}^g}$, the income elasticity of demand for all imports is a weighted average of those of imports of individual goods; and the corresponding price elasticity has a similar weighted-average property. This unification

between import demand at the macro level and the demands for the individual goods is an attractive feature of the approach. Note also that equation (5.1) is an “uppercase” version of (4.1), a further macro-micro relationship. The final row of panel B of Table 5.1 indicates that, on average, the budget share $\bar{W}_{2t} = 26.27$ percent, which means that imports account for a little over one-quarter of total expenditure. From the last two elements of that row, the income elasticity of imports is 1.77, so they are a fairly strong luxury, while their price elasticity is -0.64 .¹¹

Not only is there a demand equation for imports as a whole, but also demands for each good within imports. As shown in Appendix A7, the conditional demand for imports of group g is

$$(5.2) \quad \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} Dq_{2t}^g = \frac{\theta_2^g}{\Theta_2} DQ_{2t} + \left(\phi \frac{\Theta_2}{\bar{W}_{2t}} \right) \frac{\theta_2^g}{\Theta_2} (Dp_{2t}^g - DP_{2t}'),$$

which also has the same general form as Equation (5.1). Rows 1-4 and 6-8 of panel B of Table 5.1 contain the conditional elasticities implied by this equation for each group (other than wood). Thus, for example, from row 1, conditional on total imports remaining unchanged, the income elasticity of food imports is 0.54 and the price elasticity is -0.34 . There is also an aggregate demand equation for domestic goods (represented by the set V_1), as well as corresponding conditional demands, which are contained in panel A of Table 5.1. Panel C refers to wood (set V_3), the group with the cross-price effects. A similar approach yields the total demand for each good (from both sources), as well as the conditional demand for each of the two varieties of the good. For example, there is the demand for all food from both sources,

¹¹ Equation (5.1) is not estimated directly; rather, its parameters are derived from the estimates of those of the underlying micro system (4.2) given in Table 4.4. Note also as wood accounts for only about 3 percent of imports, the income elasticity of total imports closely approximates the -0.64 value of this paragraph.

and two conditional demands – one for domestically produced and the other for imported food. Table 5.2 contains these demands. These are consistent with the individual demand equations, as above.

This approach is useful for three purposes. First, it is a convenient way to focus attention of a variable of macroeconomic importance, total imports. Second, as will be demonstrated in the next section, the approach can be used for counter-factual analysis. A third use is for measuring goodness-of-fit. The left-hand side of the i^{th} equation of the demand model, in infinitesimal changes, is the quantity change weighted by the budget share, $w_i d \log q_i$. This share is $w_i = \frac{p_i q_i}{M}$ with $dw_i = w_i d \log p_i + w_i d \log q_i - w_i d \log M$, which shows that the variable on the left of the demand equation is the quantity component of the change in the budget share. With income and prices taken as given, the predicted change in the quantity component can be converted into budget-share projections and Table 5.3 summarised the results.¹² For comparison, we also use a “naïve” model of no-change extrapolation whereby the predicted share is last year’s observed value. Columns 2-7 of this table indicate that, for individual varieties and groups, the demand model outperforms the naïve alternative in most cases (the exceptions are “Chemicals” and “Motor Vehicles and Transport”). For all varieties and groups as a whole, the demand model again outperforms the naïve approach, as shown by columns 8-9.

6. Why Did Imports Surge?

Figure 1.1 shows that import penetration in Australia rise noticeably during the last two decades. To shed light on the reasons for this, we use the aggregation approach described in the previous section for counter-factual simulations.

¹² For full details, see Appendix A8.

Consider the change in a generic budget share: $dw_i = d\left(\frac{p_i q_i}{M}\right) = w_i \left\{ d\left(\log \frac{p_i}{P}\right) + d\left(\log \frac{q_i}{Q}\right) \right\}$, where $d(\log P) = \sum_i w_i d(\log p_i)$ and $d(\log Q) = \sum_i w_i d(\log q_i)$ are price and volume indexes satisfying $d(\log P) + d(\log Q) = d(\log M)$. Thus, the change in the share comprises price and volume components. Column 6 of Table 6.1 shows that for 6 of the 8 groups, the relative price of imports falls, which, from above, has a *negative* direct effect on the share. Such an effect cannot contribute to an explanation of the *rise* in the import share. The volume component, which is proportional to $d\left(\log \frac{q_i}{Q}\right)$, reflects the role of income and price substitution, an indirect effect of prices. For price substitution, the fall in the relative price, coupled with the negative price elasticity, leads to a rise in the share, but for two reasons this effect is only modest. First, the price elasticities are low; for example, the price elasticity of all types of imports (other than wood) is -0.64 (Table 5.1, last element of column 6 of panel B). Second, although the relative prices mostly fall, over the 21-year period, the falls are not particularly large; for example, the relative price of all imports falls by about 8.6 percent (Table 6.1, second-last element of column 6). Coupled with the low elasticity, the indirect price effect is insufficient to offset the direct effect. This leaves income as the dominant driver of the rise in the import shares. On average, income rises by approximately 0.86 percent p. a. (Table 4.1, last element of column 5), so the total increase over the whole period is about 17 percent. This is to be combined with the income elasticities, which, on average, are high; the elasticity of total imports, for example, is 1.77 (Table 5.1, last element of column 5 of panel B). It is this combination that leads to a rise in the import shares.¹³ The role of high income elasticities in driving imports agrees with prior research such as Houthakker and Magee (1969).

¹³ There is also a residual component of the demand equation and a finite-change approximation error. As shown in Appendix A9, these additional terms are accounted for in the simulations that follow. Accordingly, the differences between simulated and actual values solely reflect the influence of the counter-factual shock.

The change in income in year t is the Divisia volume index DQ_t , $t = 1996, \dots, 2017$. Suppose income now changes in all years $t > 1996$ by $DQ_t + r$. To simulate the change in total imports, we use the corresponding demand equation, equation (5.1), to eliminate the effects of observed income, add the effects of $DQ_t + r$, and hold all other factors unchanged. Accumulating these changes then leads to the simple result that in, year s , simulated imports (measured by its expenditure share, to be denoted by $\tilde{W}_{2s}$) is equal to the observed value (W_{2s}) plus the accumulated difference, that is, $\tilde{W}_{2s} = W_{2s} + \sum_{t=1996}^s (\Theta_2 - \bar{W}_{2t})r$. The term $(\Theta_2 - \bar{W}_{2t})$ is the excess of the marginal share over the budget share of imports. Denoting the mean of this term by $\bar{W}_2(\eta_2 - 1)$, with η_2 the income elasticity, simulated imports can be expressed as

$$(6.1) \quad \tilde{W}_{2s} = W_{2s} + \bar{W}_2(\eta_2 - 1)(s - 1996)r.$$

Thus, the difference in imports on account of the income shock, $\tilde{W}_{2s} - W_{2s}$, is $\bar{W}_2(\eta_2 - 1)(s - 1996)r$. This is proportional to the product of (i) the annual shock scaled up by the number of years of the shock, $(s - 1996)r$; and (ii) the deviation of the income elasticity from unity, $(\eta_2 - 1)$. Consequently, a positive shock to income results in higher imports when they are a luxury.¹⁴

To analyse the effects of income growth on imports in more detail, we consider three related counter-factual simulations:

1. *Income shock.* We use in Equation (6.1) a shock of $r = -\frac{1}{22} \sum_{t=1996}^{2017} DQ_t$, the negative of the mean income growth rate. Thus, income growth is simulated to be positive in years of above-average observed growth, and negative in below-average years, with deviations washing out over the whole period. Panel A1 of Figure 6.1 reveals that this leads to considerably more modest growth in imports share, rather than it increasing by

¹⁴ For details of the material in this paragraph, see Appendix A9.

more than 12 percentage points. As the confidence bands do not overlap with actual, the lowering of income leads to significantly lower import penetration, as is demonstrated in panel A2. The plots in panel B of this figure show the effects of the same reduction in income on imports of each good (as percentages of total expenditure on the good). The results are less dramatic, but in each case there is a noticeable decline in the share. The conclusion is clear -- higher income can account for much of the import penetration.

2. *Group expenditure shock.* The demand for imports of good g , conditional on total spending on the good, is $\frac{\bar{w}_{2t}^g}{\bar{w}_t^g} Dq_{2t}^g = \frac{\theta_2^g}{\theta^g} DQ_t^g + \left(\phi \frac{\theta^g}{\bar{w}_t^g} \right) \frac{\theta_2^g}{\theta^g} (Dp_{2t}^g - DP_t^{g'})$, as in Table 5.2. To study the effects of growth in spending on g , we use the same general approach as before and now change the Divisia volume index of the group from DQ_t^g to $DQ_t^g + r$, where $r = -\frac{1}{22} \sum_{t=1996}^{2017} DQ_t^g$. Panel C of Figure 6.1 indicates this lowers the import shares by roughly the same amount as previous income shock. The only exception to this rule is for energy and minerals, where the effect is smaller.
3. *Total imports shock.* Equation (5.2) refers to the demand for imports of good g conditional on total imports, as measured by DQ_{2t} . The effects of a change in total imports on imports of g is simulated by replacing DQ_{2t} in (5.2) with $DQ_{2t} + r$, where $r = -\frac{1}{22} \sum_{t=1996}^{2017} DQ_{2t}$. From panel D of Figure 6.1, this shock has a very substantial effect on each conditional import share, so much so that the shares at the end of the period are lower than at the start.

7. Concluding Comments

Globalisation has opened up markets in many countries and led to higher incomes, more choice for consumers, increased competition from foreign-produced goods and greater import penetration. To analyse the key drivers of import penetration, this paper developed a consumer-

demand framework that emphasises the substitutability between foreign and domestic varieties of goods. The demand for total imports is the consistent aggregation over the demands for foreign varieties of individual goods, so the macro elasticities are explicit weighted averages of their micro counterparts. Our approach extends the previous literature as it is fairly general, not involving restrictive assumptions such as homotheticity; allows for an array of hypothesis tests; and can be implemented with relatively short time-series data, which is important for those countries with limited availability of data. The approach can also be used in counterfactual simulations that isolate the separate determinants of imports.

We used the Australian experience to illustrate the application of the approach. Over the last two decades, imports have risen considerably -- from about 20 percent of total goods expenditure to about 32 percent. There have also been similar substantial rises in import penetration for individual goods. The prices of imports mostly fell, but coupled with low price elasticities, these were insufficient to account for the import surge. Income growth was the primary reason -- the higher incomes were spent on more luxurious goods, which in many cases were imports. This is an unexpected result.

It is appropriate to conclude by acknowledging the limitations of the paper. First, the supply-side of the economy is minimised by treating prices and income as given to consumers. As the prices of foreign varieties are linked to world prices, taking these as given seems not unreasonable. Many of the domestic goods have sizable service components, which tend to be nontraded. Thus, the exogeneity of the prices of these goods could be of more concern. It is also not unreasonable to take real income as given, as this usually evolves only slowly over time in response to long-term demographic/productivity trends. One way to allow for production/pricing technology to play a role and for income to be generated endogenously would be to embed our approach within a CGE model, but such an extension is beyond the scope of the paper. One aspect of our empirical results requires comment. As foreign and

domestic varieties were matched in our data, the expectation was that they would be at least moderately substitutable. This was not borne out by the results, however. Low substitutability is also reflected in our estimate of the income flexibility (the inverse of the income elasticity of the marginal utility), which is noticeably lower than previous estimates. As this issue remains a puzzle, the estimates should be treated with due care.

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Table 2.1. Notation for Domestic and Foreign Varieties

Variety i of goods in group g (1)	Variables			Coefficients of demand equations			Disturbance terms (8)
	Quantities (2)	Prices (3)	Budget shares (4)	Marginal shares (5)	Price		
					Domestic (6)	Foreign (7)	
Domestic, $i = 1$	Dq_{1t}^g	Dp_{1t}^g	$\bar{w}_{1t}^g$	θ_1^g	v_{11}^g	v_{12}^g	ε_{1t}^g
Foreign, $i = 2$	Dq_{2t}^g	Dp_{2t}^g	$\bar{w}_{2t}^g$	θ_2^g	v_{21}^g	v_{22}^g	ε_{2t}^g

Note: This table summarises the notation used for the two-variety demand model, Equation (2.11).

Table 4.1. Means and Standard Deviations,
Australia, 1996-2017

Commodity group g (1)	Variety i (2)	Budget share w_i^g (3)	Log-changes in	
			Relative price $Dp_i^g - DP$ (4)	Relative quantity $Dq_i^g - DQ$ (5)
1. Food and Agricultural Commodities	Domestic, 1	20.19 (1.23)	0.75 (3.17)	-0.77 (3.88)
	Foreign, 2	1.82 (0.47)	0.39 (5.97)	2.87 (4.97)
2. Energy and Minerals	1	22.29 (1.16)	0.36 (5.85)	-0.92 (5.50)
	2	6.53 (1.84)	0.46 (6.66)	2.45 (5.94)
3. Chemicals	1	5.32 (0.28)	-0.53 (2.90)	0.04 (4.04)
	2	2.91 (0.31)	-1.37 (4.62)	3.04 (2.96)
4. Textile, Leather, Clothing and Footwear	1	4.56 (0.55)	-0.12 (2.04)	-1.38 (3.74)
	2	1.92 (0.35)	-0.09 (7.94)	2.25 (6.42)
5. Wood and Paper Products	1	4.81 (1.02)	0.10 (1.66)	-2.58 (5.48)
	2	0.76 (0.10)	-0.26 (7.51)	-1.21 (8.06)
6. Machinery and Equipment	1	7.41 (0.32)	-0.29 (1.69)	-0.32 (3.88)
	2	7.75 (0.90)	-0.57 (6.78)	2.66 (6.57)
7. Motor Vehicles and Transport	1	5.92 (1.20)	-0.74 (1.76)	-1.96 (6.31)
	2	4.45 (0.54)	-0.83 (4.52)	2.49 (8.13)
8. Miscellaneous Manufactured Goods	1	2.48 (0.31)	0.10 (2.67)	-1.45 (4.40)
	2	0.89 (0.21)	-0.60 (7.52)	4.83 (6.72)
			Divisia price index DP : 1.43 (1.65)	Divisia quantity index DQ : 0.86 (2.47)

Notes:

- For variety i ($i = 1, 2$) in group g ($g = 1, \dots, 8$), the price (p_i^g) is the expenditure-share weighted mean of the prices of corresponding disaggregated items (see Appendix A4 for details); the corresponding quantity (q_i^g) is per capita expenditure deflated by the price.
- Columns 3 – 5: The Divisia price and quantity indexes of the last row are defined as $DP_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dp_{it}^g$ and $DQ_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$, where $\bar{w}_{it}^g$ denotes the average over years $t-1$ and t of the budget share.
- Standard deviations in parentheses.
- All entries are multiplied by 100.

Table 4.2. Domestic and Foreign Demands under Preference Dependence
 $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t') + \varepsilon_{it}^g, \quad i, j = 1, 2; g = 1, \dots, 8$

Commodity group g	Variety i	Budget share (Sample mean $\times 100$) w_i^g	Coefficients ($\times 100$)			Elasticities		
			Marginal share θ_i^g	Price coefficients		Income $\eta_i^g = \frac{\theta_i^g}{w_i^g}$	Frisch price	
				Domestic v_{i1}^g	Foreign v_{i2}^g		Domestic $F_{i1}^g = \frac{v_{i1}^g}{w_i^g}$	Foreign $F_{i2}^g = \frac{v_{i2}^g}{w_i^g}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Food and Agricultural Commodities	Domestic, 1	20.19	3.47 (5.15)	-2.26 (2.61)	0.51 (0.32)	0.17 (0.26)	-0.11 (0.12)	0.03 (0.02)
	Foreign, 2	1.82	1.59 (0.52)		-1.31 (0.25)	0.87 (0.29)	0.28 (0.17)	-0.72 (0.14)
2. Energy and Minerals	1	22.29	34.25 (6.52)	-14.35 (3.74)	-3.00 (1.56)	1.54 (0.26)	-0.64 (0.14)	-0.13 (0.06)
	2	6.53	16.18 (4.56)		-5.20 (2.27)	2.48 (0.70)	-0.46 (0.22)	-0.80 (0.30)
3. Chemicals	1	5.32	3.58 (1.72)	-1.67 (0.90)	-0.15 (0.39)	0.67 (0.32)	-0.31 (0.16)	-0.03 (0.07)
	2	2.91	3.65 (0.68)		-1.70 (0.35)	1.25 (0.24)	-0.05 (0.13)	-0.59 (0.12)
4. Textile, Leather, Clothing and Footwear	1	4.56	1.91 (1.16)	-1.38 (0.69)	0.42 (0.26)	0.42 (0.25)	-0.30 (0.14)	0.09 (0.06)
	2	1.92	1.17 (0.47)		-1.01 (0.19)	0.61 (0.26)	0.22 (0.14)	-0.53 (0.10)
5. Wood and Paper Products	1	4.81	0.18 (1.60)	-0.65 (0.88)	0.55 (0.21)	0.04 (0.34)	-0.13 (0.17)	0.12 (0.04)
	2	0.76	0.23 (0.33)		-0.67 (0.13)	0.31 (0.42)	0.73 (0.27)	-0.88 (0.17)
6. Machinery and Equipment	1	7.41	7.51 (1.82)	-3.61 (1.35)	-0.19 (0.79)	1.01 (0.26)	-0.49 (0.17)	-0.03 (0.11)
	2	7.75	12.71 (2.63)		-6.25 (0.98)	1.64 (0.32)	-0.02 (0.10)	-0.81 (0.12)
7. Motor Vehicles and Transport	1	5.92	4.68 (2.58)	-2.28 (2.13)	-0.09 (1.44)	0.79 (0.45)	-0.38 (0.35)	-0.02 (0.24)
	2	4.45	6.60 (2.18)		-3.25 (1.27)	1.48 (0.50)	-0.02 (0.32)	-0.73 (0.28)
8. Miscellaneous Manufactured Goods	1	2.48	1.17 (0.80)	-0.65 (0.48)	0.06 (0.19)	0.47 (0.34)	-0.26 (0.18)	0.02 (0.07)
	2	0.89	1.32 (0.37)		-0.73 (0.12)	1.48 (0.36)	0.07 (0.19)	-0.82 (0.12)
			Income flexibility $\phi = -0.506$ (0.092)					

Notes:

- Columns 5 – 6: As the 2×2 matrices $[v_{ij}^g], g = 1, \dots, 8$, are symmetric, only the upper triangles are presented.
- Columns 8 – 9: The Frisch price elasticity F_{ij}^g is the elasticity of demand for variety i in group g with respect to the relative price of variety j in the same group g ($i, j = 1, 2; g = 1, \dots, 8$). The price is the Frisch-deflated relative price, $Dp_{jt}^g - DP_t'$, which holds the marginal utility of income constant. The Frisch own-price elasticities, F_{ii}^g , are **emboldened**. Examples: $F_{11}^1 = -0.11$ is the Frisch own-price elasticity of the domestic variety of food etc. ($i = 1, g = 1$), while $F_{21}^1 = 0.28$ is the elasticity of the foreign variety of the same good ($i = 2, g = 1$) with respect to the price of the domestic variety ($j = 1$).
- Bootstrap standard errors with 10,000 replications in parentheses.

Table 4.3. Hypothesis Tests

A. F-tests			
[Observed F-stat (95 th and 99 th percentiles)]			
Alternative (1)	Null		
	PPI (2)	PI (3)	No price effects NP (4)
1. Preference Dependence (PD), $v_{12}^g = v_{21}^g \neq 0; g = 1, \dots, 8$	3.67 (3.16, 5.08)	3.71 (2.79, 4.69)	14.10 (2.02, 2.78)
2. Partial Preference Independence (PPI), $v_{12}^g = v_{21}^g = 0; g =$ $1, \dots, 8; g \neq 5, v_{12}^5 = v_{21}^5 \neq 0$	—	3.79 (2.33, 4.30)	47.96 (4.25, 7.26)
3. Preference Independence (PI), $v_{12}^g = v_{21}^g = 0; g = 1, \dots, 8$	—	—	91.37 (7.82, 13.95)
B. t-tests			
Comm. group g (1)	Null →	PI: $v_{12}^g = v_{21}^g = 0$	LD = PI + Domestic income elasticity is lower: $\theta_1^g/w_1^g \leq \theta_2^g/w_2^g$
	Alt. →	PD: $v_{12}^g = v_{21}^g \neq 0$	PI + Domestic income elasticity is higher: $\theta_1^g/w_1^g > \theta_2^g/w_2^g$
		[Observed t-stat (2.5 th and 97.5 th percentiles)]	[Observed t-stat (95 th percentile)]
		(2)	(3)
1. Food and Agricultural Comm.		1.17 (0.35, 3.33)	-1.04 (-0.48)
2. Energy and Minerals		-3.63 (-8.62, -2.69)	-0.44 (1.06)
3. Chemicals		-0.28 (-1.55, 1.45)	-0.93 (-0.44)
4. Textile, Leather, Cloth. and Fw.		1.16 (0.73, 3.72)	-0.57 (0.02)
5. Wood and Paper Products		2.16 (0.95, 4.36)	-0.79 (0.27)
6. Machinery and Equipment		-0.27 (-1.12, 3.36)	-2.10 (-0.75)
7. Motor Vehicles and Transport		-0.09 (-2.34, 3.60)	-1.72 (-0.31)
8. Misc. Manufactured Goods		0.25 (-0.36, 2.83)	-1.45 (-1.08)

Notes:**1. Panel A:**

- (i) Interpretation: The null hypothesis is rejected when the observed F-statistic exceeds the critical value. Critical values given in parentheses are the 95th and 99th percentiles of 10,000 bootstrap replications of the corresponding F-statistic.
- (ii) Row 1: Relative to PD, at the 1-percent level of significance, we are unable to reject PPI and PI but are able to reject NP. All three null hypotheses are rejected at the 5-percent level.
- (iii) Row 2: Relative to PPI, at the 1-percent level we are unable to reject PI, but can reject it at the 5-percent level; NP is rejected at the 5- and 1-percent levels.
- (iv) Row 3: Relative to PI, we reject NP at the 5- and 1-percent levels.

2. Panel B:

- (i) Column 2: The null is rejected when the observed t-statistic is either smaller than the lower critical value or greater than the upper critical value. Critical values given in parentheses are the 2.5th and 97.5th percentiles of 10,000 bootstrap replications of the t-statistic under PI. In all cases we are unable to reject the null.
- (ii) Column 3: The null is rejected when the observed t-statistic is greater than the critical value. Critical values given in parentheses are the 95th percentile of 10,000 bootstrap realisations of the t-statistic under LD. These tests use mean budget shares. In all cases we are unable to reject the null.

3. Some commodity names in column 1 are abbreviated.**4. See Appendix A6 for further details of the tests, as well as plots of the distributions of the F-statistics.**

Table 4.4. Domestic and Foreign Demands under Partial Preference Independence
 $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi A_{it}^g(\theta) + \delta(g)[2\gamma(i) - 1]\nu_{12}^g \Delta p_{21,t}^g + \varepsilon_{it}^g; i = 1, 2; g = 1, \dots, 8$

Commodity group g	Variety i	Budget share (Sample mean $\times 100$) w_i^g	Coefficients ($\times 100$)			Elasticities		
			Marginal share θ_i^g	Price coefficients		Income $\eta_i^g = \frac{\theta_i^g}{w_i^g}$	Frisch price	
				Domestic ν_{i1}^g	Foreign ν_{i2}^g		Domestic $F_{i1}^g = \frac{\nu_{i1}^g}{w_i^g}$	Foreign $F_{i2}^g = \frac{\nu_{i2}^g}{w_i^g}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Food and Agricultural Commodities	Domestic, 1	20.19	3.36 (5.28)	-1.21 (1.73)		0.17 (0.26)	-0.06 (0.09)	
	Foreign, 2	1.82	1.73 (0.52)		-0.62 (0.20)	0.95 (0.29)		-0.34 (0.11)
2. Energy and Minerals	1	22.29	30.74 (5.99)	-11.05 (2.02)		1.38 (0.27)	-0.50 (0.09)	
	2	6.53	17.23 (4.41)		-6.19 (1.66)	2.64 (0.68)		-0.95 (0.25)
3. Chemicals	1	5.32	3.51 (1.70)	-1.26 (0.59)		0.66 (0.32)	-0.24 (0.11)	
	2	2.91	3.68 (0.61)		-1.32 (0.29)	1.26 (0.21)		-0.45 (0.10)
4. Textile, Leather, Clothing and Footwear	1	4.56	1.75 (1.19)	-0.63 (0.39)		0.38 (0.26)	-0.14 (0.09)	
	2	1.92	1.43 (0.57)		-0.51 (0.20)	0.75 (0.30)		-0.27 (0.10)
5. Wood and Paper Products	1	4.81	0.23 (1.64)	-0.67 (0.56)	0.58 (0.17)	0.05 (0.34)	-0.14 (0.12)	0.12 (0.03)
	2	0.76	0.24 (0.33)		-0.67 (0.13)	0.32 (0.43)	0.77 (0.22)	-0.88 (0.17)
6. Machinery and Equipment	1	7.41	7.75 (1.93)	-2.78 (0.72)		1.05 (0.26)	-0.38 (0.10)	
	2	7.75	13.72 (2.31)		-4.93 (0.91)	1.77 (0.30)		-0.64 (0.12)
7. Motor Vehicles and Transport	1	5.92	4.91 (2.67)	-1.77 (0.89)		0.83 (0.45)	-0.30 (0.15)	
	2	4.45	7.15 (2.11)		-2.57 (0.74)	1.61 (0.47)		-0.58 (0.17)
8. Miscellaneous Manufactured Goods	1	2.48	1.07 (0.83)	-0.39 (0.28)		0.43 (0.34)	-0.16 (0.11)	
	2	0.89	1.49 (0.26)		-0.54 (0.11)	1.68 (0.30)		-0.60 (0.12)
			Income flexibility $\phi = -0.359$ (0.050)					

Notes:

1. The term $A_{it}^g(\theta) = \theta_i^g (Dp_{it}^g - \sum_{g=1}^8 \sum_{k=1}^2 \theta_k^g Dp_{kt}^g)$, with $\theta = [\theta_k^g]$, a vector of all the marginal shares; $\Delta p_{ij,t}^g = Dp_{it}^g - Dp_{jt}^g, i \neq j$; $\delta(g)$ is an indicator variable that equals 1 when $g = 5$ (for wood) and zero when $g \neq 5$; $\gamma(i)$ is an indicator variable that equals 1 when $i = 1$ and zero when $i = 2$; and the cross-price coefficients $\nu_{12}^g = \nu_{21}^g$. See notes to Table 4.2 for further details.
2. The Frisch own-price elasticities, F_{ii}^g , are **emboldened**.
3. Bootstrap standard errors with 10,000 replications in parentheses.

Table 5.1. Aggregated and Disaggregated Demands by Variety

Commodity group g /aggregate (1)	Demand equations (2)	Budget share (3)	Marginal share (4)	Income elasticity (5)	Own-price elasticity (6)
A. Variety 1: Domestic					
1. Food	$\frac{\bar{w}_{1t}^g}{\bar{w}_{1t}} Dq_{1t}^g = \frac{\theta_1^g}{\theta_1} DQ_{1t} + \left(\phi \frac{\theta_1}{\bar{w}_{1t}} \right) \frac{\theta_1^g}{\theta_1} (Dp_{1t}^g - DP_{1t}'), g = 1, \dots, 8, g \neq 5$	29.62	6.23	0.21	-0.06
2. Energy		32.70	57.89	1.77	-0.49
3. Chemicals		7.80	6.66	0.85	-0.24
4. Textiles		6.68	3.33	0.50	-0.14
6. Machinery		10.87	14.60	1.34	-0.38
7. Transports		8.69	9.27	1.07	-0.30
8. Misc.		3.63	2.02	0.56	-0.16
Sum		100	100		
All groups	$\bar{W}_{1t} DQ_{1t} = \theta_1 DQ_t + \phi \theta_1 (DP_{1t}' - DP_t')$	68.15	53.13	0.78	-0.28
B. Variety 2: Foreign					
1. Food	$\frac{\bar{w}_{2t}^g}{\bar{w}_{2t}} Dq_{2t}^g = \frac{\theta_2^g}{\theta_2} DQ_{2t} + \left(\phi \frac{\theta_2}{\bar{w}_{2t}} \right) \frac{\theta_2^g}{\theta_2} (Dp_{2t}^g - DP_{2t}'), g = 1, \dots, 8, g \neq 5$	6.92	3.73	0.54	-0.34
2. Energy		24.86	37.20	1.50	-0.95
3. Chemicals		11.08	7.93	0.72	-0.46
4. Textiles		7.30	3.08	0.42	-0.27
6. Machinery		29.51	29.44	1.00	-0.63
7. Transports		16.95	15.40	0.91	-0.58
8. Misc.		3.38	3.22	0.95	-0.61
Sum		100	100		
All groups	$\bar{W}_{2t} DQ_{2t} = \theta_2 DQ_t + \phi \theta_2 (DP_{2t}' - DP_t')$	26.27	46.63	1.77	-0.64
C. Variety 3: Wood					
1. Domestic	$\frac{\bar{w}_{1t}^5}{\bar{w}_{3t}} Dq_{1t}^5 = \frac{\theta_1^5}{\theta_3} DQ_{3t} + \sum_{j=1}^2 v_{1j}^5 (Dp_{jt}^5 - DP_{3t}')$	86.35	46.24	0.54	-0.01
2. Foreign	$\frac{\bar{w}_{2t}^5}{\bar{w}_{3t}} Dq_{2t}^5 = \frac{\theta_2^5}{\theta_3} DQ_{3t} + \sum_{j=1}^2 v_{2j}^5 (Dp_{jt}^5 - DP_{3t}')$	13.65	53.76	3.94	-0.05
Sum		100	100		
All groups	$\bar{W}_{3t} DQ_{3t} = \theta_3 DQ_t + \phi \theta_3 (DP_{3t}' - DP_t')$	5.57	0.45	0.08	-0.03
Sum all groups, all three varieties (A + B + C)		100	100		

Notes:

- Notation and indexes:** There are 8 groups of goods, denoted by the superscript $g = 1, \dots, 8$, and 2 items in each, domestically and foreign produced, denoted by the subscript $i = 1, 2$. The budget and marginal shares of item i of group g are $\bar{w}_{it}^g$ and θ_{it}^g , respectively. The overall Divisia volume index is $DQ_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$, where q_{it}^g is the per capita quantity demand of i in g and D is the log-change operator from $t-1$ to t . The overall Frisch price index is $DP_t' = \sum_{g=1}^8 \sum_{i=1}^2 \theta_{it}^g Dp_{it}^g$, where p_{it}^g is the price of i in g .
- Three varieties:** The $2 \times 8 = 16$ “elementary” goods are divided into 3 varieties:
 - Domestically produced goods other than Wood:** These are goods indexed by $i = 1, g = 1, \dots, 8, g \neq 5$, denoted by the set V_1 .
 - Imported goods other than Wood** are those indexed by $i = 2, g = 1, \dots, 8, g \neq 5$, denoted by V_2 .
 - Wood** refers to those goods for which $i = 1, 2, g = 5$, denoted by V_3 .
- Budget and marginal shares:** For variety k ($k = 1, 2, 3$), these shares are $\bar{W}_{kt} = \sum_{g \in V_k} \bar{w}_{kt}^g$, $\theta_k = \sum_{g \in V_k} \theta_k^g$, and the corresponding Divisia volume and Frisch price indexes are $DQ_{kt} = \sum_{g \in V_k} \frac{\bar{w}_{kt}^g}{\bar{W}_{kt}} Dq_{kt}^g$, $DP_{kt}' = \sum_{g \in V_k} \frac{\theta_k^g}{\theta_k} Dp_{kt}^g$.
- Other coefficients.** ϕ is the income flexibility, and $v_{ij}^5, i, j = 1, 2$, are the price coefficients for Wood, which satisfy $v_{12}^5 = v_{21}^5$ and $\sum_{j=1}^2 v_{ij}^5 = \phi \theta_i^5, i = 1, 2$.
- Column 1:** Commodity names abbreviated.
- Column 2:** Disturbance terms are omitted.
- Columns 3 – 4:** All entries are multiplied by 100. Budget shares are sample averages.
- Columns 5 and 6:** “Income” elasticities are with respect to the high-level aggregate. Own-price elasticities are of the Frisch type (marginal utility of income constant).
- See Appendix A7 for details of derivations.

Table 5.2. Aggregated and Disaggregated Demands by Commodity Group

Commodity group g (1)	Variety i (2)	Demand equations (3)	Budget share (4)	Marginal share (5)	Income elasticity (6)	Own-price elasticity (7)
1. Food and Agricultural Commodities	Domestic, 1	$\frac{\bar{w}_{it}^1}{\bar{w}_t^1} Dq_{it}^1 = \frac{\theta_i^1}{\theta^1} DQ_t^1 + \left(\phi \frac{\theta_i^1}{\bar{w}_t^1} \right) \frac{\theta_i^1}{\theta^1} (Dp_{it}^1 - DP_t^{1'})$	91.74	65.56	0.71	-0.06
	Foreign, 2		8.26	34.44	4.17	-0.34
	Sum		100	100		
	Both varieties	$\bar{W}_t^1 DQ_t^1 = \theta^1 DQ_t + \phi \theta^1 (DP_t^{1'} - DP_t')$	22.00	5.05	0.23	-0.08
2. Energy and Minerals	1	$\frac{\bar{w}_{it}^2}{\bar{w}_t^2} Dq_{it}^2 = \frac{\theta_i^2}{\theta^2} DQ_t^2 + \left(\phi \frac{\theta_i^2}{\bar{w}_t^2} \right) \frac{\theta_i^2}{\theta^2} (Dp_{it}^2 - DP_t^{2'})$	77.33	63.94	0.83	-0.49
	2		22.67	36.06	1.59	-0.95
	Sum		100	100		
	Both varieties	$\bar{W}_t^2 DQ_t^2 = \theta^2 DQ_t + \phi \theta^2 (DP_t^{2'} - DP_t')$	28.82	48.10	1.67	-0.60
3. Chemicals	1	$\frac{\bar{w}_{it}^3}{\bar{w}_t^3} Dq_{it}^3 = \frac{\theta_i^3}{\theta^3} DQ_t^3 + \left(\phi \frac{\theta_i^3}{\bar{w}_t^3} \right) \frac{\theta_i^3}{\theta^3} (Dp_{it}^3 - DP_t^{3'})$	64.61	48.90	0.76	-0.24
	2		35.39	51.10	1.44	-0.46
	Sum		100	100		
	Both varieties	$\bar{W}_t^3 DQ_t^3 = \theta^3 DQ_t + \phi \theta^3 (DP_t^{3'} - DP_t')$	8.23	7.24	0.88	-0.32
4. Textile, Leather, Clothing and Footwear	1	$\frac{\bar{w}_{it}^4}{\bar{w}_t^4} Dq_{it}^4 = \frac{\theta_i^4}{\theta^4} DQ_t^4 + \left(\phi \frac{\theta_i^4}{\bar{w}_t^4} \right) \frac{\theta_i^4}{\theta^4} (Dp_{it}^4 - DP_t^{4'})$	70.38	55.16	0.78	-0.14
	2		29.62	44.84	1.51	-0.27
	Sum		100	100		
	Both varieties	$\bar{W}_t^4 DQ_t^4 = \theta^4 DQ_t + \phi \theta^4 (DP_t^{4'} - DP_t')$	6.47	3.21	0.50	-0.18
5. Wood and Paper Products	1	$\frac{\bar{w}_{it}^5}{\bar{w}_t^5} Dq_{it}^5 = \frac{\theta_i^5}{\theta^5} DQ_t^5 + \sum_{j=1}^2 v_{ij}^5 (Dp_{jt}^5 - DP_t^{5'})$	86.35	46.24	0.54	-0.01
	2		13.65	53.76	3.94	-0.05
	Sum		100	100		
	Both varieties	$\bar{W}_t^5 DQ_t^5 = \theta^5 DQ_t + \phi \theta^5 (DP_t^{5'} - DP_t')$	5.57	0.45	0.08	-0.03
6. Machinery and Equipment	1	$\frac{\bar{w}_{it}^6}{\bar{w}_t^6} Dq_{it}^6 = \frac{\theta_i^6}{\theta^6} DQ_t^6 + \left(\phi \frac{\theta_i^6}{\bar{w}_t^6} \right) \frac{\theta_i^6}{\theta^6} (Dp_{it}^6 - DP_t^{6'})$	48.86	36.10	0.74	-0.38
	2		51.14	63.90	1.25	-0.63
	Sum		100	100		
	Both varieties	$\bar{W}_t^6 DQ_t^6 = \theta^6 DQ_t + \phi \theta^6 (DP_t^{6'} - DP_t')$	15.16	21.48	1.42	-0.51
7. Motor Vehicles and Transport	1	$\frac{\bar{w}_{it}^7}{\bar{w}_t^7} Dq_{it}^7 = \frac{\theta_i^7}{\theta^7} DQ_t^7 + \left(\phi \frac{\theta_i^7}{\bar{w}_t^7} \right) \frac{\theta_i^7}{\theta^7} (Dp_{it}^7 - DP_t^{7'})$	57.09	40.68	0.71	-0.30
	2		42.91	59.32	1.38	-0.58
	Sum		100	100		
	Both varieties	$\bar{W}_t^7 DQ_t^7 = \theta^7 DQ_t + \phi \theta^7 (DP_t^{7'} - DP_t')$	10.38	12.10	1.17	-0.42
8. Miscellaneous Manufactured Goods	1	$\frac{\bar{w}_{it}^8}{\bar{w}_t^8} Dq_{it}^8 = \frac{\theta_i^8}{\theta^8} DQ_t^8 + \left(\phi \frac{\theta_i^8}{\bar{w}_t^8} \right) \frac{\theta_i^8}{\theta^8} (Dp_{it}^8 - DP_t^{8'})$	73.60	41.65	0.57	-0.16
	2		26.40	58.35	2.21	-0.61
	Sum		100	100		
	Both varieties	$\bar{W}_t^8 DQ_t^8 = \theta^8 DQ_t + \phi \theta^8 (DP_t^{8'} - DP_t')$	3.37	2.58	0.77	-0.27
	Sum all groups, both varieties (1 + 2 + ... + 8)		100	100		

Notes:

1. *Notation and indexes:* See Table 5.1.
2. *Aggregation:* Adding over goods from the two sources, the budget and marginal shares of group g are $\bar{W}_t^g = \sum_{i=1}^2 \bar{w}_{it}^g$ and $\theta^g = \sum_{i=1}^2 \theta_i^g$, $g = 1, \dots, 8$. The corresponding Divisia and Frisch indexes are $DQ_t^g = \sum_{i=1}^2 (\bar{w}_{it}^g / \bar{W}_t^g) Dq_{it}^g$ and $DP_t^{g'} = \sum_{i=1}^2 (\theta_i^g / \theta^g) Dp_{it}^g$, $g = 1, \dots, 8$.
3. *Columns 4 – 5:* All entries are multiplied by 100. Budget share are sample averages.
4. *Columns 6 and 7:* “Income” elasticities are with respect to the high-level aggregate. Own-price elasticities are of the Frisch type (marginal utility of income constant).
5. See Appendix A7 for details of derivations.

Table 5.3. Budget-Share Predictions

Aggregate	Mean budget share	Root-mean-squared errors			Information inaccuracies					
					Individual items			All items jointly		
		Demand model	Naïve	Demand model better?	Demand model	Naïve	Demand model better?	Model	Naïve	Demand model better?
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
A. <u>Varieties</u>										
1. Domestic Goods	68.17	0.837	0.936	Yes	0.0164	0.0206	Yes	0.0249	0.0348	Yes
2. Foreign Goods	26.25	0.850	1.026	Yes	0.0189	0.0283	Yes			
3. Wood and Paper Products	5.58	0.240	0.273	Yes	0.0060	0.0076	Yes			
B. <u>Groups</u>										
1. Food and Agricultural Commodities	22.06	0.591	0.667	Yes	0.0101	0.0129	Yes	0.0584	0.0624	Yes
2. Energy and Minerals	28.76	1.004	1.021	Yes	0.0246	0.0249	Yes			
3. Chemicals	8.22	0.214	0.210	No	0.0030	0.0029	No			
4. Textile, Leather, Clothing and Footwear	6.51	0.163	0.190	Yes	0.0022	0.0030	Yes			
5. Wood and Paper Products	5.58	0.240	0.273	Yes	0.0060	0.0076	Yes			
6. Machinery and Equipment	15.13	0.402	0.469	Yes	0.0063	0.0085	Yes			
7. Motor Vehicles and Transport	10.38	0.560	0.522	No	0.0172	0.0149	No			
8. Miscellaneous Manufactured Goods	3.37	0.101	0.104	Yes	0.0016	0.0017	Yes			

Notes:

1. *Columns 5 – 6:* These are sample means of $w_{mt} \log \frac{w_{mt}}{\hat{w}_{mt}} + (1 - w_{mt}) \log \frac{1-w_{mt}}{1-\hat{w}_{mt}}$, where $\hat{w}_{mt}$ is either (i) the predicted budget share from the demand model; or (ii) the naïve extrapolation $w_{m,t-1}$; w_{mt} is the actual value of the budget share; and $m = 1,2,3$ (varieties) or $m = 1, \dots, 8$ (groups).
2. *Columns 8 – 9:* These are sample means of $\sum_{m=1}^n w_{mt} \log \frac{w_{mt}}{\hat{w}_{mt}}$ ($n = 3, 8$).
3. All entries are multiplied by 100.
4. See Appendix A8 for details.

Table 6.1. Two-Decade Changes in Consumption and Prices

Commodity group g (1)	Variety i (2)	Budget shares			Log-change in relative price, 1997-2017 (6)
		1996 (3)	2017 (4)	Change (5)	
1. Food and Agricultural Commodities	Domestic, 1	94.08	88.33	-5.75	0.66
	Foreign, 2	5.92	11.67	5.75	-7.19
	Total	100	100	0	14.80
2. Energy and Minerals	1	84.92	73.10	-11.82	-0.48
	2	15.08	26.90	11.82	1.62
	Total	100	100	0	7.48
3. Chemicals	1	68.98	59.01	-9.97	6.50
	2	31.02	40.99	9.97	-11.77
	Total	100	100	0	-19.29
4. Textile, Leather, Clothing and Footwear	1	76.71	59.80	-16.92	-0.18
	2	23.29	40.20	16.92	0.43
	Total	100	100	0	-3.48
5. Wood and Paper Products	1	86.63	83.17	-3.46	1.08
	2	13.37	16.83	3.46	-6.82
	Total	100	100	0	0.09
6. Machinery and Equipment	1	57.76	43.79	-13.96	3.12
	2	42.24	56.21	13.96	-2.94
	Total	100	100	0	-10.61
7. Motor Vehicles and Transport	1	67.80	43.79	-24.01	0.87
	2	32.20	56.21	24.01	-1.13
	Total	100	100	0	-18.22
8. Miscellaneous Manufactured Goods	1	84.61	62.96	-21.64	4.10
	2	15.39	37.04	21.64	-11.14
	Total	100	100	0	-3.03
All groups	1	79.67	67.25	-12.42	3.22
	2	20.33	32.75	12.42	-8.55
	Total	100	100	0	32.56

Notes:**1. All rows except the last 3:**

(i) Columns 3 – 4: The budget share of variety i of good g is expenditure on this variety as a proportion of total expenditure on g , $\frac{\bar{w}_{it}^g}{\bar{w}_t^g}$ ($g = 1, \dots, 8; i = 1, 2; t = 1996, 2017$), where $\bar{W}_t^g = \bar{w}_{1t}^g + \bar{w}_{2t}^g$ is the budget share of g .

(ii) Column 6: The relative price change over the 22-year period is $\sum_{t=1996}^{2017} (Dp_{it}^g - DP_t^g)$, where $DP_t^g = \sum_{i=1}^2 \left(\frac{\bar{w}_i^g}{\bar{w}_t^g} \right) Dp_{it}^g$ is the Divisia price index of group g , with $\bar{w}_i^g = \frac{1}{22} \sum_{t=1996}^{2017} \bar{w}_{it}^g$ and $\bar{W}^g = \frac{1}{22} \sum_{t=1996}^{2017} \bar{W}_t^g$. The “total” rows give $\sum_{t=1996}^{2017} (DP_t^g - DP_t)$, where $DP_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_i^g Dp_{it}^g$ is the Divisia price index of all varieties/goods.

2. Last 3 rows:

(i) Columns 3 – 4: The combined budget share of all 8 goods of variety i is $\bar{W}_{it} = \sum_{g=1}^8 \bar{w}_{it}^g$. The “total” row contains $\sum_{i=1}^2 \bar{W}_{it}$.

(ii) Column 6: The relative price change over the 22-year period is $\sum_{t=1996}^{2017} (DP_{it} - DP_t)$, where $DP_{it} = \sum_{g=1}^8 \left(\frac{\bar{w}_i^g}{\bar{W}_i} \right) Dp_{it}^g$ is the Divisia price index of variety i with $\bar{W}_i = \frac{1}{22} \sum_{t=1996}^{2017} \bar{W}_{it}$. The “total” row reports $\sum_{t=1996}^{2017} DP_t$.

3. Column 5: The difference between columns 4 and 3.**4. All entries are multiplied by 100.**

Figure 1.1. Import Shares, Australia (%) **Notes:**

- Panels A – H:* These panels refer to the shares of imports in sales, defined as $\frac{\bar{w}_{2t}^g}{\bar{w}_t^g}$ ($g = 1, \dots, 8; t = 1996, \dots, 2017$), where $\bar{w}_{2t}^g$ denotes imports of group g in year t as a proportion of total expenditure and $\bar{w}_t^g = \bar{w}_{1t}^g + \bar{w}_{2t}^g$ is expenditure on the domestic and imported varieties of g as a proportion of total expenditure.
- Panel I:* This panel refers to $\bar{W}_{2t} = \sum_{g=1}^8 \bar{w}_{2t}^g$, the share of imports of all goods in total expenditure.
- The box in each panel gives the change in the share over the period 1996 – 2017, in percentage points (pp).

Figure 4.1. Price-Quantity Scatters

(continued on next page)

Figure 4.1. (continued)

Notes:

1. *Horizontal axis:* The log-change in year t of the relative price of variety i of good g ($i = 1, 2; g = 1, \dots, 8$), $Dp_{it}^g - DP_t$, $t = 1, \dots, 22$, where $DP_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dp_{it}^g$ is the Divisia price index.
2. *Vertical axis:* The corresponding log-change in the relative quantity, $Dq_{it}^g - DQ_t$, where $DQ_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$ is the Divisia quantity index.
3. All values are multiplied by 100.

Figure 6.1. Import Penetration Simulations (%)**A. Total Imports, Income Shock****A1. Levels** **A2. Simulation Less Actual** **B. Income Shock****C. Spending Shock****D. Total-Import Shock**

(continued on next page)

Figure 6.1. (continued)

Notes:1. *The first row:*

- (i) Each plot refers to the expenditure share of all imports (other than wood), defined as $W_{2t} = \sum_{g=1, g \neq 5}^8 w_{2t}^g$.
- (ii) The shock is a fall in the growth in real income, with shock equal to the sample average of the growth in real income.

2. *The last 7 rows:*

- (i) Each plots refers to the share of the imported component in total sales of a good, defined as w_{2t}^g / W_t^g ($g = 1, \dots, 8$; $g \neq 5$; $t = 1995, \dots, 2017$), where w_{2t}^g denotes expenditure on imports of good g in year t as a proportion of total expenditure, and $W_t^g = w_{1t}^g + w_{2t}^g$ is the share of expenditure on the domestic and imported varieties of the good.
- (ii) There are three types of shocks (represented by panels B – D): A fall in the growth of (a) real income, (b) spending on g and (c) total import spending. The shocks are equal to the negative of the sample averages of the shocked variables.

3. Shares are percentages. The only exception is in panel A2, which refers to percentage-point changes in the share.

4. The dark (light) shaded areas indicate the 68% (95%) confidence intervals, constructed from 10,000 bootstrap replications. The solid black line in the middle of the bands represents the median. The blue solid line represents actual data.

APPENDICES

A1. The Stacked Format

Table A1.1 presents the matrix forms of four specifications of the demand model used in our study. These form was used in Section 3 and is the basis of the hypothesis tests of Table 4.3, as well as subsequent analyses in Sections 4 – 6.

A2. More on the Covariance Matrix

The $2G \times 2G$ disturbance covariance matrix of model (3.2) is $[\sigma_{kl}]$. This matrix will be structured under the following conditions:

1. *Negative covariances.* The Divisia volume index DQ_t on the right-hand side of (3.2) is the sum of the left-hand side variables, that is, $DQ_t = \sum_{k=1}^{2G} \bar{w}_{kt} Dq_{kt}$, which implies $\sum_{k=1}^{2G} \varepsilon_{kt} = 0$ and $\sum_{l=1}^{2G} \sigma_{kl} = 0$. As $\sigma_{kk} > 0$, it follows that the average covariance, $(2G - 1)^{-1} \sum_{l=1, l \neq k}^{2G} \sigma_{kl} = -(2G - 1)^{-1} \sigma_{kk}$, is negative. We shall make the stronger assumption that *each* covariance is negative.
2. *Decomposable covariances.* In order to preserve the budget constraint, a shock to one demand equation has to be offset by shocks to the others, as represented by the requirement that $\sum_{k=1}^{2G} \varepsilon_{kt} = 0$. Imagine a shock λ_k^2 to the demand for good k . How might this impact the other demands? A simple provisional answer might be that the shock has a proportional effect on all others so the covariance is of the form $-\sigma^2 \lambda_k^2$, where $\sigma > 0$ is a proportionality factor. If the same is true for a good- l shock, λ_l^2 , its impact on the others would be $-\sigma^2 \lambda_l^2$. But symmetry of the covariances requires the two effects coincide, so we must revise the answer. A natural compromise is the geometric mean of $\sigma^2 \lambda_k^2$ and $\sigma^2 \lambda_l^2$, which is $\sigma^2 \lambda_k \lambda_l$. The covariances then become $\sigma_{kl} = -\sigma^2 \lambda_k \lambda_l, k \neq l$. This specification preserves the symmetry and negativity of the covariances, but as it involves products of two factors, one for each item, it rules out specific interactions between individual pairs, which can be restrictive in certain cases. When the items are fairly broad aggregates, however, most pairwise relations are probably of a more general nature. In such a case, the dominant relationship between goods reflects the condition that at the margin, spending on each good has the same utility value with all goods having a more-or-less equal claim on the consumer's income. Thus, for broad aggregates, the above covariance specification is

probably reasonable and the one that we shall use for all pairs of commodity groups $k, l = 1, \dots, 2G, k \neq l$.

3. *Importance of goods.* The left-hand side of (3.2) involves the budget share of good k , $\bar{w}_{kt}$, which reflects the relative size of the good as measured by its expenditure. As a good that absorbs a larger part of the budget will tend to be more variable, it is likely its covariances also reflect size. We thus assume that the factor for good k , λ_k , coincides with its mean budget share, $w_k = \frac{1}{T} \sum_{t=1}^T w_{kt}$, so that

$$(A2.1) \quad \sigma_{kl} = -\sigma^2 w_k w_l, k \neq l.$$

4. *Variances.* As $\sum_{l=1}^{2G} \sigma_{kl} = 0$, Equation (A2.1) implies $\sigma_{kk} = \sigma^2 \sum_{l=1, l \neq k}^{2G} w_k w_l$, or, as $\sum_{l=1}^{2G} w_l = 1$,

$$(A2.2) \quad \sigma_{kk} = \sigma^2 w_k (1 - w_k).$$

Equations (A2.2) and (A2.3) are the variances and covariances associated with the multinomial distribution with probabilities $w_1, \dots, w_{2G}$. To interpret this, think of a random selection of commodities: We draw (with replacement) from an urn balls colour-coded that reflect the identity of commodities. When each dollar of total expenditure has the same chance of selection, the number of balls of the same colour is proportional to expenditure on the good, and the probability of selecting good k is its budget share w_k (Theil, 1967, p. 136).

The above two equations imply that the negative of the correlation coefficient between k and l is $\left\{ \left(\frac{w_k}{1-w_k} \right) \left(\frac{w_l}{1-w_l} \right) \right\}^{1/2}$, the geometric mean of the odds of drawing the two items. Denoting by $\mathbf{w} = [w_i]$ the vector of the $2G$ budget shares and $\mathbf{W} = \text{diag}[\mathbf{w}]$, Equations (A2.2) and (A2.3) for $k, l = 1, \dots, 2G$ mean the covariance matrix $[\sigma_{kl}]$ takes the form $\sigma^2(\mathbf{W} - \mathbf{w}\mathbf{w}')$, which is denoted by $\mathbf{\Sigma}$ in the text. Note that Step 2 above used the geometric mean of the two shocks. What if the arithmetic mean were used instead? The result is qualitatively similar, as expected, but not so convenient: Equations (A2.1) and (A2.2) would then become, respectively, $\sigma_{kl} = -\frac{\sigma^2}{2}(w_k + w_l)$ and $\sigma_{kk} = \sigma^2(G - 1)w_k + \frac{\sigma^2}{2}$.

Many demand systems can be written in the form $y_{it} = \beta'_i \mathbf{x}_t + \varepsilon_{it}, i = 1, \dots, n, E(\varepsilon_t \varepsilon'_t) = \mathbf{\Sigma}$. The usual approach is to treat this as a multivariate regression and estimate by SURE or ML, which involves the inverse of the covariance matrix $\mathbf{\Sigma}^{-1}$. The matrix $\mathbf{\Sigma}$ is symmetric positive semi-definite, but otherwise unrestricted and according to the usual approach, is estimated by mean squares and cross-products of the residuals. But as shown by Chen (1995), Laitinen (1978),

Meisner (1979), Selvanathan (1991) and Theil (1987), such an approach can lead to a serious understatement of the standard errors when the sample size (T) is small relative to the number of goods (n). Laitinen (1978) established that Σ is nonsingular only when $T > 2n$. The multinomial approach deals with this issue by setting $\Sigma = \sigma^2(\mathbf{W} - \mathbf{w}\mathbf{w}')$, leading to the estimation of a single equation, as discussed in the text.

The covariance matrix of the reduced system and its inverse [Equation (3.3) of the text] are:

$$\tilde{\Sigma} = \sigma^2(\tilde{\mathbf{W}} - \tilde{\mathbf{w}}\tilde{\mathbf{w}}'), \quad \tilde{\Sigma}^{-1} = \frac{1}{\sigma^2} \left(\tilde{\mathbf{W}}^{-1} + \frac{1}{w_{2G}} \mathbf{u}' \right).$$

Recognising that $\tilde{\mathbf{W}}\mathbf{t} = \tilde{\mathbf{w}}$ and $\tilde{\mathbf{w}}'\tilde{\mathbf{W}}^{-1} = \mathbf{t}'$, it is straightforward to verify this inverse:

$$\begin{aligned} \tilde{\Sigma} \tilde{\Sigma}^{-1} &= (\tilde{\mathbf{W}} - \tilde{\mathbf{w}}\tilde{\mathbf{w}}') \left(\tilde{\mathbf{W}}^{-1} + \frac{1}{w_{2G}} \mathbf{u}' \right) \\ &= \tilde{\mathbf{W}}\tilde{\mathbf{W}}^{-1} + \frac{1}{w_{2G}} \tilde{\mathbf{W}}\mathbf{u}' - \tilde{\mathbf{w}}\tilde{\mathbf{w}}'\tilde{\mathbf{W}}^{-1} - \frac{1}{w_{2G}} \tilde{\mathbf{w}}\tilde{\mathbf{w}}'\mathbf{u}' \\ &= \mathbf{I} + \frac{1}{w_{2G}} \tilde{\mathbf{w}}\mathbf{t}' - \tilde{\mathbf{w}}\mathbf{t}' - \frac{1}{w_{2G}} \tilde{\mathbf{w}}(1 - w_{2G})\mathbf{t}' \quad [\text{as } \tilde{\mathbf{w}}'\mathbf{t} = (1 - w_{2G})] \\ &= \mathbf{I} + \tilde{\mathbf{w}}\mathbf{t}' \left\{ \frac{1}{w_{2G}} - 1 - \frac{1}{w_{2G}} (1 - w_{2G}) \right\} = \mathbf{I} \blacksquare \end{aligned}$$

A3. More on Estimation

This appendix describes the estimation procedures used to derive the results presented in Section 4 of the text.

An Iterative Procedure

Model (3.1) of the text is nonlinear in the parameters due to the term $A_{it}^g(\boldsymbol{\theta})$, but this was ignored above by treating the vector of marginal shares, $\boldsymbol{\theta}$, as known. We deal with the nonlinearity with the following iterative procedure:

Step 1: Obtain initial estimates of the marginal shares $\boldsymbol{\theta} = \{\theta_1^1, \theta_2^1, \dots, \theta_1^8, \theta_2^8\}$ by regressing

$\bar{w}_{it}^g Dq_{it}^g$ on DQ_t . Denote these by $\hat{\boldsymbol{\theta}}_0 = \{\hat{\theta}_{1(0)}^1, \hat{\theta}_{2(0)}^1, \dots, \hat{\theta}_{1(0)}^8, \hat{\theta}_{2(0)}^8\}$. The initial Frisch price index is then $DP'_{t(0)} = \sum_{g=1}^G \sum_{i=1}^2 \hat{\theta}_{i(0)}^g Dp_{it}^g$ and $A_{it}^g(\hat{\boldsymbol{\theta}}_0) = \hat{\theta}_{i(0)}^g (Dp_{it}^g - DP'_{t(0)})$.

Step 2: Use $A_{it}^g(\hat{\boldsymbol{\theta}}_0)$ to construct the matrix $\mathbf{X}_t^*$ (see Appendix A1 for details). Then compute the first-round estimate of the coefficient vector $\boldsymbol{\beta}$ and $A_{it}^g(\hat{\boldsymbol{\theta}}_1)$.

Step 3: Reconstruct $\mathbf{X}_t^*$ using $A_{it}^g(\hat{\boldsymbol{\theta}}_1)$, and compute the second-round estimates of $\boldsymbol{\beta}$ and $A_{it}^g(\hat{\boldsymbol{\theta}}_2)$.

Repeat this step until convergence is reached.

Step 4: Use the converged estimates and constraints (2.12) and (2.13) of the text to obtain estimates of the eliminated parameters.

Bootstrap Standard Errors

To avoid relying on asymptotics, we use the following bootstrap procedure:

Step 1: Using the converged estimates, extract the $2G \times 1$ vectors of residuals $\mathbf{e}_t^* = \mathbf{y}_t^* - \mathbf{X}_t^* \hat{\boldsymbol{\beta}}$ ($t = 1, \dots, T$), the elements of which are the weighted commodity-specific residuals, ε_{it}^{g*} ($i = 1, 2; g = 1, \dots, G$).

Step 2: For each t , i and g , generate a bootstrap residual u_{it}^g by randomly drawing (with replacement) from the corresponding commodity-specific residuals.¹⁵

Step 3: Construct a bootstrap sample as $\mathbf{y}_t^{*\#} = \mathbf{X}_t^* \hat{\boldsymbol{\beta}} + \mathbf{u}_t$, where $\mathbf{u}_t = \{u_{it}^g\}$.

Step 4: Repeat steps 2 – 3 until we have T vectors of $\mathbf{y}_t^{*\#}$.

Step 5: Use $\mathbf{y}_t^{*\#}$ to obtain the bootstrap estimate $\hat{\boldsymbol{\beta}}^\# = (\sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{X}_t^*)^{-1} \sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{y}_t^{*\#}$.

Step 6: Repeat 10,000 times steps 2 – 5. The standard deviations of the 10,000 estimates are the bootstrap standard errors. The standard errors of the elasticities are computed similarly, with means of the budget shares.

A4. The Data

We collected data for various manufacturing sectors in Australia. Our data inputs were obtained from supply-use tables (SUT), international trade statistics and national accounts, all of which are provided by the Australian Bureau of Statistics. Table A4.1 presents detailed descriptions of the data and their sources. Note that in this paper, we exclude service sectors to ensure availability of measurable import data. Additionally, non-merchandise goods are mostly complimentary rather than substitutable with imported services.

As these datasets have different aggregation structure and correspond to different time frequencies, we apply a number of transformations to construct a unified database with consistent timeframe and commodity classification. Figure A4.1 provides the data construction schematics.

Specifically, the following adjustments were applied:

1. *Commodity aggregation.* The values of the 60 goods classified in the Standardised International Trade Classification (SITC) and 57 goods in the SUT were aggregated into 20 broad commodity groups, using the structures presented in Tables A4.2 and A4.3.

¹⁵ In order to preserve the cross-commodity correlation structure, we draw vectors of residuals.

2. *Time aggregation.* The price indices are quarterly, while the value data are published on an annual basis. We converted the quarterly prices into annual data using value-share-weighted average prices.
3. *Domestic sales.* The domestic sales value of a given product is derived by the difference between domestic production and export sales.
4. *Scale deflation.* The values were deflated by population converting them into a per capita basis.
5. *Quantities.* The quantities of domestic and imported varieties were derived by deflating nominal values by the corresponding prices.

Using Table A4.4, the 20 commodities are further classified into $G = 8$ broad groups which form the basis of the analyses presented in this paper. The steps involved in the process to compress SITC and SUT disaggregated into 8 groups are detailed in Figure A4.1. Expenditures of these groups are computed by aggregating the expenditures of underlying commodities. Group prices are expenditure-weighted price indices. Each of the groups now contains two categories: Domestic and foreign varieties. The data span over $T = 23$ years from 1995 to 2017. One observation is lost when we construct the moving average budget shares and the logarithmic changes in prices and quantities.

Based on the group data, we present the Divisia price and quantity indices, their variances and their correlation in Table A4.5. Figure A4.2 is a scatterplot of quantity standard deviations against price standard deviations, which reveals that for the majority of observations, quantities are more dispersed than prices. From column 6 of Table A4.5, it can be seen that the cross-commodity price-quantity correlations are negative. These results agree with prior studies as summarised by Clements (2019).

A5. The Slutsky Coefficients

Equations (2.5) and (2.8) of the text represent, respectively, the relative and absolute price versions of the Rotterdam model. These are linked by the relation between the Slutsky coefficients, the coefficients of the undeflated price changes (π_{ij}), and the coefficients attached to the Frisch-deflated relative prices (v_{ij}):

$$(A5.1) \quad \pi_{ij} = v_{ij} - \phi \theta_i \theta_j; \quad i, j = 1, \dots, n.$$

A similar relationship holds for the domestic-foreign model (2.11). For group g and variety i , the substitution term of that model is

$$\sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t') = \sum_{j=1}^2 v_{ij}^g \{Dp_{jt}^g - (\sum_{j=1}^2 v_{ij}^g) \sum_{h=1}^G \sum_{j=1}^2 \theta_j^h Dp_{jt}^h\}.$$

As $\sum_{j=1}^2 v_{ij}^g = \phi \theta_i^g$, which is constraint (2.13), the above becomes

$$\sum_{h=1}^G \sum_{j=1}^2 \{v_{ij}^g \delta_{gh} - \phi \theta_i^g \theta_j^h\} Dp_{jt}^h = \sum_{h=1}^G \sum_{j=1}^2 \pi_{ij}^{gh} Dp_{jt}^h,$$

where δ_{gh} denotes the Kronecker delta and

$$(A5.2) \quad \pi_{ij}^{gh} = v_{ij}^g \delta_{gh} - \phi \theta_i^g \theta_j^h, \quad i, j = 1, 2; g, h = 1, \dots, G$$

are the Slutsky coefficients, which have the same form as those in (A5.1). At the end of Section 2, it was stated that the Slutsky price elasticities implied by model (2.11) are $S_{ij}^{gh} = F_{ij}^{gh} - \phi \eta_i^g \theta_j^h$, which are the coefficients in (A5.2) divided by the budget share, with $F_{ij}^{gh} = \frac{v_{ij}^g}{w_{it}^g} \delta_{gh}$ the Frisch price elasticity.

A6. Hypothesis Tests

In this appendix, we present the details of the bootstrap tests discussed in Section 4. The null hypothesis of the joint significance of the price coefficients are tested using F-statistics (panel A of Table 4.3 contains the results), while the null of lower domestic income elasticities (LD) is tested using a one-tail t-statistic (panel B of Table 4.3). Additionally, the null of preference independence (PI) is tested using both an F-test (panel A) and t-tests (panel B).

We denote the general form of an unrestricted model by $\mathbf{y}_t^* = \mathbf{X}_t^* \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t^*$ and its restricted counterpart as $\mathbf{y}_t^* = \mathbf{X}_t^{*R} \boldsymbol{\beta}^R + \boldsymbol{\varepsilon}_t^R$. After weighting, the pooled OLS estimators of these models take the forms: $\hat{\boldsymbol{\beta}} = (\sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{X}_t^*)^{-1} \sum_{t=1}^T \mathbf{X}_t^{*'} \mathbf{y}_t^*$; $\hat{\boldsymbol{\beta}}^R = (\sum_{t=1}^T \mathbf{X}_t^{*R'} \mathbf{X}_t^{*R})^{-1} \sum_{t=1}^T \mathbf{X}_t^{*R'} \mathbf{y}_t^*$. The bootstrap tests are as follows:

Step 1: Use the procedures described in Appendix A3 to obtain bootstrap estimates and standard errors of the unrestricted model. Denote these by $\hat{\boldsymbol{\beta}}^\#$ and $SE(\hat{\boldsymbol{\beta}}^\#)$.

Step 2: Use the elements of $\hat{\boldsymbol{\beta}}^\#$ and $SE(\hat{\boldsymbol{\beta}}^\#)$ to form $t_{PI}^{g\#} = \frac{\hat{v}_{ij}^{g\#}}{SE(\hat{v}_{ij}^{g\#})}$ and $t_{LD}^{g\#} =$

$$\frac{\frac{\hat{\theta}_1^{g\#}}{w_1^g} - \frac{\hat{\theta}_2^{g\#}}{w_2^g}}{\sqrt{\left[\frac{SE(\hat{\theta}_1^{g\#})}{w_1^g}\right]^2 + \left[\frac{SE(\hat{\theta}_2^{g\#})}{w_2^g}\right]^2}}, \text{ where } \hat{\theta}_1^{g\#} \text{ and } \hat{\theta}_2^{g\#} \text{ denote the bootstrap estimates of the domestic}$$

and foreign marginal shares and $SE(\hat{\theta}_1^{g\#})$ and $SE(\hat{\theta}_2^{g\#})$ are their standard errors; and w_1^g and w_2^g are the mean budget shares.

Step 3: Generate 10,000 bootstrap t -statistics by repeating steps 1 – 2. We reject the PI null

$H_0: v_{ij}^g = 0$ ($i \neq j; g = 1, \dots, 8$) at the 5% significance level if the *observed* test statistic,

$t_{PI} = \frac{\hat{v}_{ij}^{g*}}{SE(\hat{v}_{ij}^{g*})}$, is either smaller than the 2.5th percentile or larger than the 97.5th percentile of

$t_{PI}^{g\#}$. We reject the LD null $H_0: \theta_1^g/w_1^g \leq \theta_2^g/w_2^g$ ($g = 1, \dots, 8$) if the *observed* test statistic,

$$t_{LD} = \frac{\frac{\hat{\theta}_1^{g*}}{w_1^g} - \frac{\hat{\theta}_2^{g*}}{w_2^g}}{\sqrt{\left[\frac{SE(\hat{\theta}_1^{g*})}{w_1^g}\right]^2 + \left[\frac{SE(\hat{\theta}_2^{g*})}{w_2^g}\right]^2}}, \text{ is larger than the 95}^{th} \text{ percentile of } t_{LD}^{g\#}.$$

Step 4: To test the joint hypotheses, we first compute the observed and bootstrap estimates of the

restricted model, i.e., $\hat{\beta}^R$ and $\hat{\beta}^{R\#}$. Then, the bootstrap F-statistic is:

$$F^{\#} = \frac{RSS_R^{\#} - RSS_U^{\#}}{RSS_U^{\#}} \cdot \frac{df_{dem}}{df_{num}},$$

where $RSS_R^{\#} = \sum_{t=1}^T (\mathbf{y}_t^{*R\#} - \mathbf{X}_t^{*R} \hat{\beta}^{R\#})' (\mathbf{y}_t^{*R\#} - \mathbf{X}_t^{*R} \hat{\beta}^{R\#})$ and $RSS_U^{\#} = \sum_{t=1}^T (\mathbf{y}_t^{*R\#} - \mathbf{X}_t^{*} \hat{\beta}^{\#})' (\mathbf{y}_t^{*R\#} - \mathbf{X}_t^{*} \hat{\beta}^{\#})$ are the bootstrap residual sums of squared errors of the restricted and unrestricted models, respectively; $\mathbf{y}_t^{*R\#}$ denotes the bootstrap value generated under the null; and df_{dem} and df_{num} denote the degrees of freedom (see Table A6.1). The *observed* test statistic is:

$$F = \frac{RSS_R - RSS_U}{RSS_U} \cdot \frac{df_{dem}}{df_{num}},$$

where $RSS_R = \sum_{t=1}^T (\mathbf{y}_t^* - \mathbf{X}_t^{*R} \hat{\beta}^R)' (\mathbf{y}_t^* - \mathbf{X}_t^{*R} \hat{\beta}^R)$ and $RSS_U = \sum_{t=1}^T (\mathbf{y}_t^* - \mathbf{X}_t^* \hat{\beta})' (\mathbf{y}_t^* - \mathbf{X}_t^* \hat{\beta})$.

Step 5: Generate 10,000 bootstrap values of $F^{\#}$ by repeating step 4. The null hypothesis is rejected at the 5% significance level if F is larger than the 95th percentile of $F^{\#}$.

The plots of the distributions of the bootstrap F-statistics (indicated by the solid black curves) are presented in Figure A6.1. As can be seen, in many cases these curves closely track the asymptotic F-statistic distributions.

A7. Derivations for the Macro Aggregates and Micro Elements

There are 2 items in each group of goods (domestically and foreign produced) and there are 8 groups. Thus, there are 16 “elementary” goods. For the 7 groups other than the 5th, the demand models are of a preference independence form, viz.,

$$(A7.1) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi \theta_i^g (Dp_{it}^g - DP_t^g) + \varepsilon_{it}^g, \quad i = 1, 2; g = 1, \dots, 8; g \neq 5.$$

For the 5th group “Wood and Paper Products” (which for simplicity, is referred to as “Wood”), we have

$$(A7.2) \quad \bar{w}_{it}^5 Dq_{it}^5 = \theta_i^5 DQ_t + \sum_{j=1}^2 v_{ij}^5 (Dp_{jt}^5 - DP_t') + \varepsilon_{it}^5, \quad i = 1, 2,$$

with $v_{12}^5 = v_{21}^5, \sum_{j=1}^2 v_{ij}^5 = \phi \theta_i^5, i = 1, 2$. Here, $DQ_t = \sum_{g=1}^G \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$ and $DP_t' = \sum_{g=1}^G \sum_{i=1}^2 \theta_i^g Dp_{it}^g$. Together, Equations (A7.1) and (A7.2) constitute the “partial preference independence” (PPI) model.

We divide the 16 elementary goods into 3 varieties:

1. *Domestically produced goods other than Wood*: Goods in this variety are indexed by $i = 1, g = 1, \dots, 8, g \neq 5$. Denote these by the set V_1 .
2. *Imported goods other than Wood* are those indexed by $i = 2, g = 1, \dots, 8, g \neq 5$. Denote by V_2 .
3. *Wood* are those for which $i = 1, 2, g = 5$. Denote by V_3 .

Equation (A7.1) contains on the right-hand side only the own (relative) price, while (A7.2) has both the own price and the cross prices within the Wood group. In the PPI setting, there are no price effects of goods from other groups, so that $v_{ij}^{gh} = 0, i, j = 1, 2, g \neq h$. This implies the three varieties are separable in the utility function and so there exists well-defined aggregates and sub-aggregates of goods, as shown below.

Aggregating by Variety

This subsection shows how we can aggregate the demands equations for members of a given variety. Each of the three varieties is considered separately.

Domestic Goods (V_1): To aggregate variety-1 goods, we set the subscript $i = 1$ and add variables over groups, that is, over the superscript $g = 1, \dots, 8, g \neq 5$. Thus, the budget and marginal shares of variety 1 are

$$\bar{W}_{1t} = \sum_{g \in V_1} \bar{w}_{1t}^g, \quad \Theta_1 = \sum_{g \in V_1} \theta_1^g,$$

and the corresponding Divisia volume index and Frisch price index are

$$(A7.3) \quad DQ_{1t} = \sum_{g \in V_1} \frac{\bar{w}_{1t}^g}{\bar{W}_{1t}} Dq_{1t}^g, \quad DP_{1t}' = \sum_{g \in V_1} \frac{\theta_1^g}{\Theta_1} Dp_{1t}^g.$$

The volume index is a weighted average of the changes in the quantities demanded of variety-1 goods, with weights equal to $\bar{w}_{1t}^g / \bar{W}_{1t}$, the expenditure shares of goods within the variety. These

weights are all positive and have a unit sum. The above price index has a similar interpretation, but now the weights are the within-variety marginal shares θ_1^g / Θ_1 .

Next, aggregate both sides of system (A7.1) for $i = 1$ over $g \in V_1$:

$$\sum_{g \in V_1} \bar{w}_{1t}^g Dq_{1t}^g = \sum_{g \in V_1} \theta_1^g DQ_t + \sum_{g \in V_1} \phi \theta_1^g (Dp_{1t}^g - DP_t') + \sum_{g \in V_1} \varepsilon_{1t}^g.$$

Then, using definition (A7.3) and $\Theta_1 = \sum_{g \in V_1} \theta_i^g$, the term on the left-hand side and the first term on the right of the above become

$$\sum_{g \in V_1} \bar{w}_{1t}^g Dq_{1t}^g = \bar{W}_{1t} DQ_{1t}, \sum_{g \in V_1} \theta_1^g DQ_t = \Theta_1 DQ_t.$$

The substitution term is

$$\sum_{g \in V_1} \phi \theta_1^g (Dp_{1t}^g - DP_t') = \phi \Theta_1 \sum_{g \in V_1} \frac{\theta_1^g}{\Theta_1} (Dp_{1t}^g - DP_t') = \phi \Theta_1 (DP_{1t}' - DP_t').$$

Consequently, the demand for V_1 as a group is

$$(A7.4) \quad \bar{W}_{1t} DQ_{1t} = \Theta_1 DQ_t + \phi \Theta_1 (DP_{1t}' - DP_t') + E_{1t},$$

where $E_{1t} = \sum_{g \in V_1} \varepsilon_{1t}^g$. This is an “uppercase” version of (A7.1), demonstrating that V_1 is a preference independent group.

Dividing both sides of Equation (A7.4) by $\bar{W}_{1t}$, it can be seen that $\frac{\Theta_1}{\bar{W}_{1t}}$ is the income elasticity of demand for V_1 . This can be expressed as

$$\frac{\Theta_1}{\bar{W}_{1t}} = \frac{\sum_{g \in V_1} \theta_i^g}{\bar{W}_{1t}} = \sum_{g \in V_1} \frac{\bar{w}_{1t}^g}{\bar{W}_{1t}} \frac{\theta_i^g}{\bar{w}_{1t}^g},$$

which shows that the group income elasticity is a weighted average of those of the members of the group, the weights being the within-group budget shares $\frac{\bar{w}_{1t}^g}{\bar{W}_{1t}}$. As $\phi \frac{\Theta_1}{\bar{W}_{1t}}$ is the own-price elasticity of V_1 , this also is a share-weighted average of the corresponding elasticities of the members, that is, $\phi \frac{\Theta_1}{\bar{W}_{1t}} = \sum_{g \in V_1} \frac{\bar{w}_{1t}^g}{\bar{W}_{1t}} \left(\phi \frac{\theta_i^g}{\bar{w}_{1t}^g} \right)$.

Given the allocation of income to variety V_1 , as measured by DQ_{1t} , this is then distributed to the goods within the variety. To derive the form of the implied demand equations, note that as Equations (A7.1) and (A7.4) both involve DQ_t , this variable can be eliminated by combining the two equations. Thus, from (A7.4), $DQ_t = \frac{\bar{W}_{1t}}{\Theta_1} DQ_{1t} - \phi (DP_{1t}' - DP_t') - \frac{E_{1t}}{\Theta_1}$; substituting the right-hand side of this equation for DQ_t in (A7.1) gives

$$\begin{aligned} \bar{w}_{1t}^g Dq_{1t}^g &= \theta_1^g \left\{ \frac{\bar{W}_{1t}}{\Theta_1} DQ_{1t} - \phi (DP_{1t}' - DP_t') - \frac{E_{1t}}{\Theta_1} \right\} + \phi \theta_1^g (Dp_{1t}^g - DP_t') + \varepsilon_{1t}^g \\ &= \frac{\theta_1^g}{\Theta_1} \bar{W}_{1t} DQ_{1t} + \phi \theta_1^g (Dp_{1t}^g - DP_{1t}') + \varepsilon_{1t}^g - \frac{\theta_1^g}{\Theta_1} E_{1t}. \end{aligned}$$

Dividing through by $\bar{W}_{1t}$, we obtain

$$(A7.5) \quad \frac{\bar{w}_{1t}^g}{\bar{W}_{1t}} Dq_{1t}^g = \frac{\theta_1^g}{\theta_1} DQ_{1t} + \left(\phi \frac{\theta_1}{\bar{W}_{1t}} \right) \frac{\theta_1^g}{\theta_1} (Dp_{1t}^g - DP'_{1t}) + \mu_{1t}^g, g = 1, \dots, 8, g \neq 5.$$

This equation has on the right-hand side variables that pertain to variety V_1 only: DQ_{1t} and the relative price $Dp_{1t}^g - DP'_{1t}$, where the price deflator is the Frisch index for that variety, DP'_{1t} . The disturbance term is $\mu_{1t}^g = \frac{1}{\bar{W}_{1t}} \left(\varepsilon_{1t}^g - \frac{\theta_1^g}{\theta_1} E_{1t} \right)$, which is proportional to the difference between the original disturbance of (A7.1), ε_{1t}^g , and a fraction θ_1^g/θ_1 of the group disturbance E_{1t} . System (A7.5) contains demand equations for domestic good g , $g = 1, \dots, 8, g \neq 5$, given the demand for those goods as a group. Equation (A7.5) can be called “conditional” demands; and they also have the same form as equations (A7.1) and (A7.4).

Foreign Goods (V_2): The concepts for variety V_2 parallel Equations (A7.3), (A7.4) and (A7.5) and simply involve changing the first subscript from 1 to 2:

$$(A7.6) \quad DQ_{2t} = \sum_{g \in V_2} \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} Dq_{2t}^g, \quad DP'_{2t} = \sum_{g \in V_2} \frac{\theta_2^g}{\theta_2} Dp_{2t}^g, \quad \text{with } \bar{W}_{2t} = \sum_{g \in V_2} \bar{w}_{2t}^g, \quad \theta_2 = \sum_{g \in V_2} \theta_2^g,$$

$$(A7.7) \quad \bar{W}_{2t} DQ_{2t} = \theta_2 DQ_t + \phi \theta_2 (DP'_{2t} - DP'_t) + E_{2t}, \quad \text{with } E_{2t} = \sum_{g \in V_2} \varepsilon_{2t}^g,$$

$$(A7.8) \quad \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} Dq_{2t}^g = \frac{\theta_2^g}{\theta_2} DQ_{2t} + \left(\phi \frac{\theta_2}{\bar{W}_{2t}} \right) \frac{\theta_2^g}{\theta_2} (Dp_{2t}^g - DP'_{2t}) + \mu_{2t}^g, g = 1, \dots, 8, g \neq 5,$$

where $\mu_{2t}^g = \frac{1}{\bar{W}_{2t}} \left(\varepsilon_{2t}^g - \frac{\theta_2^g}{\theta_2} E_{2t} \right)$.

Wood (V_3): The equation system (A7.2) gives the demands for products in group 5, Wood, which constitute V_3 . There are two elements in V_3 , wood from domestic and foreign sources. The distinguishing feature of system (A7.2) is that $v_{ij}^5 \neq 0, i \neq j$, so it is not of the preference independent form, unlike (A7.1). But we can still aggregate over the domestic and foreign demands ($i = 1, 2$) to give

$$(A7.9) \quad DQ_{3t} = \sum_{i=1}^2 \frac{\bar{w}_{it}^5}{\bar{W}_{3t}} Dq_{it}^5, \quad DP'_{3t} = \sum_{i=1}^2 \frac{\theta_i^5}{\theta_3} Dp_{it}^5, \quad \text{with } \bar{W}_{3t} = \sum_{i=1}^2 \bar{w}_{it}^5, \quad \theta_3 = \sum_{i=1}^2 \theta_i^5,$$

$$(A7.10) \quad \bar{W}_{3t} DQ_{3t} = \theta_3 DQ_t + \phi \theta_3 (DP'_{3t} - DP'_t) + E_{3t}, \quad \text{with } E_{3t} = \sum_{i=1}^2 \varepsilon_{it}^5,$$

$$(A7.11) \quad \frac{\bar{w}_{it}^5}{\bar{W}_{3t}} Dq_{it}^5 = \frac{\theta_i^5}{\theta_3} DQ_{3t} + \sum_{j=1}^2 v_{ij}^5 (Dp_{jt}^5 - DP'_{3t}) + \mu_{it}^5, i = 1, 2,$$

where $\mu_{it}^5 = \frac{1}{\bar{W}_{3t}} \left(\varepsilon_{it}^5 - \frac{\theta_i^5}{\theta_3} E_{3t} \right)$.

Equation (A7.10) can be verified as follows. We have from Equation (A7.2):

$$\sum_{i=1}^2 \bar{w}_{it}^5 Dq_{it}^5 = \sum_{i=1}^2 \theta_i^5 DQ_t + \sum_{i=1}^2 \sum_{j=1}^2 v_{ij}^5 (Dp_{jt}^5 - DP'_t) + \sum_{i=1}^2 \varepsilon_{it}^5.$$

It follows from (A7.9) that the term on the left of the above is $\bar{W}_{3t}DQ_{3t}$ and the first one on the right is Θ_3DQ_t . The substitution term is $\sum_{i=1}^2 \sum_{j=1}^2 v_{ij}^5(Dp_{jt}^5 - DP_t')$, which by symmetry is equal to $\sum_{i=1}^2 \sum_{j=1}^2 v_{ji}^5(Dp_{jt}^5 - DP_t')$. The constraint below Equation (A7.2), $\sum_{j=1}^2 v_{ij}^5 = \phi\theta_i^5$, is equivalent to $\sum_{i=1}^2 v_{ji}^5 = \phi\theta_j^5$, so that

$$\sum_{i=1}^2 \sum_{j=1}^2 v_{ji}^5(Dp_{jt}^5 - DP_t') = \phi \sum_{j=1}^2 \theta_j^5(Dp_{jt}^5 - DP_t') = \phi\Theta_3(DP_{3t}' - DP_t').$$

This is the substitution term of equation (A7.10).

To derive (A7.11), we proceed as before and rearrange (A7.10) as $DQ_t = \frac{\bar{W}_{3t}DQ_{3t}}{\Theta_3} - \phi(DP_{3t}' - DP_t') - \frac{E_{3t}}{\Theta_3}$ and then substitute into (A7.2) to give

$$\bar{w}_{it}^5 Dq_{it}^5 = \theta_i^5 \left\{ \frac{\bar{W}_{3t}DQ_{3t}}{\Theta_3} - \phi(DP_{3t}' - DP_t') - \frac{E_{3t}}{\Theta_3} \right\} + \sum_{j=1}^2 v_{ij}^5(Dp_{jt}^5 - DP_t') + \varepsilon_{it}^5.$$

Using $\sum_{j=1}^2 v_{ij}^5 = \phi\theta_i^5$, the substitution term of the above becomes

$$\begin{aligned} & -\phi\theta_i^5(DP_{3t}' - DP_t') + \sum_{j=1}^2 v_{ij}^5(Dp_{jt}^5 - DP_t') \\ & = -\phi\theta_i^5(DP_{3t}' - DP_t') + \sum_{j=1}^2 v_{ij}^5 Dp_{jt}^5 - \phi\theta_i^5 DP_t' = \sum_{j=1}^2 v_{ij}^5(Dp_{jt}^5 - DP_{3t}'). \end{aligned}$$

Equation (A7.11) then follows directly.

Aggregating by Group

As each good involves domestically and foreign varieties, we can also aggregate over the two varieties to derive the total demand for each. That is, now we add over the i subscript rather than the g superscript. This leads to the budget and marginal shares for g

$$\bar{W}_t^g = \sum_{i=1}^2 \bar{w}_{it}^g, \quad \Theta^g = \sum_{i=1}^2 \theta_i^g,$$

the group disturbance term

$$E_t^g = \sum_{i=1}^2 \varepsilon_{it}^g,$$

the indices

$$DQ_t^g = \sum_{i=1}^2 \frac{\bar{w}_{it}^g}{\bar{W}_t^g} Dq_{it}^g, \quad DP_t^{g'} = \sum_{i=1}^2 \frac{\theta_i^g}{\Theta^g} Dp_{it}^g,$$

and the group demand equations

$$(A7.12) \quad \bar{W}_t^g DQ_t^g = \Theta^g DQ_t + \phi\Theta^g (DP_t^{g'} - DP_t') + E_t^g, \quad g = 1, \dots, 8.$$

Equation (A7.12) applies to all 8 groups, including group 5, which is

$$(A7.13) \quad \bar{W}_t^5 DQ_t^5 = \Theta^5 DQ_t + \phi\Theta^5 (DP_t^{5'} - DP_t') + E_t^5.$$

Since this group is the only one exhibiting preference dependence among its varieties, it was singled out before and placed in its own variety, V_3 . But as the group as a whole is preference

independent, just like the others, its group demand (A7.13) is of the same form as that of the others. Moreover, as the marginal share of (A7.13), Θ^5 , coincides with that of V_3 from Equation (A7.9), Θ_3 , it follows that the corresponding Frisch price indexes of (A7.13) are the same as those of (A7.9), that is, $DP_t^{5'} = DP_{3t}'$. Similarly for the disturbances: $E_t^5 = E_{3t}$. Accordingly, Equation (A7.13) coincides with (A7.10), the group demand for V_3 . This is as it should be as the two approaches to lead to the same aggregated demand for this group.

To derive the demands within groups, we combine Equations (A7.1) and (A7.12) to eliminate DQ_t , as before. Re-arrangements then yield the conditional demands for groups other than the 5th:

$$(A7.14) \quad \frac{\bar{w}_{it}^g}{\bar{w}_t^g} Dq_{it}^g = \frac{\theta_i^g}{\Theta^g} DQ_t^g + \left(\phi \frac{\Theta^g}{\bar{w}_t^g} \right) \frac{\theta_i^g}{\Theta^g} (Dp_{jt}^g - DP_t^{g'}) + \xi_{it}^g, i = 1, 2, g = 1, \dots, 8, g \neq 5.$$

where $\xi_{it}^g = \frac{1}{\bar{w}_t^g} \left(\varepsilon_{it}^g - \frac{\theta_i^g}{\Theta^g} E_t^g \right)$. For the 5th group, the conditional demands are:

$$(A7.15) \quad \frac{\bar{w}_{it}^5}{\bar{w}_t^5} Dq_{it}^5 = \frac{\theta_i^5}{\Theta^5} DQ_t^5 + \sum_{j=1}^2 v_{ij}^5 (Dp_{jt}^5 - DP_t^{5'}) + \xi_{it}^5, i = 1, 2,$$

where $\xi_{it}^5 = \frac{1}{\bar{w}_t^5} \left(\varepsilon_{it}^5 - \frac{\theta_i^5}{\Theta^5} E_t^5 \right)$. For reasons similar to those discussed above, after making the appropriate notational equivalences, Equation (A7.15) coincides with (A7.11).

Summary

A summary of the results is given in Table A7.1. The aggregated values of budget shares, marginal shares and elasticities from the two approaches are presented in Tables 4.5 and 4.6.

A8. The Budget-Share Predictions

In this appendix, we derive the budget-share predictions implied by our demand models, starting with the analytical foundations from Theil (1975/76, Chap. 5). Consider a function $f(\mathbf{x})$ depending on a vector of arguments $\mathbf{x}$ with continuous derivatives up to the third order. Taylor's theorem means that the difference $f(\mathbf{x} + \mathbf{h}) - f(\mathbf{h})$ can be expressed as

$$(A8.1) \quad f(\mathbf{x} + \mathbf{h}) - f(\mathbf{h}) = \frac{1}{2} \mathbf{h}' (\mathbf{f}_{\mathbf{x}} + \mathbf{f}_{\mathbf{x}+\mathbf{h}}) + O_3,$$

where $\mathbf{f}_{\mathbf{x}}$ and $\mathbf{f}_{\mathbf{x}+\mathbf{h}}$ denote the gradients of $f(\cdot)$ at $\mathbf{x}$ and $\mathbf{x} + \mathbf{h}$, and O_3 is a remainder term of the third degree. Thus, $\frac{1}{2} \mathbf{h}' (\mathbf{f}_{\mathbf{x}} + \mathbf{f}_{\mathbf{x}+\mathbf{h}})$ is a second-order approximation to the difference, but only requires information on the two slope vectors.

Since $w_i = \frac{p_i q_i}{M}$, its infinitesimal change is

$$(A8.2) \quad dw_i = d\left(\frac{p_i q_i}{M}\right) = w_i d(\log p_i) + w_i d(\log q_i) - w_i d(\log M).$$

The derivatives of w_i with respect to these logarithmic arguments are

$$\frac{\partial w_i}{\partial \log p_i} = w_i, \quad \frac{\partial w_i}{\partial \log q_i} = w_i, \quad \frac{\partial w_i}{\partial \log M} = -w_i.$$

Hence, the gradient of w_i is $[w_{i,t-1} \ w_{i,t-1} \ -w_{i,t-1}]'$ in year $t-1$ and $[w_{it} \ w_{it} \ -w_{it}]'$ in year t . The average of the two gradients is

$$(A8.3) \quad [\bar{w}_{it} \ \bar{w}_{it} \ -\bar{w}_{it}]' = \frac{1}{2}(\mathbf{f}_x + \mathbf{f}_{x+h}).$$

where $\bar{w}_{it} = \frac{1}{2}(w_{it} + w_{i,t-1})$, $\mathbf{x} = [\log p_{it} \ \log q_{it} \ \log M_t]'$ and $\mathbf{x} + \mathbf{h} = [\log p_{i,t-1} \ \log q_{i,t-1} \ \log M_{t-1}]'$.

Next, define the vector of log-changes as

$$(A8.4) \quad \mathbf{h} = [Dp_{it} \ Dq_{it} \ DM_t]'$$

Substituting (A8.3) and (A8.4) into (A8.1) gives

$$(A8.5) \quad \Delta w_{it} = \bar{w}_{it} Dp_{it} + \bar{w}_{it} Dq_{it} - \bar{w}_{it} DM_t + O_3.$$

Equation (A8.5) is the finite-change extension of (A8.2). Again, the first three terms on the right of (A8.5) are a second-order approximation to the change in the budget share. Since $\sum_{i=1}^n \bar{w}_{it} = 1$, summing both sides of (A8.5) over $i = 1, \dots, n$ gives $0 = \sum_{i=1}^n \bar{w}_{it} Dp_{it} + \sum_{i=1}^n \bar{w}_{it} Dq_{it} - DM_t + O_3$, or $\sum_{i=1}^n \bar{w}_{it} Dq_{it} = DM_t - \sum_{i=1}^n \bar{w}_{it} Dp_{it} + O_3$, so that

$$(A8.6) \quad DQ_t = DM_t - \sum_{i=1}^n \bar{w}_{it} Dp_{it} + O_3.$$

Combining (A8.5) and (A8.6) gives

$$(A8.7) \quad w_{it} - w_{i,t-1} = \bar{w}_{it} Dq_{it} - \bar{w}_{it} DQ_t + \bar{w}_{it} (Dp_{it} - DP_t) + O_3,$$

where $DP_t = \sum_{i=1}^n w_{it} Dp_{it}$ denotes the Divisia price index. Equation (A8.7) describes the change in the i^{th} budget share as the sum of 3 components and a third-order remainder term. The predicted value from the models we use is $\bar{w}_{it} Dq_{it} - \hat{\varepsilon}_{it}$, where $\hat{\varepsilon}_{it} = \bar{w}_{it} Dq_{it} - \hat{\theta}_i DQ_t - \sum_{j=1}^n \hat{v}_{ij} (Dp_{jt} - DP'_t)$ denotes the t^{th} residual of the i^{th} equation. Replacing $\bar{w}_{it} Dq_{it}$ in (A8.7) with $\bar{w}_{it} Dq_{it} - \hat{\varepsilon}_{it}$, the difference between the predicted share ($\hat{w}_{it}$) and $w_{i,t-1}$ is

$$(A8.8) \quad \hat{w}_{it} - w_{i,t-1} = (\bar{w}_{it} Dq_{it} - \hat{\varepsilon}_{it}) - \bar{w}_{it} DQ_t + \bar{w}_{it} (Dp_{it} - DP_t) + O_3.$$

Finally, subtracting (A8.7) from (A8.8) gives $\hat{w}_{it} = w_{it} - \hat{\varepsilon}_{it}$ for the prediction of w_{it} .

As a comparison benchmark, we use a naïve no-change extrapolation: $\hat{w}_{it} = w_{i,t-1}$. These predictions can be interpreted as coming from a demand equation of the form $\bar{w}_{it} Dq_{it} = \bar{w}_{it} DQ_t - \bar{w}_{it} (Dp_{it} - DP_t)$, where the remainder term O_3 is ignored. This model is of the preference-

independence type with unitary income elasticities ($\theta_i = \bar{w}_{it} \forall i$) and income flexibility ($\phi = -1$). A measure of the accuracy of the n budget share predictions is the information inaccuracy

$$\sum_{i=1}^n w_{it} \log \frac{w_{it}}{\hat{w}_{it}}.$$

This measure increases when the absolute discrepancies $|\hat{w}_{it} - w_{it}|$ increase, and vanishes only when the predictions are perfect, that is, $\hat{w}_{it} = w_{it}, i = 1, \dots, n$. Rather than dealing with all n shares jointly, the quality of the prediction of one good can be analysed using a similar measure. This involves comparing with actual the prediction of the i^{th} share, $\hat{w}_{it}$, and that of the combined share of all others, $1 - \hat{w}_{it}$. That is

$$w_{it} \log \frac{w_{it}}{\hat{w}_{it}} + (1 - w_{it}) \log \frac{1 - w_{it}}{1 - \hat{w}_{it}}.$$

The above approach can be applied to the aggregated demand models that refer to (i) the 3 varieties (imports, domestic products and “Wood”) and (ii) the 8 groups. To do this, define the residuals as:

$$\hat{E}_{kt} = \bar{W}_{kt} DQ_{it} - \hat{\Theta}_k DQ_t - \hat{\phi} \hat{\Theta}_k (DP'_{kt} - DP'_t), k = 1, 2, 3; t = 1996, \dots, 2017,$$

$$\hat{E}_t^g = \bar{W}_t^g DQ_t^g - \hat{\Theta}^g DQ_t - \hat{\phi} \hat{\Theta}^g (DP_t^{g'} - DP'_t), g = 1, \dots, 8,$$

and the predicted budget shares as $\hat{W}_{kt} = W_{kt} - \hat{E}_{kt}$ and $\hat{W}_t^g = W_t^g - \hat{E}_t^g$, where $W_{kt} = \sum_{g \in V_k} w_{kt}^g$ and $W_t^g = \sum_{i=1}^2 w_{it}^g$.¹⁶ For the wood group (indexed by $k = 3$ and $g = 5$), there is the predicted share using the first approach, viz., $\hat{W}_{3t}$, as well as the prediction from the second approach, $\hat{W}_t^5$. By construction, the two predictions coincide, i.e., $\hat{W}_{3t} = \hat{W}_t^5$. The corresponding naïve extrapolations are $W_{k,t-1}$ and W_{t-1}^g . Figure A8.1 plots the actual and predicted budget shares for domestic- and foreign-sources good and for each commodity group. In most cases, the model seems to perform satisfactorily.

Section 6 considered quality of predictions for the whole period. However, when each year is considered separately, as in Table A8.1, the picture is somewhat different with the demand model outperforming the naïve model in 11/22 years when predicting the variety shares, and in 12/22 years when predicting the group shares. This contrasts possibly reflects the considerable year-on-year noise in the data, much of which is eliminated when averaging over the whole period. The substantial serial dependence from one year to the next of the shares is a further reason for the seemingly reasonable performance of the no-change predictions.

¹⁶ Equivalently, $\hat{E}_{kt}$ and $\hat{E}_t^g$ are the corresponding sums of the residuals of the item-specific equations.

A9. The Counter-Factual Simulations

In the following discussion, we describe the procedure used to simulate import budget-shares as a result of exogenous shocks to each of the three sources: (i) Real income (as measured by the overall Divisia quantity index DQ_t); (ii) individual demands for each group g (DQ_t^g); and (iii) total import demand (DQ_{2t}). Since the “Wood and Paper Products” group constitutes its own variety, we confine the analyses to non-Wood commodities only. As the share of wood in total imports, $w_{2t}^5/(\sum_{g=1}^8 w_{2t}^g)$, is the lowest among the 8 groups (at about 3 percent on average), the results can be interpreted as closely approximating total imports.

We shall use the superscript p ($p = 1, 2, 3$) to indicate the above three scenarios. Denote the level and change of the simulated import share of group g as $\left(\frac{w_{2t}^g}{w_t^g}\right)^{(p)}$ and $\Delta \left(\frac{w_{2t}^g}{w_t^g}\right)^{(p)}$; and the level and change of the corresponding total import share as $\tilde{W}_{2t}^{(p)}$ and $\Delta \tilde{W}_{2t}^{(p)}$. To isolate the influence of the shock, all variables other than the shocked one retain their actual values. The shock is a changed rate of growth, so that the log-change in a variable X is time-invariant: $\tilde{DX}_t = DX_t + r_t$ where $r_t = r \forall t$. That is, the growth in the shocked variable changes from DX_t to $DX_t + r$, so the change in the rate of growth is approximately $100 \times r$ percent per annum in each year.

Next, recall from Appendix A7 that:

- The unconditional demand for variety i ($i = 1, 2$ denoting the domestic and foreign sources) of commodity group g ($g = 1, \dots, 8; g \neq 5$) is

$$(A9.1) \quad \bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \sum_{j \in S_g} v_{ij}^g (Dp_{jt}^g - DP_t') + \varepsilon_{it}^g.$$

- The demand for the combination of both varieties of group g is

$$(A9.2) \quad \bar{W}_t^g DQ_t^g = \theta^g DQ_t + \phi \theta^g (DP_t^{g'} - DP_t') + E_{it}^g.$$

- The demand for total imports is

$$(A9.3) \quad \bar{W}_{2t} DQ_{2t} = \theta_2 DQ_t + \phi \theta_2 (DP_{2t}' - DP_t') + E_{2t}.$$

- The imports share of group g is

$$(A9.4) \quad \frac{\bar{w}_{2t}^g}{\bar{W}_t^g} Dq_{2t}^g = \frac{\theta_2^g}{\theta^g} DQ_t^g + \left(\phi \frac{\theta^g}{\bar{W}_t^g} \right) \frac{\theta_2^g}{\theta^g} (Dp_{2t}^g - DP_t^{g'}) + \xi_{it}^g.$$

- The conditional demand for group g within imports is

$$(A9.5) \quad \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} Dq_{2t}^g = \frac{\theta_2^g}{\theta_2} DQ_{2t} + \left(\phi \frac{\theta_2}{\bar{W}_{2t}} \right) \frac{\theta_2^g}{\theta_2} (Dp_{2t}^g - DP_{2t}') + \mu_{2t}^g.$$

Scenario 1: A Change in Real Income

From Equations (A8.7) and (A9.1), the change in imports of group g is

$\Delta w_{2t}^g = w_{2t}^g - w_{2,t-1}^g = (\theta_2^g - \bar{w}_{2t}^g)DQ_t + \bar{w}_{2t}^g(Dp_{2t}^g - DP_t) + \sum_{j \in S_g} v_{2j}^g(Dp_{jt}^g - DP_t') + \varepsilon_{2t}^g + O_3$, where O_3 is a third-order remainder term. Simulating $\widetilde{DQ}_t = DQ_t + r$, and setting all other terms at the observed values, gives a change in the share of

$$\begin{aligned}
 \Delta \widetilde{w}_{2t}^g &= \widetilde{w}_{2t}^g - \widetilde{w}_{2,t-1}^g \\
 &= (\theta_2^g - \bar{w}_{2t}^g)\widetilde{DQ}_t + \bar{w}_{2t}^g(Dp_{2t}^g - DP_t) + \sum_{j \in S_g} v_{2j}^g(Dp_{jt}^g - DP_t') + \varepsilon_{2t}^g + O_3 \\
 (A9.6) \quad &= (\theta_2^g - \bar{w}_{2t}^g)r + (\theta_2^g - \bar{w}_{2t}^g)DQ_t + \bar{w}_{2t}^g(Dp_{2t}^g - DP_t) + \sum_{j \in S_g} v_{2j}^g(Dp_{jt}^g - DP_t') + \\
 &\quad \varepsilon_{2t}^g + O_3 \\
 &= \Delta w_{2t}^g + (\theta_2^g - \bar{w}_{2t}^g)r.
 \end{aligned}$$

Then, taking the initial value to be $w_{2,1995}^g$, the simulated level at time s ($s = 1996, \dots, 2017$) is the sum of $w_{2,1995}^g$ and all simulated changes after 1995:

$$\begin{aligned}
 \widetilde{w}_{2s}^g &= w_{2,1995}^g + \sum_{t=1996}^s \Delta \widetilde{w}_{2t}^g \\
 (A9.7) \quad &= w_{2,1995}^g + \sum_{t=1996}^s [\Delta w_{2t}^g + (\theta_2^g - \bar{w}_{2t}^g)r] \\
 &= (w_{2,1995}^g + \sum_{t=1996}^s \Delta w_{2t}^g) + \sum_{t=1996}^s (\theta_2^g - \bar{w}_{2t}^g)r \\
 &= w_{2s}^g + (s-1)r \left[\frac{1}{s-1} \sum_{t=1996}^s (\theta_2^g - \bar{w}_{2t}^g) \right].
 \end{aligned}$$

Here, w_{2s}^g is the observed share at s and $\frac{1}{s-1} \sum_{t=2}^s (\theta_2^g - \bar{w}_{2t}^g)$ is the mean of the excess of the marginal share over the budget share, or the mean of $\bar{w}_{2t}^g(\eta_2^g - 1)$, where η_2^g denotes the income elasticity. By construction, the effects of the shocks accumulate over time and is captured in the second term of (A9.7). To illustrate, suppose $s-1 = 20$ years, the shock to income growth is $r = 0.02$, or about 2 percent, and the income elasticity is $\eta_2^g = 1.5$. It follows that $\widetilde{w}_{2s}^g = w_{2s}^g + 20 \times 0.02 \times \bar{w}_{2s}^g(1.5 - 1) \approx w_{2s}^g(1 + 0.4 \times 0.5) = 1.2w_{2s}^g$. Thus, in this example, the simulated share after 2-percent additional income growth (in each of 20 years) about 20 percent above the observed value, a difference ten times as large as the annual income shock.

Similar to (A9.6), the simulated change in the budget share of g is

$$\Delta \widetilde{W}_t^g = \Delta W_{2t}^g + (\Theta^g - \bar{W}_t^g)r,$$

and, similar to (A9.7), the simulated level is

$$(A9.8) \quad \widetilde{W}_s^g = W_s^g + \sum_{t=1996}^s (\Theta^g - \bar{W}_t^g)r.$$

Next, by combining (A9.7) and (A9.8) the simulated level of the conditional import share is

$$(A9.9) \quad \left(\frac{w_{2s}^g}{W_s^g} \right)^{(1)} = \frac{\tilde{w}_{2s}^g}{\tilde{W}_s^g} = \frac{w_{2s}^g + \sum_{t=1996}^s (\theta_2^g - \bar{w}_{2t}^g)r}{W_s^g + \sum_{t=1996}^s (\theta_2^g - \bar{W}_t^g)r}.$$

Equation (A9.9) refers to the simulated level of the share of imports in total spending on g following the assumed income change, where the superscript 1 indicates the first simulation.

From (A9.3), the simulated change in spending on all imports (as a proportion of total spending on all goods) is

$$\Delta \tilde{W}_{2t}^{(1)} = \Delta W_{2t} + (\theta_2 - \bar{W}_{2t})r,$$

which implies a level of

$$(A9.10) \quad \tilde{W}_{2s}^{(1)} = W_{2s} + \sum_{t=1996}^s (\theta_2 - \bar{W}_{2t})r.$$

Scenario 2: A Shock to Spending on Group g

Following the same approach as above, given a change on real expenditure on group g , $\bar{DQ}_t^g = DQ_t^g + r$ ($g = 1, \dots, 8; g \neq 5$), the change in conditional share of g is

$$\begin{aligned} \Delta \left(\frac{w_{2t}^g}{W_t^g} \right)^{(2)} &= \left(\frac{w_{2t}^g}{W_t^g} \right) - \left(\frac{w_{2,t-1}^g}{W_{t-1}^g} \right) \\ &= \left(\frac{\theta_2^g}{\theta^g} - \frac{\bar{w}_{2t}^g}{\bar{W}_t^g} \right) (DQ_t^g + r) + \left(\phi \frac{\theta^g}{\bar{W}_t^g} \right) \frac{\theta_2^g}{\theta^g} (Dp_{2t}^g - DP_t^{g'}) + \frac{\varepsilon_{2t}^g}{\bar{W}_t^g} \\ &= \Delta \frac{w_{2t}^g}{W_t^g} + \left(\frac{\theta_2^g}{\theta^g} - \frac{\bar{w}_{2t}^g}{\bar{W}_t^g} \right) r, \end{aligned}$$

and the corresponding level is

$$(A9.11) \quad \left(\frac{w_{2s}^g}{W_s^g} \right)^{(2)} = \frac{w_{2s}^g}{W_s^g} + \sum_{t=1996}^s \left(\frac{\theta_2^g}{\theta^g} - \frac{\bar{w}_{2t}^g}{\bar{W}_t^g} \right) r.$$

Scenario 3: A Change in Total Imports

Consider a rise in imports equal to $\bar{DQ}_{2t} = DQ_{2t} + r$. This might be the subsequent response to a capital-account surplus caused by a surge in the demand for Australian assets by foreigners. Whatever the cause, the simulated change in the total import share is

$$\begin{aligned} \Delta \tilde{W}_{2t}^{(3)} &= \tilde{W}_{2t}^{(3)} - \tilde{W}_{2,t-1}^{(3)} \\ (A9.12) \quad &= \bar{W}_{2t} (DQ_{2t} + r) + \bar{W}_{2t} (DP_{2t} - DP_t) - \bar{W}_{2t} DQ_t + O_3 \\ &= \Delta W_{2t} + r, \end{aligned}$$

while the level is

$$\begin{aligned} (A9.13) \quad \tilde{W}_{2s}^{(3)} &= W_{2,1995} + \sum_{t=1996}^s \Delta \tilde{W}_{2t}^{(3)} = W_{2,1995} + \sum_{t=1996}^s (\Delta W_{2t} + r \bar{W}_{2t}) \\ &= (W_{2,1995} + \sum_{t=1996}^s \Delta W_{2t}) + \sum_{t=1996}^s r \bar{W}_{2t} \end{aligned}$$

$$= W_{2s} + \sum_{t=1996}^s r \bar{W}_{2t}.$$

From equation (A9.5) the simulated share of g in imports is

$$(A9.14) \quad \left(\frac{\bar{w}_{2s}^g}{W_{2s}} \right)^{(3)} = \frac{w_{2s}^g}{W_{2s}} + \sum_{t=1996}^s \left(\frac{\theta_2^g}{\Theta_2} - \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}} \right) r.$$

Combining (A9.13) and (A9.14) gives the share of imports in total spending on g :

$$(A9.15) \quad \left(\frac{\bar{w}_{2s}^g}{W_s^g} \right)^{(3)} = \left(\frac{w_{2s}^g}{W_{2s}} \right)^{(3)} \tilde{W}_{2s}^{(3)} (W_s^g)^{-1},$$

where W_s^g is the observed share of group g in total expenditure.

Summary

A summary of the results of this appendix is given in Table A9.1.

A10. Additional Results

Including Intercepts

To allow for autonomous consumption trends, we add intercepts, α_i^g , to model (2.11) to give

$$(A10.1) \quad \bar{w}_{it}^g Dq_{it}^g = \alpha_i^g + \theta_i^g DQ_t + \sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t') + \varepsilon_{it}^g, i = 1, 2; g = 1, \dots, G.$$

These intercepts satisfy $\sum_{g=1}^G \sum_{i=1}^2 \alpha_i^g = 0$. If income and prices are unchanged, then $\bar{w}_{it}^g Dq_{it}^g = \alpha_i^g$, or $Dq_{it}^g = \frac{\alpha_i^g}{\bar{w}_{it}^g}$, so it can be seen that $\frac{\alpha_i^g}{\bar{w}_{it}^g}$ is interpreted as the residual exponential trend rate of growth in consumption of the good. The estimates of model (A10.1) in Table A10.1 reveal many of the intercepts are insignificant, while the majority of other estimates do not differ greatly from those presented in Table 4.2.

The Preference-Independence Estimates

Table A10.2 presents the estimates of the preference independence model. As can be seen from column 2, the marginal share of domestic wood is negative, something that violates preference independence.

More Price Elasticities

Tables A10.3 and A10.4 present the own-price elasticities implied by the preference independence and partial preference independence models. The Frisch elasticities presented in columns 8 and 9 of Table 4.4 of the main text are reproduced in column 3 of Table A10.4.

Appendix References

- Chen, D. (1995). "Undersized Samples and Demand Analysis." Chapter 5 in E. A. Selvanathan and K. W. Clements (eds) Recent Developments in Applied Demand Analysis: Alcohol, Advertising and Global Consumption. Springer-Verlag: Berlin/Heidelberg. Pp. 191-220.
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Table A1.1. Demand Models in Matrix Form

A. <u>Specification</u>	B. <u>Matrix Form</u> [Reference in the main text]
1. Preference Dependence	$\mathbf{y}_t = [\mathbf{DQ}_t \ \mathbf{A}_t \ \mathbf{DP}_t] \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$ [Equation (3.2)]
2. Preference Independence	$\mathbf{y}_t = [\mathbf{DQ}_t \ \mathbf{A}_t] \boldsymbol{\beta}^{PI} + \boldsymbol{\varepsilon}_t^{PI}$ [Equation (4.1)]
3. Partial Preference Independence	$\mathbf{y}_t = [\mathbf{DQ}_t \ \mathbf{A}_t \ \mathbf{DP}_t^{PPI}] \boldsymbol{\beta}^{PPI} + \boldsymbol{\varepsilon}_t^{PPI}$ [Equation (4.2)]
4. No Price Effect	$\mathbf{y}_t = \mathbf{DQ}_t \boldsymbol{\beta}^{NP} + \boldsymbol{\varepsilon}_t^{NP}$

C. Model Elements ($G = 8$)

$\mathbf{DQ}_t = \begin{bmatrix} DQ_t & 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & DQ_t & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & DQ_t & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & DQ_t & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & DQ_t & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & DQ_t \end{bmatrix}_{(2G \times 2G)}$ <p>$DQ_t \mathbf{I}$, where $\mathbf{I}$ is a $2G \times 2G$ identity matrix.</p>	$\mathbf{A}_t = \begin{bmatrix} A_{1t}^1(\boldsymbol{\theta}) \\ A_{2t}^1(\boldsymbol{\theta}) \\ A_{1t}^2(\boldsymbol{\theta}) \\ A_{2t}^2(\boldsymbol{\theta}) \\ \vdots \\ A_{1t}^G(\boldsymbol{\theta}) \\ A_{2t}^G(\boldsymbol{\theta}) \end{bmatrix}_{(2G \times 1)},$ <p>where $A_{it}^g(\boldsymbol{\theta}) = \theta_i^g (Dp_{it}^g - \sum_{g=1}^G \sum_{k=1}^2 \theta_k^g Dp_{kt}^g)$ with $\boldsymbol{\theta} = [\theta_k^g]$, a vector of $2G$ marginal shares.</p>
$\mathbf{DP}_t = \begin{bmatrix} \Delta p_{21,t}^1 & 0 & \dots & 0 \\ -\Delta p_{21,t}^1 & 0 & \dots & 0 \\ 0 & \Delta p_{21,t}^2 & \dots & 0 \\ 0 & -\Delta p_{21,t}^2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \Delta p_{21,t}^G \\ 0 & 0 & \dots & -\Delta p_{21,t}^G \end{bmatrix}_{(2G \times G)};$ $\mathbf{DP}_t^{PPI} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ \Delta p_{21,t}^5 \\ -\Delta p_{21,t}^5 \\ \vdots \\ 0 \\ 0 \end{bmatrix}_{(2G \times 1)}, \quad \text{where } \Delta p_{ij,t}^g = Dp_{it}^g - Dp_{jt}^g \ (i, j = 1, 2; i \neq j) \text{ which satisfies } \Delta p_{ij,t}^g = -\Delta p_{ji,t}^g \ (g = 1, \dots, 8).$	$\boldsymbol{\beta} = \begin{bmatrix} \theta_1^1 \\ \theta_2^1 \\ \vdots \\ \theta_1^G \\ \theta_2^G \\ \phi \\ v_{12}^1 \\ v_{12}^2 \\ \vdots \\ v_{12}^G \end{bmatrix}_{([3G+1] \times 1)}; \quad \boldsymbol{\beta}^{PI} = \begin{bmatrix} \theta_1^1 \\ \theta_2^1 \\ \vdots \\ \theta_1^G \\ \theta_2^G \\ \phi \end{bmatrix}_{([2G+1] \times 1)};$ $\boldsymbol{\beta}^{PPI} = \begin{bmatrix} \theta_1^1 \\ \theta_2^1 \\ \vdots \\ \theta_1^G \\ \theta_2^G \\ \phi \\ v_{12}^5 \end{bmatrix}_{([2G+2] \times 1)}; \quad \boldsymbol{\beta}^{NP} = \begin{bmatrix} \theta_1^1 \\ \theta_2^1 \\ \vdots \\ \theta_1^G \\ \theta_2^G \end{bmatrix}_{(2G \times 1)}.$

Note: This table presents the stacked format of the four specifications of the demand model. For estimation, these are weighted by budget shares, implemented by multiplying both sides of the unweighted model by $\sqrt{\mathbf{W}^{-1}}$, a diagonal matrix with the reciprocals of the square roots of the sample-average budget shares on the diagonal.

SUPPLEMENTARY MATERIALS

A-21

Table A4.1. Data Description and Sources

Variable (1)	Unit (2)	Frequency (3)	Sample period (4)	Description (5)	Source (6)
A. <u>Trade Values</u>					
1. Merchandise imports	\$A mil.	Monthly	01/1988 – 04/2019	Standard Trade Classification (SITC): <ul style="list-style-type: none">• 60 merchandise commodities (2-digit)• 10 broad commodities (1-digit)	ABS-5368. Available at https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailedPage/5368.0Apr%202019?OpenDocument
2. Merchandise exports					
3. Imports		Yearly	1995 – 2017	IO classification: <ul style="list-style-type: none">• 57 merchandise commodities (2-digit)	ABS.Stat: Supply-Use Tables. Available at http://stat.data.abs.gov.au/index.aspx
4. Exports					
5. Domestic production					
B. <u>Prices</u>					
6. Import price	Index	Quarterly	09/1981 – 03/2019	IO classification: <ul style="list-style-type: none">• 57 merchandise commodities (2-digit)	ABS-6457. Available at https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailedPage/6457.0Mar%202019?OpenDocument
7. Export price					
8. Domestic price					

Table A4.2. Mappings from 60 SITC Goods to 20 Commodities

60 goods (1)	20 commodities (2)
1. Meat and meat preparations ;	Meat Products
2. Dairy products and birds' eggs ;	Dairy Products and Egg
3. Fish (excl. marine mammals) crustaceans, molluscs and aquatic invertebrates, and preparations	Fish Products
4. Cereals and cereal preparations ;	Other Food Products
5. Vegetables and fruit ;	Other Food Products
6. Sugars, sugar preparations and honey ;	Other Food Products
7. Coffee, tea, cocoa, spices, and manufactures thereof ;	Other Food Products
8. Feeding stuff for animals (excl. unmilled cereals) ;	Other Food Products
9. Miscellaneous edible products and preparations ;	Other Food Products
10. Beverages;	Beverage and Tobacco
11. Tobacco and tobacco manufactures ;	Beverage and Tobacco
12. Hides, skins and furskins, raw ;	Other Manufactures
13. Oil-seeds and oleaginous fruits ;	Other Manufactures
14. Crude rubber (incl. synthetic and reclaimed) ;	Other Manufactures
15. Cork and wood ;	Wood and Products
16. Pulp and waste paper ;	Paper Products
17. Textile fibres (excl. wool tops and other combed wool) and their wastes	Textile and Leather
18. Crude fertilizers (excl. those of Division 56) and crude minerals	Other Manufactures
19. Metalliferous ores and metal scrap ;	Other Manufactures
20. Crude animal and vegetable materials, nes ;	Other Manufactures
21. Coal, coke and briquettes ;	Coal, Petroleum and Gas
22. Petroleum, petroleum products and related materials ;	Coal, Petroleum and Gas
23. Gas, natural and manufactured ;	Coal, Petroleum and Gas
24. Animal oils and fats ;	Other Manufactures
25. Fixed vegetable fats and oils, crude, refined or fractionated ;	Other Manufactures
26. Animal or vegetable fats and oils, processed; waxes of animal or vegetable origin etc.;	Other Manufactures
27. Organic chemicals ;	Basic Chemicals
28. Inorganic chemicals ;	Basic Chemicals
29. Dyeing, tanning and colouring materials ;	Basic Chemicals
30. Medicinal and pharmaceutical products ;	Pharmaceutical Products
31. Essential oils and resinoids and perfume materials; etc.	Basic Chemicals
32. Fertilisers (excl. those of group 272) ;	Basic Chemicals
33. Plastics in primary forms ;	Basic Chemicals
34. Plastics in non-primary forms ;	Basic Chemicals
35. Chemical materials and products, nes ;	Basic Chemicals
36. Leather, leather manufactures, nes, and dressed furskins ;	Textile and Leather
37. Rubber manufactures, nes ;	Textile and Leather
38. Cork and wood manufactures (excl. furniture) ;	Wood and Products
39. Paper, paperboard and articles of paper pulp, of paper or of paperboard ;	Paper Products
40. Textile yarn, fabrics, made-up articles nes, and related products ;	Other Manufactures
41. Non-metallic mineral manufactures, nes ;	Non Metals
42. Iron and steel ;	Iron Steel
43. Non-ferrous metals ;	Non Ferrous Metals
44. Power generating machinery and equipment ;	Machinery Equipment
45. Machinery specialized for particular industries ;	Machinery Equipment
46. Metalworking machinery ;	Machinery Equipment
47. General industrial machinery and equipment, nes, and machine parts, nes ;	Machinery Equipment
48. Office machines and automatic data processing machines ;	Machinery Equipment
49. Telecommunications and sound recording and reproducing apparatus and equipment ;	Machinery Equipment
50. Electrical machinery, apparatus and appliances, nes, and electrical parts thereof;	Machinery Equipment
51. Road vehicles (incl. air-cushion vehicles) ;	Motor Vehicles and Parts
52. Transport equipment (excl. road vehicles) ;	Transport Equipment
53. Prefabricated buildings and sanitary, plumbing, heating and lighting fixtures and fittings, nes ;	Other Manufactures
54. Furniture and parts thereof; bedding, mattresses, mattress supports etc.;	Furniture
55. Travel goods, handbags and similar containers ;	Other Manufactures
56. Articles of apparel and clothing accessories ;	Clothing and Footwear
57. Footwear ;	Clothing and Footwear
58. Professional, scientific and controlling instruments and apparatus, nes ;	Other Manufactures
59. Photographic apparatus, equipment and supplies and optical goods, nes; watches and clocks ;	Other Manufactures
60. Miscellaneous manufactured articles, nes ;	Other Manufactures

Note: Source of column 1 is the Standard International Trade Classification System of the United Nations.

Table A4.3. Mappings from 57 SUT Goods to 20 Commodities

57 goods (1)	20 commodities (2)
1. Aquaculture	Fish Products
2. Coal mining	Coal, Petroleum and Gas
3. Oil and gas extraction	Coal, Petroleum and Gas
4. Iron Ore Mining	Coal, Petroleum and Gas
5. Non Ferrous Metal Ore Mining	Coal, Petroleum and Gas
6. Non Metallic Mineral Mining	Coal, Petroleum and Gas
7. Meat and Meat product Manufacturing	Meat Products
8. Processed Seafood Manufacturing	Fish Products
9. Dairy Product Manufacturing	Dairy Products and Egg
10. Fruit and Vegetable Product Manufacturing	Other Food Products
11. Oils and Fats Manufacturing	Other Food Products
12. Grain Mill and Cereal Product Manufacturing	Other Food Products
13. Bakery Product Manufacturing	Other Food Products
14. Sugar and Confectionery Manufacturing	Other Food Products
15. Other Food Product Manufacturing	Other Food Products
16. Soft Drinks, Cordials and Syrup Manufacturing	Beverage and Tobacco
17. Beer Manufacturing	Beverage and Tobacco
18. Wine, Spirits and Tobacco	Beverage and Tobacco
19. Textile Manufacturing	Textile and Leather
20. Tanned Leather, Dressed Fur and Leather Product Manufacturing	Textile and Leather
21. Textile Product Manufacturing	Textile and Leather
22. Knitted Product Manufacturing	Clothing and Footwear
23. Clothing Manufacturing	Clothing and Footwear
24. Footwear Manufacturing	Clothing and Footwear
25. Sawmill Product Manufacturing	Wood and Products
26. Other Wood Product Manufacturing	Wood and Products
27. Pulp, Paper and Paperboard Manufacturing	Paper Products
28. Paper Stationery and Other Converted Paper Product Manufacturing	Paper Products
29. Printing (including the reproduction of recorded media)	Paper Products
30. Petroleum and Coal Product Manufacturing	Coal, Petroleum and Gas
31. Human Pharmaceutical and Medicinal Product Manufacturing	Pharmaceutical Products
32. Veterinary Pharmaceutical and Medicinal Product Manufacturing	Pharmaceutical Products
33. Basic Chemical Manufacturing	Basic Chemicals
34. Cleaning Compounds and Toiletry Preparation Manufacturing	Basic Chemicals
35. Polymer Product Manufacturing	Non Metals
36. Natural Rubber Product Manufacturing	Non Metals
37. Glass and Glass Product Manufacturing	Non Metals
38. Ceramic Product Manufacturing	Non Metals
39. Cement, Lime and Ready-Mixed Concrete Manufacturing	Non Metals
40. Plaster and Concrete Product Manufacturing	Non Metals
41. Other Non-Metallic Mineral Product Manufacturing	Non Metals
42. Iron and Steel Manufacturing	Iron Steel
43. Basic Non-Ferrous Metal Manufacturing	Non Ferrous Metals
44. Forged Iron and Steel Product Manufacturing	Iron Steel
45. Structural Metal Product Manufacturing	Non Ferrous Metals
46. Metal Containers and Other Sheet Metal Product manufacturing	Non Ferrous Metals
47. Other Fabricated Metal Product manufacturing	Non Ferrous Metals
48. Motor Vehicles and Parts; Other Transport Equipment manufacturing	Motor Vehicles and Parts
49. Ships and Boat Manufacturing	Transport Equipment
50. Railway Rolling Stock Manufacturing	Transport Equipment
51. Aircraft Manufacturing	Transport Equipment
52. Professional, Scientific, Computer and Electronic Equipment Manufacturing	Machinery Equipment
53. Electrical Equipment Manufacturing	Machinery Equipment
54. Domestic Appliance Manufacturing	Machinery Equipment
55. Specialised and other Machinery and Equipment Manufacturing	Machinery Equipment
56. Furniture Manufacturing	Furniture
57. Other Manufactured Products	Other Manufactures

Note: Source of column 1 is the Supply-Use Tables provided by Australian Bureau of Statistics.

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Table A4.4. Mappings from 20 Commodities into 8 Groups

Groups (1)	20 Commodities				
	(2)	(3)	(4)	(5)	(6)
1. Food and Agricultural Commodities	Dairy Products and Egg	Fish Products	Beverage and Tobacco	Meat Products	Other Food Products
2. Energy and Minerals	Coal, Petroleum and Gas	Iron Steel	Non-Ferrous Metals	Non Metals	
3. Chemicals	Basic Chemicals	Pharmaceutical Products			
4. Textile, Leather, Clothing and Footwear	Textile and Leather	Clothing and Footwear			
5. Wood and Paper Products	Wood Products	Paper Products			
6. Machinery and Equipment	Machinery Equipment				
7. Motor Vehicles and Transport	Motor Vehicles and Parts	Transport Equipment			
8. Miscellaneous Manufactured Goods	Other Manufactures	Furniture			

Note: Columns 2 – 6 are from Tables A4.2 and A4.3.

Table 4.5. Divisia Price and Quantity Indices,
Variances and Correlations

Year	Index ($\times 10^2$)		Variance ($\times 10^4$)		Correlation ρ_t
	Price DP_t	Quantity DQ_t	Price V_t^p	Quantity V_t^q	
(1)	(2)	(3)	(4)	(5)	(6)
1996	-0.04	1.90	4.90	11.80	-0.60
1997	-1.46	2.90	5.30	8.80	-0.60
1998	1.07	3.10	13.80	8.50	0.41
1999	4.55	0.70	10.40	22.10	-0.72
2000	2.70	1.50	10.00	46.80	-0.73
2001	2.58	0.80	54.70	57.00	-0.73
2002	1.45	2.00	5.10	23.50	-0.79
2003	-1.08	4.30	4.80	24.00	-0.39
2004	0.95	1.10	65.80	56.50	-0.94
2005	3.52	4.20	23.90	33.30	-0.41
2006	4.40	0.20	13.80	19.30	0.08
2007	3.09	2.40	10.40	27.20	-0.04
2008	1.67	4.50	42.40	57.50	-0.77
2009	1.51	-1.40	54.00	43.60	-0.62
2010	-0.66	-3.20	35.80	46.10	-0.48
2011	1.26	1.30	8.50	12.30	-0.49
2012	0.16	2.50	9.10	34.60	-0.33
2013	1.69	-5.00	6.00	16.80	-0.39
2014	1.95	-1.50	24.60	20.20	-0.68
2015	-0.24	-2.00	32.40	14.40	-0.09
2016	2.30	-0.90	19.50	12.90	-0.15
2017	0.17	-0.40	13.90	28.20	-0.94
Mean	1.43	0.86	21.32	28.43	-0.47
Median	1.48	1.20	13.80	23.75	-0.54
SD	1.65	2.47	18.39	16.21	0.34

Notes:

1. *Columns 2 – 3:* The price and quantity indices are $DP_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dp_{it}^g$; $DQ_t = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g Dq_{it}^g$.
2. *Columns 4 – 5:* The price and quantity variances are $V_t^p = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g (Dp_{it}^g - DP_t)^2$ and $V_t^q = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g (Dq_{it}^g - DQ_t)^2$.
3. *Column 6:* The price-quantity correlation is $\rho_t = V_t^{pq} (V_t^p V_t^q)^{-1/2}$, where $V_t^{pq} = \sum_{g=1}^8 \sum_{i=1}^2 \bar{w}_{it}^g (Dp_{it}^g - DP_t)(Dq_{it}^g - DQ_t)$ is the price-quantity covariance.

Table A6.1. Functional Form and Degrees of Freedom
[**Numerator d.f.** (Denominator d.f.)]

Unrestricted/alternative model (1)	Number of unconstrained parameters (2)	Restricted/null model		
		Least ← restrictive		→ Most restrictive
		PPI (3)	PI (4)	NP (5)
1. Preference Dependence (PD) $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t') + \varepsilon_{it}^g$	$\theta_i^g: 15;$ $v_{12:}^g: 8; \phi: 1$ Total = 24	7 (328)	8 (328)	9 (328)
2. Partial Preference Independence (PPI) $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi A_{it}^g(\theta) + v_{12}^5 [2\gamma(i = 1) - 1] \Delta p_{21,t}^5 + \varepsilon_{it}^g$	$\theta_i^g: 15;$ $v_{12:}^5: 1; \phi: 1$ Total = 17	—	1 (335)	2 (335)
3. Preference Independence (PI) $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + v_{ii}^g (Dp_{it}^g - DP_t') + \varepsilon_{it}^g$	$\theta_i^g: 15; \phi: 1$ Total = 16	—	—	1 (336)
4. No price effects (NP) $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \varepsilon_{it}^g$	$\theta_i^g: 15$ Total = 15	—	—	—

Notes: The numerator degrees of freedom are **emboldened** and equal to the difference in the number of unconstrained parameters in unrestricted/alternative and restricted/null models. The denominator degrees of freedom equal the difference between the number of observations ($22 \times 16 = 352$) and number of independent variables in the unrestricted model.

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Table A7.1. Aggregating and Disaggregating Demands[illegible]

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Notes:

1. There are 8 elementary goods with each split according to where it was produced domestically or imported. Thus, there are 16 items identified in panel A. These are aggregated in 2 ways:
 - (i) Into the 3 varieties: (a) Domestically produced, excluding “Wood” (V_1); (b) Imported excluding “Wood” (V_2) and (c) “Wood” from both domestic and foreign sources (V_3). These groups are represented in panel B.
 - (ii) Into the 8 groups corresponding to the elementary goods: These groups are represented in panel D.
2. Panels C and E refer to budget allocations within aggregations (i) and (ii) above.
3. *Column 3*: The budget shares are sample means.
4. *Column 7*: The “income” elasticities represent elasticities with respect to the high-level aggregates.
5. *Column 8*: The own-price elasticities are of the Frisch variety (which holds marginal utility of income constant).
6. The item “Wood” represents “Wood and Paper Products”.

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Table A8.1. Year-on-Year Evaluation of Budget-Share Predictions, Information Inaccuracies

Year	A. <u>Three varieties</u>			B. <u>Eight groups</u>		
	Demand model	Naïve	Demand model better?	Demand model	Naïve	Demand model better?
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1996	0.47	0.23	No	1.72	1.79	Yes
1997	0.51	0.40	No	1.78	1.55	No
1998	1.71	12.83	Yes	2.73	2.85	Yes
1999	0.31	0.08	No	5.73	2.20	No
2000	9.29	7.91	No	1.27	1.91	Yes
2001	0.78	4.12	Yes	13.22	7.08	No
2002	8.38	3.42	No	9.15	1.91	No
2003	2.02	4.35	Yes	5.08	6.04	Yes
2004	0.76	1.16	Yes	6.45	2.24	No
2005	0.29	4.58	Yes	4.07	11.47	Yes
2006	7.32	6.52	No	3.78	7.83	Yes
2007	0.50	1.19	Yes	5.14	14.03	Yes
2008	1.94	2.99	Yes	10.26	6.34	No
2009	0.82	5.71	Yes	12.43	11.06	No
2010	0.95	3.74	Yes	16.08	13.13	No
2011	0.62	0.59	No	2.32	3.74	Yes
2012	8.77	12.55	Yes	7.41	9.07	Yes
2013	4.47	0.03	No	1.72	6.02	Yes
2014	0.31	1.31	Yes	3.47	2.64	No
2015	3.48	2.57	No	4.26	17.02	Yes
2016	0.31	0.18	No	4.52	5.86	Yes
2017	0.75	0.14	No	5.82	1.57	No
Mean	2.49	3.48	No. of	5.84	6.24	No. of
SD	3.00	3.67	“Yes”: 11/22	3.98	4.53	“Yes”: 12/22

Notes: All entries are multiplied by 10^4 .

Table A9.1. Import Demand Simulations

Simulated variable	Shock to		
	Income $\widehat{DQ}_t = DQ_t + r$	Spending on group g $\widehat{DQ}_t^g = DQ_t^g + r$ ($g = 1, \dots, 8; g \neq 5$)	Total imports $\widehat{DQ}_{2t} = DQ_{2t} + r$
(1)	(2)	(3)	(4)
Import penetration of g $\left(\frac{w_{2s}^g}{\bar{w}_s^g}\right)^{(p)}$	$\frac{w_{2s}^g + \sum_{t=1996}^s (\theta_2^g - \bar{w}_{2t}^g)r}{W_s^g + \sum_{t=1996}^s (\Theta^g - \bar{W}_t^g)r}$ Eq. (A9.9)	$\frac{w_{2s}^g}{W_s^g} + \sum_{t=1996}^s \left(\frac{\theta_2^g}{\Theta^g} - \frac{\bar{w}_{2t}^g}{\bar{W}_t^g}\right)r$ Eq. (A9.11)	$\left[\frac{w_{2s}^g}{W_{2s}} + \sum_{t=1996}^s \left(\frac{\theta_2^g}{\Theta_2} - \frac{\bar{w}_{2t}^g}{\bar{W}_{2t}}\right)r\right] \times [W_{2s} + \sum_{t=1996}^s \bar{W}_{2t}r](W_s^g)^{-1}$ Eq. (A9.15)
Total imports $\widehat{W}_{2s}^{(p)}$	$W_{2s} + \sum_{t=1996}^s (\Theta_2 - \bar{W}_{2t})r$ Eq. (A9.10)	— —	$W_{2s} + \sum_{t=1996}^s \bar{W}_{2t}r$ Eq. (A9.13)

Note: “Imports” refer to non-Wood commodities only ($g \neq 5$).

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Table A10.1. Domestic and Foreign Demands Under Preference Dependence With Intercepts

$$\bar{w}_{it}^g Dq_{it}^g = \alpha_i^g + \theta_i^g DQ_t + \sum_{j=1}^2 v_{ij}^g (Dp_{jt}^g - DP_t') + \varepsilon_{it}^g, \quad i = 1, 2; g = 1, \dots, 8$$

Commodity group g	Variety i	Budget share (Sample mean $\times 100$) w_i^g	Coefficients ($\times 100$)				Elasticities		
			Intercept α_i^g	Marginal share θ_i^g	Price coefficients		Income $\eta_i^g = \frac{\theta_i^g}{w_i^g}$	Frisch price	
					Domestic v_{i1}^g	Foreign v_{i2}^g		Domestic $F_{i1}^g = \frac{v_{i1}^g}{w_i^g}$	Foreign $F_{i2}^g = \frac{v_{i2}^g}{w_i^g}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Food and Agricultural Commodities	Domestic, 1	20.19	0.03 (0.13)	3.12 (5.14)	-2.42 (2.82)	0.67 (0.35)	0.15 (0.25)	-0.12 (0.14)	0.03 (0.02)
	Foreign, 2	1.82	0.05 (0.01)	0.89 (0.58)		-1.17 (0.27)	0.49 (0.32)	0.37 (0.19)	-0.64 (0.15)
2. Energy and Minerals	1	22.29	-0.24 (0.18)	38.06 (7.01)	-17.75 (4.02)	-3.51 (1.63)	1.71 (0.31)	-0.80 (0.18)	-0.16 (0.07)
	2	6.53	0.10 (0.09)	14.05 (5.13)		-4.34 (2.57)	2.15 (0.79)	-0.54 (0.25)	-0.66 (0.39)
3. Chemicals	1	5.32	0.01 (0.05)	3.46 (2.00)	-1.81 (1.13)	-0.12 (0.43)	0.65 (0.38)	-0.34 (0.21)	-0.02 (0.08)
	2	2.91	0.07 (0.02)	2.82 (0.81)		-1.45 (0.41)	0.97 (0.28)	-0.04 (0.15)	-0.50 (0.14)
4. Textile, Leather, Clothing and Footwear	1	4.56	-0.05 (0.04)	2.56 (1.24)	-2.05 (0.80)	0.62 (0.29)	0.56 (0.27)	-0.45 (0.18)	0.14 (0.06)
	2	1.92	0.05 (0.02)	0.59 (0.51)		-0.94 (0.20)	0.31 (0.27)	0.32 (0.15)	-0.49 (0.10)
5. Wood and Paper Products	1	4.81	-0.07 (0.05)	0.95 (1.67)	-1.02 (0.99)	0.49 (0.23)	0.20 (0.35)	-0.21 (0.21)	0.10 (0.05)
	2	0.76	-0.01 (0.01)	0.33 (0.34)		-0.68 (0.13)	0.44 (0.44)	0.65 (0.30)	-0.89 (0.17)
6. Machinery and Equipment	1	7.41	-0.04 (0.05)	7.94 (1.97)	-4.23 (1.56)	-0.21 (0.85)	1.07 (0.27)	-0.57 (0.21)	-0.03 (0.11)
	2	7.75	0.12 (0.09)	11.30 (2.98)		-6.10 (1.10)	1.46 (0.38)	-0.03 (0.11)	-0.79 (0.14)
7. Motor Vehicles and Transport	1	5.92	-0.12 (0.08)	5.96 (2.81)	-3.38 (2.38)	0.05 (1.51)	1.01 (0.47)	-0.57 (0.40)	0.01 (0.25)
	2	4.45	0.07 (0.07)	5.76 (2.38)		-3.27 (1.30)	1.29 (0.53)	0.01 (0.34)	-0.73 (0.29)
8. Miscellaneous Manufactured Goods	1	2.48	-0.02 (0.02)	1.56 (0.85)	-0.99 (0.57)	0.12 (0.22)	0.63 (0.34)	-0.40 (0.23)	0.05 (0.09)
	2	0.89	0.03 (0.01)	0.96 (0.45)		-0.66 (0.14)	1.08 (0.50)	0.14 (0.25)	-0.74 (0.16)
Income flexibility (ϕ) = -0.559 (0.061)									

Notes:

- Column 6: As the 2×2 matrices $[v_{ij}^g]$, $g = 1, \dots, 8$, are symmetric, only the upper triangle is presented.
- Columns 9 – 10: The Frisch price elasticity F_{ij}^g is the elasticity of demand for variety i in group g with respect to the price of variety j in the same group g ($i, j = 1, 2; g = 1, \dots, 8$), with the marginal utility of income constant. The Frisch own-price elasticities, F_{ii}^g , are **bolded**. The across-group Frisch elasticities are zero.
- Bootstrap standard errors with 10,000 replications in parentheses.

Table A10.2. Domestic and Foreign Demands under Preference Independence

$$\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + v_{ii}^g (Dp_{jt}^g - DP_t') + \xi_{it}^g, \quad i = 1, 2; g = 1, \dots, 8$$

Commodity group g	Variety i	Coefficients ($\times 100$)		Elasticities	
		Marginal share θ_i^g	Price v_{ii}^g	Income $\eta_i^g = \frac{\theta_i^g}{w_i^g}$	Price $F_{ii}^g = \frac{v_{ii}^g}{w_i^g}$
(1)	(2)	(3)	(4)	(5)	(6)
1. Food and Agricultural Commodities	Domestic, 1	3.31 (4.23)	-1.20 (1.74)	0.16 (0.21)	-0.06 (0.09)
	Foreign, 2	1.74 (1.27)	-0.63 (0.18)	0.96 (0.70)	-0.35 (0.10)
2. Energy and Minerals	1	30.77 (4.45)	-11.14 (2.20)	1.38 (0.20)	-0.50 (0.10)
	2	17.47 (2.52)	-6.33 (1.62)	2.67 (0.39)	-0.97 (0.25)
3. Chemicals	1	3.54 (2.17)	-1.28 (0.59)	0.67 (0.41)	-0.24 (0.11)
	2	3.70 (1.61)	-1.34 (0.25)	1.27 (0.55)	-0.46 (0.08)
4. Textile, Leather, Clothing and Footwear	1	1.77 (2.01)	-0.64 (0.41)	0.39 (0.44)	-0.14 (0.09)
	2	1.44 (1.31)	-0.52 (0.19)	0.75 (0.68)	-0.27 (0.10)
5. Wood and Paper Products	1	-0.20 (2.07)	0.07 (0.55)	-0.04 (0.43)	0.01 (0.11)
	2	0.57 (0.82)	-0.21 (0.12)	0.74 (1.08)	-0.27 (0.16)
6. Machinery and Equipment	1	7.75 (2.56)	-2.81 (0.76)	1.05 (0.35)	-0.38 (0.10)
	2	13.70 (2.65)	-4.96 (0.87)	1.77 (0.34)	-0.64 (0.11)
7. Motor Vehicles and Transport	1	4.92 (2.29)	-1.78 (0.92)	0.83 (0.39)	-0.30 (0.16)
	2	7.17 (2.00)	-2.60 (0.73)	1.61 (0.45)	-0.58 (0.16)
8. Miscellaneous Manufactured Goods	1	1.07 (1.48)	-0.39 (0.29)	0.43 (0.60)	-0.16 (0.12)
	2	1.50 (0.89)	-0.54 (0.10)	1.69 (1.00)	-0.61 (0.11)
Income flexibility $\phi = -0.362$ (0.037)					

Note: Bootstrap standard errors with 10,000 replications in parentheses.

Table A10.3. Own-Price Elasticities under Preference Independence

$$\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + v_{ii}^g (Dp_{it}^g - DP_t') + \varepsilon_{it}^g, \quad i = 1, 2; g = 1, \dots, 8$$

Commodity group g	Variety i	Own-price elasticities		
		Frisch $F_{ii}^g = \frac{v_{ii}^g}{w_i^g}$	Slutsky $S_{ii}^{gg} = \frac{\pi_{ii}^g}{w_i^g}$	Marshallian $M_{ii}^{gg} = S_{ii}^{gg} - w_i^g \eta_i^g$
(1)	(2)	(3)	(4)	(5)
1. Food and Agricultural Commodities	Domestic, 1	-0.059 (0.086)	-0.057 (0.082)	-0.091 (0.134)
	Foreign, 2	-0.347 (0.100)	-0.340 (0.098)	-0.358 (0.103)
2. Energy and Minerals	1	-0.500 (0.099)	-0.346 (0.053)	-0.654 (0.092)
	2	-0.968 (0.248)	-0.799 (0.172)	-0.974 (0.205)
3. Chemicals	1	-0.241 (0.111)	-0.233 (0.104)	-0.268 (0.120)
	2	-0.460 (0.085)	-0.443 (0.081)	-0.480 (0.086)
4. Textile, Leather, Clothing and Footwear	1	-0.141 (0.090)	-0.138 (0.086)	-0.156 (0.098)
	2	-0.271 (0.099)	-0.267 (0.097)	-0.281 (0.102)
5. Wood and Paper Products	1	0.015 (0.114)	0.015 (0.113)	0.017 (0.129)
	2	-0.269 (0.160)	-0.268 (0.158)	-0.274 (0.162)
6. Machinery and Equipment	1	-0.379 (0.102)	-0.350 (0.089)	-0.427 (0.104)
	2	-0.640 (0.113)	-0.552 (0.091)	-0.689 (0.105)
7. Motor Vehicles and Transport	1	-0.301 (0.156)	-0.286 (0.138)	-0.335 (0.163)
	2	-0.583 (0.164)	-0.541 (0.144)	-0.613 (0.162)
8. Miscellaneous Manufactured Goods	1	-0.157 (0.116)	-0.155 (0.113)	-0.166 (0.121)
	2	-0.611 (0.111)	-0.601 (0.108)	-0.616 (0.110)

Note: Bootstrap standard errors with 10,000 replications in parentheses.

Table A10.4. Own-Price Elasticities under Partial Preference Independence
 $\bar{w}_{it}^g Dq_{it}^g = \theta_i^g DQ_t + \phi A_{it}^g(\theta) + D(g=5)[2\gamma(i=1) - 1]v_{12}^g \Delta p_{21,t}^g + \varepsilon_{it}^g;$
 $i = 1, 2; g = 1, \dots, 8$

Commodity group g	Variety i	Own-price elasticities		
		Frisch $F_{ii}^g = \frac{\nu_{ii}^g}{w_i^g}$	Slutsky $S_{ii}^{gg} = \frac{\pi_{ii}^g}{w_i^g}$	Marshallian $M_{ii}^{gg} = S_{ii}^{gg} - w_i^g \eta_i^g$
(1)	(2)	(3)	(4)	(5)
1. Food and Agricultural Commodities	Domestic, 1	-0.059 (0.086)	-0.057 (0.079)	-0.090 (0.132)
	Foreign, 2	-0.343 (0.111)	-0.337 (0.107)	-0.355 (0.111)
2. Energy and Minerals	1	-0.495 (0.091)	-0.343 (0.051)	-0.650 (0.098)
	2	-0.952 (0.254)	-0.787 (0.169)	-0.961 (0.201)
3. Chemicals	1	-0.239 (0.110)	-0.230 (0.103)	-0.266 (0.119)
	2	-0.455 (0.099)	-0.439 (0.093)	-0.475 (0.097)
4. Textile, Leather, Clothing and Footwear	1	-0.139 (0.087)	-0.137 (0.085)	-0.154 (0.096)
	2	-0.269 (0.103)	-0.265 (0.100)	-0.279 (0.105)
5. Wood and Paper Products	1	-0.016 (0.111)	-0.016 (0.112)	-0.018 (0.129)
	2	-0.115 (0.140)	-0.114 (0.139)	-0.117 (0.143)
6. Machinery and Equipment	1	-0.375 (0.097)	-0.346 (0.085)	-0.424 (0.101)
	2	-0.635 (0.117)	-0.548 (0.091)	-0.685 (0.104)
7. Motor Vehicles and Transport	1	-0.298 (0.149)	-0.283 (0.139)	-0.332 (0.165)
	2	-0.578 (0.166)	-0.537 (0.142)	-0.608 (0.160)
8. Miscellaneous Manufactured Goods	1	-0.155 (0.112)	-0.154 (0.110)	-0.165 (0.118)
	2	-0.607 (0.123)	-0.598 (0.120)	-0.613 (0.121)

Notes:

1. Column 3 coincides with columns 8 and 9 of Table 4.4.
2. Bootstrap standard errors with 10,000 replications in parentheses.

Figure A4.1. Data Construction

Notes: Database numberings (e.g., “Data 1.0”) are consistent with column 1 of Table A4.1.

Figure A4.2. Quantity and Price Dispersion

Figure A6.1. Distributions of F-statistics

Notes: This figure presents the distributions of bootstrap F-statistics using 10,000 replications. In each plot:

1. The solid black curve indicates the bootstrap density function.
2. The dashed blue curve represents the asymptotic F-distribution density function with appropriate degrees of freedom.
3. The dashed red and dotted green vertical lines indicate the 95th and 99th percentiles of the bootstrap sample.
4. The black solid vertical line represents the observed F-statistic.

Figure A8.1. Budget-Share Predictions

Notes:

1. *Panel A*: Grey solid lines are the actual shares $W_{kt} = \sum_{g \in V_k} w_{kt}^g$ ($k = 1, 2$); blue dots are the predicted shares $W_{kt} - \hat{E}_{kt}$, where $\hat{E}_{kt}$ is the residual from the demand equation.
2. *Panel B*: Grey solid lines are the actual shares $W_t^g = \sum_{i=1}^2 w_{it}^g$ ($g = 1, \dots, 8$); blue dots are the predicted shares $W_t^g - \hat{E}_t^g$, where $\hat{E}_t^g$ is the residual from the demand equation.
3. All values are percentage shares.