Estimation of Consumption Elasticities for OECD Countries: Testing Price Asymmetry with Alternative Dynamic Panel Data Techniques

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INTRODUCTION

In recent years, the dynamic panel data literature has begun to focus on panels in which the number of cross-sectional observations (N) and the number of time-series observations (T) are both large. The availability of data with greater frequency is certainly a key contributor to this shift. Some cross-national and cross-state data sets, for example, are now large enough in T such that each nation (or state) can be estimated separately. See Blackburne and Frank, (2007) for further details.

The asymptotics of large N, large T dynamic panels are quite different from the asymptotics of traditional large N, small T dynamic panels. Small T panel estimation usually relies on fixed or random effects estimators, or a combination of fixed effects estimators and instrumental variable estimators, such as the Arellano and Bond, (1991) GMM estimator. These methods require pooling individual groups and allowing only the intercepts to differ across the groups. One of the central findings from the large N, large T literature, however, is that the assumption of homogeneity of slope parameters is often inappropriate. This point has been made by Pesaran and Smith (1995); Im et al. (2003), Pesaran et al; (1997, 1999), Phillips and Moon, (2000)[1].

With the increase in time observations inherent in large N, large T dynamic panels, nonstationarity is also a concern. Recent papers by Pesaran et al. (1997, 1999) offer two important new techniques to estimate nonstationary dynamic panels in which the parameters are heterogeneous across groups: the mean-group and pooled mean-group estimators. The mean-group estimator (MG) (see Pesaran and Smith, 1995) relies on estimating N time series regressions and averaging the coefficients, while the pooled mean-group estimator (PMG) (see Pesaran et al., 1997,1999) relies on a combination of pooling and averaging of coefficients.

[1] For further discussion of this literature see chapter 12 in (Baltagi, 2001).

In recent empirical research, the MG and PMG estimators have been applied in a variety of settings. Freeman, (2000), for example, uses the estimators to evaluate state-level alcohol consumption over the period 1961 to 1995. Martinez-Zarzoso and Bengochea-Morancho, (2004) employ them in an estimation of an environmental Kuznets curve in a panel of 22 OECD nations over a period 1975 to 1998. Frank, (2005) uses the MG and PMG estimators to evaluate the long-term impact of income inequality on economic growth in a panel of U.S. states over the period 1945 to 2001.

This paper applies the MG and PMG estimators to a panel of OECD nations for the years 1970–2004. We present a simple dynamic model of oil consumption as a function of income and prices. As in previous studies, we allow demand to respond asymmetrically to price shocks. Specifically, this paper has three goals:

- test the degree of heterogeneity in oil consumption among the OECD nations
- test the asymmetric response of oil consumption with respect to price
- estimate precise price and income elasticities for OECD oil consumption

This paper proceeds as follows. Section 2 discusses the methods involved, including price decomposition and alternative dynamic panel estimators. Section 3 briefly describes the data. Section 4 presents the results and Section 5 concludes.

METHODOLOGY

Demand Asymmetries

Following the recent work of Gately and Huntington, (2002), this paper allows for asymmetric price response in oil demand. Models that assume price symmetry when, in fact, it does not exist introduce model misspecification and downwardly bias income elasticity estimates. Accordingly, we decompose the world price of oil (in logs), P_t, into three components:

$$P_{max,t} = max(P_t, P_{t-1}) \tag{1}$$

$$P_{rec,t} = \sum_{t=1}^{T} max(0, (P_t - P_{t-1}) - (P_{max,t} - P_{max,t-1})) \tag{2}$$

$$P_{cut,t} = \sum_{t=1}^{T} min(0, P_t - P_{t-1}) \tag{3}$$

$P_{max,t}$,and $P_{rec,t}$, are non-decreasing series while $P_{cut,t}$, is non-increasing. Figure 1 presents the decomposed real oil price series for the period 1970-2004.

The decomposition of price listed above is convenient since it allows for simple testing of symmetric consumption responses to price changes. At any point in time, the following identity holds:

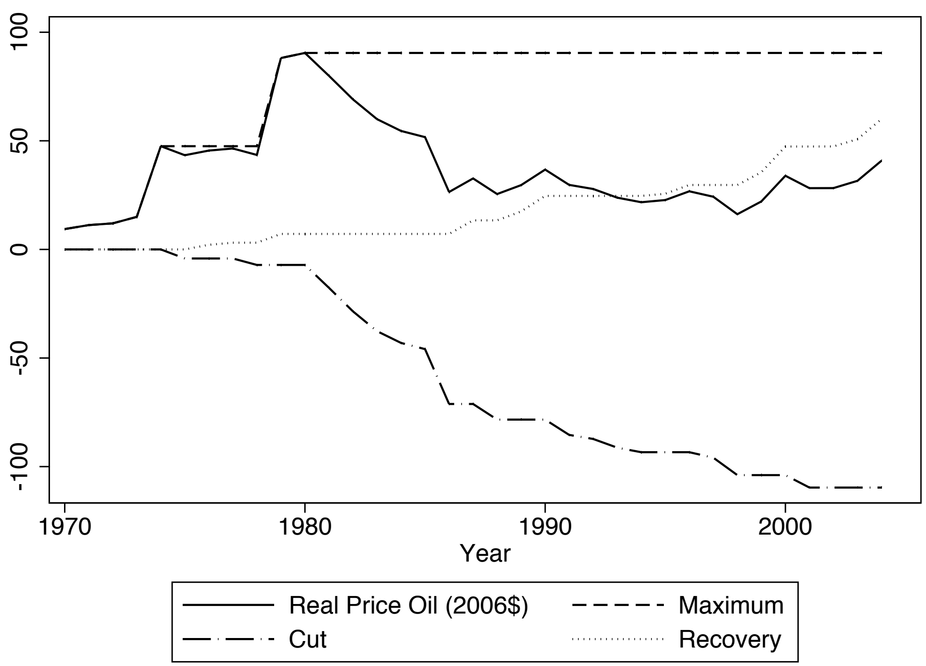
$$P_t = P_{max,t} + P_{rec,t} + P_{cut,t} \tag{4}$$

Given a simple demand model of the form

$$q_t = \alpha + \beta_1 P_{max,t} + \beta_2 P_{rec,t} + \beta_3 P_{cut,t} + \epsilon_t \tag{5}$$

the null hypothesis of price response symmetry is tested as $\beta_1 = \beta_2 = \beta_3$. Under the alternative hypothesis of price asymmetry, at least one β_i is statistically different. Prior research convincingly argues that $|\beta_1| > |\beta_2| > |\beta_3|$. Our results partially confirm this.

Figure 1
Price Decomposition



OIL DEMAND MODEL

We estimate a reduced form energy demand model where per capita oil demand is a log-linear function of the real price of oil (which is common across all countries) and real per capita GDP.

Assume the long-run demand function

$$q_{it} = \theta_{0i} + \theta_{1i}p_t + \theta_{2i}y_{it} + \mu_i + \epsilon_{it} \tag{6}$$

where the number of nations i=1,2, ..., N, the number of time periods t =1,2, ..., T, q_{it}, is the log of per capita oil consumption (million tonnes), p_t is the log of real price of oil (2006$ per barrel), and y_{it} is the log of real per capita income. If the variables are $I(1)$ and cointegrated, then the error term is $I(0)$ for all i. The *ARDL* (1,1,1) dynamic panel specification of (6) is

$$q_{it} = \delta_{10i}p_t + \delta_{11i}p_{t-1} + \delta_{20i}y_{it} + \delta_{21i}y_{i,t-1} + \lambda_i q_{i,t-1}\mu_i + \epsilon_{it} \tag{7}$$

The error correction re-parametrization of (7) is

$$\Delta q_{it} = \phi_i \left(q_{i,t-1} - \theta_{0i} - \theta_{1i}p_t - \theta_{2i}y_{it}\right) + \delta_{11i}\Delta p_t + \delta_{21i}\Delta y_{it} + \epsilon_{it} \tag{8}$$

where

$\phi_i = -(1-\lambda_i)$, $\theta_{0i} = \frac{\mu_i}{1-\lambda_i}$, $\theta_{it} = \frac{\delta_{10i}+\delta_{11i}}{1-\lambda_i}$, and $\theta_{2i} = \frac{\delta_{20i}+\delta_{21i}}{1-\lambda_i}$.

The error-correction speed of adjustment parameter, ϕ_i, and the long-run coefficients, θ_{1i} and θ_{2i} are of primary interest. One would expect ϕ_i to be negative if the variables exhibit a return to long-run equilibrium. Economic theory indicates the long-run price elasticity, θ_{1i}, should be negative and the long-run income elasticity, θ_{2i} to be positive. Further, to allow for price asymmetries, we substitute the price decomposition from equation (1) above.

THE MEAN-GROUP AND POOLED | MEAN-GROUP ESTIMATORS

The recent literature on dynamic heterogeneous panel estimation in which both and are large suggests several approaches to the estimation of equation (8). On one extreme, a fixed effects (FE) estimation approach could be utilized in which the time series data for each group is pooled and only the intercepts are allowed to differ across groups. If the slope coefficients are in fact not identical, however, then the FE approach produces inconsistent and potentially misleading results. On the other extreme, the model could be estimated separately for each individual group, and a simple arithmetic average of the coefficients could be calculated. This is the mean-group (MG) estimator proposed by Pesaran and Smith, (1995). With this estimator, the intercepts, slope coefficients, and error variances are all allowed to differ across groups.

More recently, Pesaran et al., (1997), Pesaran et al., (1999) have proposed a pooled mean-group (PMG) estimator that combines both pooling and averaging. This intermediate estimator allows the intercept, short-run coefficients, and error variances to differ across the groups (as would the MG estimator), but constrains the long-run coefficients to be equal across groups (as would a FE estimator). Since equation (8) is nonlinear in the parameters, Pesaran et al., (1999) develop a maximum likelihood (ML) method to estimate the parameters.

Expressing the likelihood as the product of each cross-section's likelihood and taking the log yields:

$$l_T(\theta', \varphi', \sigma') = -\frac{T}{2}\sum_{i=1}^{N} ln(2\pi\sigma_i^2) - \frac{1}{2}\sum_{i=1}^{N}\frac{1}{\sigma_i^2}(\Delta y_i - \phi_i\xi_i(\theta))' H_i(\Delta y_i - \phi_i\xi_i(\theta)) \quad (9)$$

for i =1, ..., N, where , $\xi_i(\theta) = y_{i,t-1} - X_i\theta_i$, $H_i = I_T - W_i(W_i' W_i)W_i$, I_T , is an identity matrix of order T, and

$$W_i = (\Delta y_{i,t-1}, \ldots, \Delta y_{i,t-p+1}, \Delta X_i, \Delta X_{i,t-1}, \ldots, \Delta X_{i,t-q+1}).$$

The parameter estimates from iterated conditional likelihood maximization are asymptotically identical to those from full-information maximum likelihood. But the estimated covariance matrix is not. However, since the distribution of the pooled mean-group parameters is known, we are able to recover the full covariance matrix for all estimated parameters. As shown in Pesaran et al., (1999), the covariance matrix can be estimated by the inverse of

$$\begin{bmatrix} \sum_{i=1}^{N}\frac{\hat{\phi}_i^2 X_i' X_i}{\hat{\sigma}_i^2} & \frac{-\hat{\phi}_1 X_1'\hat{\xi}_1}{\hat{\sigma}_1^2} & \cdots & \frac{-\hat{\phi}_N X_N'\hat{\xi}_N}{\hat{\sigma}_N^2} & \frac{-\hat{\phi}_1 X_1' W_1}{\hat{\sigma}_1^2} & \cdots & \frac{-\hat{\phi}_N X_N' W_N}{\hat{\sigma}_N^2} \\ & \frac{\hat{\xi}_1'\hat{\xi}_1}{\hat{\sigma}_1^2} & \cdots & 0 & \frac{\hat{\xi}_1' W_1}{\hat{\sigma}_1^2} & \cdots & 0 \\ & & \ddots & \vdots & \vdots & \ddots & \vdots \\ & & & \frac{\hat{\xi}_N'\hat{\xi}_N}{\hat{\sigma}_N^2} & 0 & \cdots & \frac{\hat{\xi}_N' W_N}{\hat{\sigma}_N^2} \\ & & & & \frac{W_1' W_1}{\hat{\sigma}_1^2} & \cdots & 0 \\ & & & & & \ddots & \vdots \\ & & & & & & \frac{W_N' W_N}{\hat{\sigma}_N^2} \end{bmatrix} \quad (10)$$

The mean-group parameters are simply the unweighted means of the individual coefficients. For example, the mean-group estimate of the error correction coefficient, ϕ, is:

$$\hat{\phi} = N^{-1}\sum_{i=1}^{N}\hat{\phi}_i \tag{11}$$

with the variance

$$\hat{\Delta}_{\hat{\phi}} = \frac{1}{N(N-1)}\sum_{i=1}^{N}(\hat{\phi}_i - \hat{\phi})^2 \tag{12}$$

The mean and variance of other short-run coefficients are similarly estimated[2].

DATA

We use annual aggregate data for 27 OECD nations to estimate the oil demand model in equation (8)[3]. These data are taken from Alan Heston and Aten, (2006), IEA, (2006), and encompass the years 1970 through 2004. Summary statistics for the data are listed in Table 0. Figure 2 shows oil consumption (million tonnes) and income (real GDP per capita) for the 27 OECD countries in our sample.

Although we expect OECD countries, as a whole, to be a homogeneous group, our estimation procedures do not impose parameter homogeneity. At one extreme, the mean-group estimator allows for complete heterogeneity while the dynamic fixed effects estimator imposes parameter homogeneity across all countries. As a compromise, the pooled mean-group estimator allows for country-specific short-run adjustments while imposing common long-run elasticities[4]. The next section presents results of these alternative estimators.

RESULTS

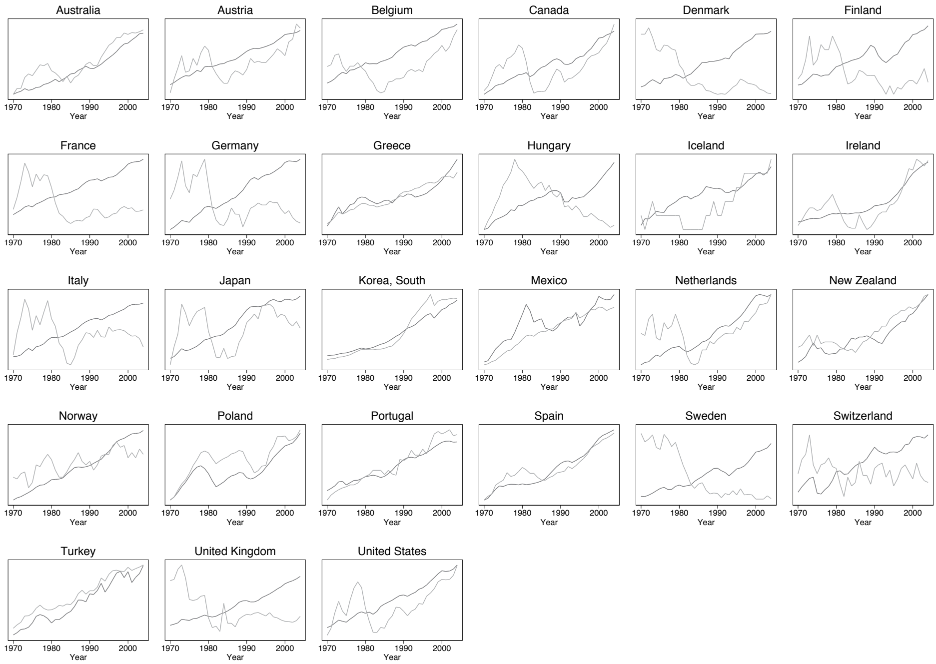
Im et al., (2003) developed a unit root test for dynamic heterogeneous panels based on the the augmented Dickey–Fuller statistics averaged across all panels.

[2] All models are estimated in Stata using the **xtpmg** command developed by Blackburne and Frank, (2007).

[3] Due to data sparsity, Luxembourg, Czech Republic, and Slovakia are dropped from our sample.

[4] Our model (8) includes income in the long-run equation which imposes the same speed of adjustment parameter on income and price. When estimated in this way, the long-run income elasticities were implausibly large. Following [Gately and Huntington, 2002], we reparametrized our model so that each country *instantaneously* adjusts to income.

Figure 2
OECD Per Capita Oil Consumption and Income]



MEAN-GROUP ESTIMATION

The mean-group estimator is the least restrictive of all estimations we consider. Model (8) is estimated independently for each country via ordinary least squares. The country-specific regression estimates for the mean-group model are listed in Table 5.

The estimated (instantaneous) income elasticity of .636 is quite plausible. Further, the long-run adjustment parameter, ϕ =-.23, indicates oil demand moves toward long-run equilibrium at a rate of 23% per year. Note the estimated price elasticities are not statistically different from zero. In fact, since the price coefficients are so imprecisely estimated, the hypothesis of price symmetry is not rejected[5]. These results exemplify the reason researchers pool data, if possible: there is not enough intra-country data variation for precise parameter estimates.

[5] The test yields a χ^2_2 statistic of 1.02. The corresponding p-value is .600.

Table 1
OECD Country Mean Statistics

Country	Oil Consumption	Real GDP (2006$)	Population
Australia	31.62	20,230.15	16,316,271.49
Austria	11.34	20,564.82	7,765,886.91
Belgium	27.86	19,128.36	9,973,123.17
Canada	81.78	20,777.17	26,935,737.46
Denmark	12.23	21,876.40	5,164,047.06
Finland	11.21	17,669.87	4,929,411.46
France	98.27	19,723.86	57,294,371.77
Germany	136.82	19,797.17	79,676,279.66
Greece	14.18	11,992.03	9,905,299.89
Hungary	8.65	9,318.39	10,419,609.57
Iceland	0.68	20,032.92	247,243.20
Ireland	5.70	14,418.69	3,487,859.20
Italy	93.74	17,764.94	56,570,715.43
Japan	241.96	18,751.73	119,837,178.57
Korea, South	51.47	8,755.94	41,245,183.86
Mexico	58.44	6,874.63	79,701,564.94
Netherlands	37.16	20,271.80	14,718,023.54
New Zealand	4.94	17,551.91	3,377,838.74
Norway	9.13	23,651.83	4,215,137.60
Poland	16.00	6,506.01	36,741,996.60
Portugal	10.47	12,248.06	9,850,355.97
Spain	51.66	14,486.69	38,186,561.03
Sweden	20.20	20,303.75	8,526,435.06
Switzerland	12.63	25,252.59	6,769,738.29
Turkey	20.82	4,424.15	52,663,862.60
United Kingdom	85.84	18,683.08	57,450,871.43
United States	806.49	25,780.08	246,064,078.23
Overall	72.64	16,919.89	37,334,617.88

Table 2
Augmented Dickey–Fuller Unit Root Tests

Variable	*Z(t)*	*p*-value
$P_{max,t}$	-3.664	0.0047
$P_{rec,t}$	2.305	0.9990
$P_{cut,t}$	0.092	0.9655

critical values 1%: -3.689, 5%: -2.975, 10%: -2.619

Table 3
Im, Pesaran, and Shin Panel Unit Root Tests

Variable	W_{tbar}	*p*-value
y_1	-1.0459	0.1478
oil_t	-.5601	0.2877

demeaned, trend included lag lengths chosen via AIC

Table 4
Estimation Results

	Dynamic Fixed Effects	Mean Group	Pooled Mean Group
EC_1	-0.0467***	-0.230***	-0.0770***
	(0.00801)	(0.0366)	(0.00761)
$\Delta P_{max,t}$	-0.0254***	-0.00556	-0.0153*
	(0.00815)	(0.00866)	(0.00852)
$\Delta P_{rec,t}$	0.0158	-0.00316	-0.00041
	(0.0198)	(0.0116)	(0.0162)
$\Delta P_{cut,t}$	0.00142	0.00298	0.000864
	(0.0154)	(0.0208)	(0.015)
Δy_t	0.524***	0.636***	0.661***
	(0.0613)	(0.0958)	(0.095)
$P_{max,t}$	-0.779***	-0.471	-0.464***
	(0.16)	(0.352)	(0.0766)
$\Delta P_{rec,t}$	-0.556***	-0.182	-0.223**
	(0.214)	(0.137)	(0.0882)
$P_{cut,t}$	-0.532***	-0.273	-0.267***
	(0.147)	(0.198)	(0.0668)
$constant$	-0.493***	-2.974***	-0.897***
	(0.109)	(0.489)	(0.0875)
Observations	918	918	918
R-squared	0.26		
Number of groups	27		

Table 5
Mean-Group Model Estimates

Country	EC_t	$P_{max,t}$	$P_{rec,t}$	$P_{cut,t}$	$\Delta P_{max,t}$	$\Delta P_{prec,t}$	$\Delta P_{cut,t}$	ΔGDP_t	constant
Australia	-0.0874	-0.343	-0.424	-0.353	0.0456*	0.0417	0.00709	0.252	-1.051
	(0.109)	(0.461)	(0.792)	(0.605)	(0.0275)	(0.0618)	(0.0492)	(0.358)	(1.434)
Austria	-0.289*	-0.131	0.267*	0.0723	-0.0449	-0.08	-0.0659	0.397	-3.743*
	(0.161)	(0.125)	(0.139)	(0.0811)	(0.0413)	(0.0975)	(0.0707)	(0.459)	(2.211)
Belgium	-0.163	-0.352*	0.311	-0.0464	-0.0612	0.0884	-0.119*	0.795*	-1.909
	(.112)	(0.203)	(0.228)	(0.166)	(0.0422)	(0.0892)	(0.0677)	(0.437)	(1.398)
Canada	0.0141	1.661	0.83	1.92	0.0313	-0.0181	0.0388	0.853***	0.232
	(.0993)	(11.7)	(4.614)	(12.13)	(0.0246)	(0.0589)	(0.0465)	(0.242)	(1.25)
Denmark	-0.0936	-0.401	-0.532	-0.326	-0.0171	-0.0357	0.096	0.932**	-1.094
	(.0903)	(0.29)	(0.822)	(0.61)	(0.0447)	(0.1)	(0.0791)	(0.411)	(1.087)
Finland	-0.335*	-0.111	0.0695	0.116	-0.0482	0.0708	-0.0501	0.213	-4.165
	(0.197)	(0.103)	(0.129)	(0.0814)	(0.0437)	(0.0969)	(0.0774)	(0.244)	(2.564)
France	-0.112	-0.572	-0.162	-0.187	-5.09E-05	0.00234	-0.00015	1.143**	-1.263
	(0.0848)	(0.442)	(0.368)	(0.329)	(0.0312)	(0.075)	(0.0541)	(0.446)	(1.111)
Germany	-0.172	-0.175	0.0311	-0.00486	-0.00735	-0.0788	-0.0459	1.482***	-2.188
	(0.105)	(0.127)	(0.164)	(0.103)	(0.0296)	(0.0699)	(0.0518)	(0.359)	(1.388)
Greece	-0.113	-0.125	-0.434	-0.343	-0.00277	0.164***	0.0668	0.704***	-1.483
	(0.0967)	(0.284)	(0.553)	(0.257)	(0.0294)	(0.0622)	(0.0471)	(0.231)	(1.394)
Hungary	-0.310**	0.0721	-0.141	0.138	-0.0357	0.0436	0.059	0.184	-4.349*
	(0.149)	(0.115)	(0.151)	(0.0881)	(0.0456)	(0.108)	(0.0842)	(0.281)	(2.22)
Iceland	-0.378**	-0.205*	-0.0617	-0.196	-0.00113	0.0164	0.196	-0.308	-4.573**
	(0.159)	(0.107)	(0.225)	(0.145)	(0.0816)	(0.181)	(0.14)	(0.434)	(2.015)
Ireland	-0.188**	-0.337	0.810**	0.272	0.0876	-0.0251	-0.388***	1.669***	-2.350**
	(0.0868)	(0.213)	(0.319)	(0.214)	(0.0546)	(0.135)	(0.11)	(0.508)	(1.177)
Italy	-0.220**	-0.177**	-0.162	-0.125	-0.00146	0.00364	0.0278	0.737***	-2.792**
	(0.0992)	(0.0867)	(0.126)	(0.0904)	(0.0217)	(0.0455)	(0.0355)	(0.222)	(1.316)

Japan	-0.136*	-0.418*	-0.495	-0.446	0.0454	-0.00531	0.0756	0.863**	-1.6
	(0.0794)	(0.251)	(0.391)	(0.313)	(0.0331)	(0.0748)	(0.057)	(0.343)	(1.03)
Korea, South	-0.0271	-0.68	-2.847	-2.216	-0.039	-0.137	0.152	1.144***	-0.313
	(0.0685)	(2.573)	(7.593)	(4.389)	(0.0521)	(0.136)	(0.109)	(0.311)	(1.077)
Mexico	-0.354***	0.282***	-0.0687	-0.0692**	-0.0467**	-0.00442	-0.00395	0.789***	-5.452***
	(0.0788)	(0.0217)	(0.0505)	(0.0309)	(0.0229)	(0.0417)	(0.0331)	(0.114)	(1.218)
Netherlands	-0.198	-0.24	0.325	0.0823	-0.0507	0.0146	-0.0776	0.916	-2.384
	(0.145)	(0.167)	(0.285)	(0.167)	(0.053)	(0.123)	(0.088)	(0.704)	(1.824)
New Zealand	-0.325**	-0.201***	-0.0325	-0.188**	-0.0304	-0.0211	0.0587	-0.546	-4.146**
	(0.128)	(0.0712)	(0.131)	(0.0897)	(0.0437)	(0.0921)	(0.0741)	(0.349)	(1.702)
Norway	-0.404**	-0.00323	-0.0928	-0.0476	-0.0747**	0.0286	0.0493	0.744*	-5.283**
	(0.16)	(0.0379)	(0.089)	(0.0529)	(0.0355)	(0.084)	(0.0649)	(0.434)	(2.092)
Poland	0.0435	0.213	-0.255	-0.382	-0.00552	0.0132	-0.0262	0.910***	0.688
	(0.0958)	(0.436)	(1.453)	(1.314)	(0.0349)	(0.0864)	(0.0691)	(0.182)	(1.487)
Portugal	-0.473***	0.075	0.0737	-0.190**	0.0101	-0.0999	0.0143	0.0646	-6.785***
	(0.173)	(0.0645)	(0.132)	(0.0796)	(0.0569)	(0.143)	(0.107)	(0.403)	(2.541)
Spain	-0.0517	-0.63	0.0584	-0.4	0.0361	-0.0374	0.0608	0.564	-0.576
	(0.124)	(1.927)	(1.226)	(1.393)	(0.0396)	(0.102)	(0.0718)	(0.528)	(1.768)
Sweden	-0.225	-0.204	0.0559	0.158	-0.00317	-0.0433	0.015	0.299	-2.706
	(0.156)	(0.129)	(0.242)	(0.169)	(0.0555)	(0.132)	(0.0985)	(0.564)	(1.921)
Switzerland	-0.618***	-0.0833***	-0.00506	0.0436	-0.0218	-0.00363	-0.137**	0.427	-7.910***
	(0.173)	(0.0295)	(0.0556)	(0.0335)	(0.0394)	(0.0811)	(0.0631)	(0.268)	(2.263)
Turkey	-0.231**	-0.123	-0.158	-0.213*	-0.0317	0.0271	0.0396	0.675***	-3.333*
	(0.111)	(0.151)	(0.193)	(0.117)	(0.0401)	(0.0979)	(0.0779)	(0.212)	(1.719)
United King-dom	-0.768***	-0.150***	-0.0571	-0.0138	0.124**	-0.0336	0.0746	0.211	-9.823***
	(0.165)	(0.0268)	(0.0571)	(0.0352)	(0.0507)	(0.103)	(0.081)	(0.512)	(2.118)
United States	-0.00358	-9.371	-1.822	-4.428	-0.00627	0.0231	-0.0372	1.058***	0.0515
	(0.0696)	(182.2)	(37.87)	(88.3)	(0.0183)	(0.0405)	(0.0313)	(0.175)	(0.873)

Standard errors are listed in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

POOLED-MEAN GROUP ESTIMATION

Table 4 lists results of the pooled mean-group estimator for model (8). In this context, the PMG estimator allows for heterogeneous short-run dynamics and common long-run price elasticities. The first equation presents the normalized cointegrating vector[6]. The country-specific estimates are listed in Table 6.

Referring to Table 4, the pooled mean-group estimated precisely. The long-run price elasticities are significantly negative. The estimated long-run price effect is asymmetric. The test of price symmetry is $\chi^2_2 = 17.91$, with p-value <0.001. Results indicate demand responds equally to price recoveries and price cuts, but is twice as responsive to a new historical maximum price (comparing -.223, -.267, and -464, respectively). The average long-run income elasticity (0.661) is significant, correctly signed, and in line with previous studies.

A serious potential problem exists, however, with the pooled mean-group estimation. Since the model includes a lagged-dependent variable, there is a possibility of endogeneity bias in the parameter estimates. The existence of such an endogeneity problem is tested via the familiar Hausman test. In this context the mean-group estimator is consistent under both the null and alternative hypotheses. The pooled mean-group estimator is efficient under the null, but is inconsistent under the alternative. The Hausman test statistic is 1.62 with a p-value of 0.6552 which rejects the presence of endogeneity bias at the traditional levels of significance. This was to be expected since, in fact, the parameter estimates did not change much between procedures but the precision increased dramatically.

DYNAMIC FIXED EFFECTS

We can further restrict the parameters by imposing complete parameter homogeneity. Recall the pooled mean-group estimator restricted long-run price responses and speed of adjustment to be equal across countries yet allowed for country-specific income responses and short-run adjustments. Under dynamic fixed effects all parameters are assumed equal across all countries. If dynamic fixed effects does not result in model misspecification, there are two advantages in such a specification. Firstly, dynamic fixed effects results in a parsimonious model, which is always preferred. Secondly, if we expect OECD countries to be a homogeneous group modelling as such is aligned with our prior.

Table 6
Pooled Mean-Group Estimates

Country	EC_t	$P_{max,t}$	$P_{rec,t}$	$P_{cut,t}$	$\Delta P_{max,t}$	$\Delta P_{prec,t}$	$\Delta P_{cut,t}$	ΔGDP_t	constant
Australia	-0.0705***	-0.464***	-0.223**	-0.267***	0.0423*	0.0472	-0.0207	0.316	-0.818***
	(0.0225)	(0.0766)	(0.0882)	(0.0668)	(0.023)	(0.0467)	(0.0363)	(0.299)	(0.266)
Austria	-0.106***	-0.464***	-0.223**	-0.267***	-0.0513	-0.022	-0.0231	0.281	-1.237***
	(0.0334)	(0.0766)	(0.0882)	(0.0668)	(0.0363)	(0.0745)	(0.0562)	(0.408)	(0.404)
Belgium	-0.0895**	-0.464***	-0.223**	-0.267***	-0.0845**	0.174**	-0.1000*	0.713*	-1.011**
	(0.0397)	(0.0766)	(0.0882)	(0.0668)	(0.0343)	(0.0719)	(0.0549)	(0.407)	(0.447)
Canada	-0.0568***	-0.464***	-0.223**	-0.267***	0.0274	0.0257	0.0315	0.758***	-0.641***
	(0.0203)	(0.0766)	(0.0882)	(0.0668)	(0.0211)	(0.045)	(0.0356)	(0.211)	(0.228)
Denmark	-0.0731**	-0.464***	-0.223**	-0.267***	-0.0184	-0.0687	0.0769	1.001***	-0.849**
	(0.0299)	(0.0766)	(0.0882)	(0.0668)	(0.0372)	(0.0773)	(0.0594)	(0.346)	(0.339)
Finland	-0.0815***	-0.464***	-0.223**	-0.267***	-0.0452	-0.0238	0.0182	0.203	-0.919**
	(0.0316)	(0.0766)	(0.0882)	(0.0668)	(0.0378)	(0.0778)	(0.0603)	(0.228)	(0.364)
France	-0.112***	-0.464***	-0.223**	-0.267***	0.00813	-0.0543	0.0359	1.431***	-1.316***
	(0.0254)	(0.0766)	(0.0882)	(0.0668)	(0.0258)	(0.0552)	(0.0416)	(0.359)	(0.31)
Germany	-0.0684***	-0.464***	-0.223**	-0.267***	-0.016	-0.0708	-0.036	1.480***	-0.818***
	(0.024)	(0.0766)	(0.0882)	(0.0668)	(0.0232)	(0.0501)	(0.0387)	(0.286)	(0.285)
Greece	-0.0755***	-0.464***	-0.223**	-0.267***	-0.0228	0.159***	0.0312	0.476***	-0.875***
	(0.0172)	(0.0766)	(0.0882)	(0.0668)	(0.0244)	(0.0473)	(0.036)	(0.173)	(0.21)
Hungary	-0.0590**	-0.464***	-0.223**	-0.267***	0.023	-0.171*	0.153**	0.352	-0.709**
	(0.0267)	(0.0766)	(0.0882)	(0.0668)	(0.0438)	(0.0935)	(0.0738)	(0.279)	(0.331)
Iceland	-0.182***	-0.464***	-0.223**	-0.267***	-0.0571	0.151	0.0983	-0.648*	-1.992**
	(0.0692)	(0.0766)	(0.0882)	(0.0668)	(0.068)	(0.143)	(0.106)	(0.352)	(0.789)
Ireland	-0.0952**	-0.464***	-0.223**	-0.267***	0.0784	0.0616	-0.272***	1.411***	-1.178***
	(0.0377)	(0.0766)	(0.0882)	(0.0668)	(0.0487)	(0.115)	(0.0838)	(0.378)	(0.443)
Italy	-0.0880***	-0.464***	-0.223**	-0.267***	-0.0164	-0.00382	0.000772	0.857***	-1.035***
	(0.021)	(0.0766)	(0.0882)	(0.0668)	(0.0176)	(0.0356)	(0.0277)	(0.191)	(0.26)
Japan	-0.134***	-0.464***	-0.223**	-0.267***	0.03	0.017	0.0297	0.749***	-1.543***
	(0.0319)	(0.0766)	(0.0882)	(0.0668)	(0.0262)	(0.0554)	(0.0442)	(0.255)	(0.387)

Korea, South	-0.0137	-0.464***	-0.223**	-0.267***	-0.0535	-0.144	0.082	1.240***	-0.158
	(0.0149)	(0.0766)	(0.0882)	(0.0668)	(0.0459)	(0.11)	(0.0767)	(0.251)	(0.182)
Mexico	-0.0148	-0.464***	-0.223**	-0.267***	0.0346	-0.0632	-0.0111	0.927***	-0.173
	(0.0131)	(0.0766)	(0.0882)	(0.0668)	(0.0224)	(0.0491)	(0.0391)	(0.145)	(0.164)
Netherlands	-0.0928*	-0.464***	-0.223**	-0.267***	-0.0602	0.0839	-0.0511	0.624	-1.050*
	(0.0486)	(0.0766)	(0.0882)	(0.0668)	(0.0418)	(0.0906)	(0.0672)	(0.59)	(0.549)
New Zealand	-0.105***	-0.464***	-0.223**	-0.267***	-0.0884**	0.0845	-0.0264	-0.36	-1.218**
	(0.0394)	(0.0766)	(0.0882)	(0.0668)	(0.0347)	(0.0747)	(0.0571)	(0.307)	(0.475)
Norway	-0.0208	-0.464***	-0.223**	-0.267***	-0.0935***	-0.0293	0.0433	0.945**	-0.25
	(0.0307)	(0.0766)	(0.0882)	(0.0668)	(0.0317)	(0.0696)	(0.0535)	(0.403)	(0.348)
Poland	-0.00026	-0.464***	-0.223**	-0.267***	0.00902	-0.0224	0.00665	0.861***	-0.00425
	(0.0241)	(0.0766)	(0.0882)	(0.0668)	(0.029)	(0.0657)	(0.0499)	(0.161)	(0.311)
Portugal	-0.0578	-0.464***	-0.223**	-0.267***	0.0174	-0.0427	-0.0524	0.271	-0.677
	(0.0361)	(0.0766)	(0.0882)	(0.0668)	(0.0523)	(0.129)	(0.0911)	(0.368)	(0.439)
Spain	-0.0428	-0.464***	-0.223**	-0.267***	0.0202	0.00539	0.0598	0.741*	-0.495
	(0.0284)	(0.0766)	(0.0882)	(0.0668)	(0.0327)	(0.0834)	(0.0559)	(0.45)	(0.334)
Sweden	-0.0622**	-0.464***	-0.223**	-0.267***	-0.0146	-0.0805	0.0503	0.33	-0.716**
	(0.0316)	(0.0766)	(0.0882)	(0.0668)	(0.0464)	(0.104)	(0.0734)	(0.492)	(0.356)
Switzerland	-0.0823**	-0.464***	-0.223**	-0.267***	-0.0629*	-0.0781	-0.0882	0.481*	-0.951**
	(0.0362)	(0.0766)	(0.0882)	(0.0668)	(0.0354)	(0.075)	(0.0582)	(0.288)	(0.424)
Turkey	-0.110***	-0.464***	-0.223**	-0.267***	-0.0356	0.0393	0.000122	0.727***	-1.426***
	(0.0258)	(0.0766)	(0.0882)	(0.0668)	(0.0338)	(0.077)	(0.0577)	(0.182)	(0.352)
United Kingdom	-0.120**	-0.464***	-0.223**	-0.267***	0.0146	-0.00573	0.00576	0.64	-1.427**
	(0.0598)	(0.0766)	(0.0882)	(0.0668)	(0.0467)	(0.0976)	(0.0759)	(0.535)	(0.706)
United States	-0.0652***	-0.464***	-0.223**	-0.267***	0.00278	0.0208	-0.0184	1.044***	-0.736***
	(0.0168)	(0.0766)	(0.0882)	(0.0668)	(0.0146)	(0.0309)	(0.0242)	(0.15)	(0.193)
	-0.0622**	-0.464***	-0.223**	-0.267***	-0.0146	-0.0805	0.0503	0.33	-0.716**
	(0.0316)	(0.0766)	(0.0882)	(0.0668)	(0.0464)	(0.104)	(0.0734)	(0.492)	(0.356)

Table 4 lists results from dynamic fixed effects. Note all parameters of interest are correctly signed and significantly different from zero. The long-run price elasticities have increased in magnitude while the income elasticity has decreased in magnitude. Unlike the previous models, the hypothesis of price symmetry is not rejected at the 5% level[7]. The Hausman test statistic is 16.51 which a p-value of 0.0009. The test of parameter homogeneity across countries is rejected.

The associated p-value of 0.0009 for the Hausman specification test indicates the dynamic fixed effects model suffers from endogeneity bias. The bias is a result of the constraint that all OECD countries respond identically to income changes[8]. In other words, the Hausman test leads us to the conclusion that the assumption that OECD nations share the same short-run dynamics and long-run income elasticity is incorrect. Based on this, the dynamic fixed effects model is biased and the results should be discarded.

CONCLUSION

Using recently developed dynamic panel data techniques we estimated a non-structural demand model for OECD nations. According to our analysis, oil demand responds asymmetrically to price shocks. Specifically, we observed the demand is quite sensitive to new historical maximum prices yet only moderately sensitive to price recoveries and cuts. Unlike previous studies, we fail to reject that demand responds equally to price recoveries and price cuts. Our results indicate the long-run price elasticity for a price maximum is nearly twice as great (-.464) as for other price movements (approx. -0.25).

Original models we estimated, but not reported here, imposed the same speed of adjustment of oil demand to income shocks as to the price shocks. Doing so resulted in implausibly large income elasticities[9]. Following Gately and Huntington (2002), the results presented in this paper allow oil demand to adjust immediately to income shocks. The resulting estimated income elasticity is 0.66

For OECD nations over the period 1970–2004, we conclude all countries share a common long-run price elasticity and speed of adjustment to equilibrium. With respect to income, each nation responds immediately. Further, we reject the hypothesis of income elasticity homogeneity within our sample.

[7] The corresponding p-value is 0.0516.

[8] Recall Figure 2 to see why, in fact, that is unlikely.

[9] By implausible we mean greater than unity. We expect income elasticities for OECD countries to be bound between 0 and 1.

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