Applied Economics Letters, 2009, **16**, 803–807

Panel data model comparison for empirical saving-investment relations

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The Feldstein–Horioka puzzle has triggered a broad range of econometric specifications to investigate saving-investment (SI) relations. In this article, we attempt to determine a family of econometric models that is most suitable in explaining actual ratios of domestic investment to GDP via cross-validation techniques. Comparing between, pooled, time and country dependent specifications of the SI relation, the country dependent model is best performing. Moreover, error correction models formalizing adjustment dynamics of domestic investment ratios are markedly outperformed by static panel models. Supporting evidence for a cointegration relation between domestic saving and investment ratios is not found.

I. Introduction

The idea to learn about international capital mobility from saving and investment data remains appealing since it has been highlighted by Feldstein and Horioka (1980). By means of a between regression for OECD countries, Feldstein and Horioka (1980) document a strong correlation between ratios of domestic investment and saving to GDP, which is argued to be at odds with capital mobility. The so-called 'Feldstein Horioka puzzle' has provoked a lively discussion of the Saving-Investment (SI) relation. Numerous empirical specifications have been employed. Basically we can classify empirical models into three categories. Static models comprising basic panel specifications formalized to explain domestic investment ratios conditional on saving ratios constitute the first category. In this framework, for instance, time-dependent SI relations investigated by Sinn (1992) and country specific SI relations considered by Obstfeld (1986) are encountered. A second class of models is given in terms of first differences of domestic saving and investment ratios (Feldstein, 1983), which may be regarded as 'weakly dynamic'. More general dynamic patterns are formalized in a third set of empirical contributions comprising error correction models (ECMs) (Jansen, 1996). Although no consensus on a potential cointegration relation between saving and investment has been achieved yet, most recent empirical investigations for the SI relation adopt an ECM approach (e.g. Ho, 2002; Abbott and Vita, 2003; Özmen and Parmaksiz, 2003).

Given that the empirical literature on the SI relation comprises rather heterogenous econometric models it is surprising that the relative merits of competing model classes have not yet been provided in a systematic and comprehensive fashion. The major purpose of this article is to determine a family of econometric models that is most suitable in explaining actual investment ratios via Cross-Validation (CV) techniques (Allen, 1974).

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Applied Economics Letters ISSN 1350–4851 print/ISSN 1466–4291 online © 2009 Taylor & Francis
http://www.informaworld.com
DOI: 10.1080/13504850701221949

First, we undertake a systematic comparison of between, pooled, time dependent and country dependent specifications of the SI relation in static models. Second, we distinguish the scope of static and weakly dynamic models addressing the SI relation. This comparison is informative to uncover potential mean reverting features of the saving and investment ratio since differencing stationary time series will likely involve a loss in accuracy of fit. In the opposite case of nonstationary ratios, a model in first differences is suitable to guard against spurious regressions. Since taking first differences of investment ratios will also remove individual effects, this comparison sheds light on the prevalence of individual effects as a characteristic of investment ratios. Third, weakly dynamic models are contrasted against ECMs to distinguish cointegrating features from scenarios of independent stochastic trends governing the domestic saving and investment ratio.

Most empirical debates on the Feldstein–Horioka puzzle concentrate on one or two specific cross sections of time series data. As another contribution of this article, we investigate four specific cross sections and a general cross section (W97) sampled from all over the world. The latter is one of the largest cross sections that has been considered to analyse the SI relation. The four considered specific cross sections are major OECD members (O26), the Euro area (E11), nonEuro but OECD countries (E15) and less developed economies (L68). A list of the investigated economies is given in the Appendix. Annual data spanning the period 1971 to 2002 drawn from the World Development Indicators CD-Rom 2004 is analysed.

The remainder of the article is organized as follows: In the next Section we introduce the considered panel data models and model selection criteria. Empirical results obtained from the model comparison are provided in Section III. Section IV summarizes briefly our main findings and concludes.

II. Model Specifications and Selection

An unrestricted static representation of the relationship between domestic investment and saving may be given as

$$I^*_{it} = a_{it} + b_{it}S^*_{it} + u_{it}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T \tag{1}$$

where $I^*_{it} = I_{it}/Y_{it}$ and $S^*_{it} = S_{it}/Y_{it}$, with I_{it}, S_{it} and Y_{it} denoting gross domestic investment, gross domestic saving and gross domestic product (GDP) in time period t and country i, respectively. To implement the relation in (1) empirically, we consider pooled, between, time and cross section specific regression:

$$\begin{aligned}
\text{pol}: &\quad I^*_{it} = a + bS^*_{it} + u_{it},\\
\text{bet}: &\quad \overline{I^*_i} = a + b\overline{S^*_i} + \overline{u}_i,\\
\text{tim}: &\quad I^*_{it} = a_t + b_tS^*_{it} + u_{it},\\
\text{cro}: &\quad I^*_{it} = a_i + b_iS^*_{it} + u_{it},
\end{aligned}$$

where $\overline{I^*_i} = 1/T\sum_{t=1}^{T} I^*_{it}$ and $\overline{S^*_i} = 1/T\sum_{t=1}^{T} S^*_{it}$. Apart from general static models as formalized in (1), SI relations can be considered in 'weakly dynamic' models as

$$\Delta I^*_{it} = c_{it} + d_{it}\Delta S^*_{it} + v_{it} \tag{2}$$

where Δ is the first difference operator, e.g. $\Delta I^*_{it} = I^*_{it} - I^*_{i,t-1}$. As when implementing (1) we will provide CV measures for pooled, between, time and cross section specific regressions of ΔI^*_{it} on ΔS^*_{it}. In a further step we specify a set of ECMs comprising

$$\begin{aligned}
\text{ecm1}: &\quad \Delta I^*_{it} = \gamma_i + \alpha_i(I^*_{i,t-1} - \beta_i S^*_{i,t-1}) + \eta_i\Delta S^*_{it} + w_{it},\\
\text{ecm2}: &\quad \Delta I^*_{it} = \gamma_i + \alpha_i(I^*_{i,t-1} - S^*_{i,t-1}) + \eta_i\Delta S^*_{it} + w_{it},\\
\text{ecm3}: &\quad \Delta I^*_{it} = \gamma_i + \alpha_i(I^*_{i,t-1} - S^*_{i,t-1}) + w_{it}.
\end{aligned}$$

All the ECM specifications formalize cross sectional parameter dependence since CV criteria estimated for the model class in (2) will show that time dependence is likely not an important feature of the parametric description of ΔI^*_{it}.

To discriminate panel based estimators at an aggregated level we use the following CV criterion:

$$cv = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}\left|I^*_{it} - \hat{I}^*_{it}\right| \tag{3}$$

where 'forecasts' $\hat{I}^*_{it}$ are based on so-called leave one out or jackknife estimators.[1] Note that opposite to in-sample fitting out-of-sample criteria are not trivially affected by the dimension of a models' parameter space.

III. Results

The panels A, B and C of the Table 1 show CV estimates for models specified in levels and first differences and ECMs, respectively. Apart from

[1] Apart from model comparison by means of absolute forecast errors we also consider CV criteria derived from squared forecast errors. The results are similar as those from (3).

giving raw CV measures (cv) we also show scale invariant normalized results ($\widetilde{cv}$). For the purpose of normalization, CV estimates from cross section specific model formalizations are set to unity. All models describing ΔI^*_{it} share the same benchmark model for normalization such that an immediate contrasting of 'weakly dynamic' models as (2) and ECMs is feasible.

Static panel models

Concentrating on the model family (1) the overall evidence is that country specific panel models provide the most suitable framework to investigate the SI relation. This model class uniformly yields smallest CV estimates over all cross sections. For the largest cross section (W97) we find that all remaining modelling approaches perform similarly poor in comparison with cross section specific modelling. It turns out that the second best model, time specific regressions, is about 40% in excess of the corresponding estimates obtained from cross section specific regressions. The results are also remarkable in the sense that time dependent regressions which allow a relatively large number of model parameters, namely 64 ($T = 32$), perform similar to the highly restricted pooled regression models encountering only two parameters. With regard to the relative performance of cross section specific regressions against between regressions, CV estimates for the latter are between 16% (O15) and 69% (E11) worse.

Static vs. weakly dynamic models

Similarly, for weakly dynamic model families cross section specific model formalizations uniformly

Table 1. Panel model comparison

	cv	$\widetilde{cv}$	cv	$\widetilde{cv}$	Model	cv	$\widetilde{cv}$
Model	A: Static		B: Dynamic			C: ECM	
W97							
bet	4.46	1.40	6.18	1.45	ecm1	5.74	1.34
pol	4.47	1.41	5.94	1.39	ecm2	5.90	1.38
tim	4.44	1.40	6.50	1.52	ecm3	5.40	1.26
cro	3.17	1.00	4.27	1.00			
L68							
bet	4.96	1.38	6.65	1.33	ecm1	6.84	1.36
pol	4.98	1.39	6.39	1.27	ecm2	6.90	1.38
tim	5.04	1.40	7.16	1.43	ecm3	6.06	1.21
cro	3.59	1.00	5.02	1.00			
O26							
bet	2.87	1.38	3.33	1.41	ecm1	3.02	1.29
pol	2.87	1.38	3.09	1.31	ecm2	3.53	1.50
tim	2.66	1.28	3.31	1.41	ecm3	3.85	1.64
cro	2.08	1.00	2.35	1.00			
O15							
bet	2.51	1.16	3.72	1.43	ecm1	3.54	1.36
pol	2.52	1.17	3.80	1.46	ecm2	4.12	1.59
tim	2.62	1.21	4.81	1.85	ecm3	4.27	1.64
cro	2.16	1.00	2.60	1.00			
E11							
bet	3.30	1.69	3.02	1.49	ecm1	2.32	1.15
pol	2.94	1.51	2.90	1.44	ecm2	2.72	1.35
tim	2.72	1.39	3.52	1.74	ecm3	3.28	1.62
cro	1.96	1.00	2.02	1.00			

Notes: The table shows absolute (cv) and normalized ($\widetilde{cv}$) CV estimates. In panels A (models in levels) and B (models in first differences), the considered implementations of panel models are the between (bet), pooled (pol), time (tim) and cross section specific (cro) regression. Smallest CV estimates are normalized to unity. With regard to models in first difference we compute CV criteria for the level of the investment ratio using the model family in (2) and recursive forecasts $\hat{I}^*_{it-1}, t = 2, \ldots, T$, initialized with the first observation I^*_{i1}. Results obtained in Panel C are for the ECMs where the CV estimates are normalized in the way that the corresponding CV estimates for the cross-section dependent regression in first differences is equal to unity.

outperform the remaining panel based estimation schemes. Furthermore, CV estimates are clearly in favour of a specification explaining the investment ratio rather than its changes. Cross section specific panel approaches to changes of the investment ratio yield CV estimates that are between 3% (E11) and 40% (L68) worse than corresponding statistics obtained for the level representation.

Weakly dynamic vs. error correction models

Although model representations of changes of the investment ratio have been outperformed by level representations it is still interesting to address the issue of potential error correction dynamics. Comparing normalized CV estimates ($\widetilde{cv}$) in Panels B and C of Table 1, we find that none of the cross section specific ECM versions closely approaches the corresponding 'weakly dynamic' model $\Delta I_{it} = c_i + d_i \Delta S^*_{it} + v_{it}$. Overall CV estimates obtained from cross section specific ECMs are between 15% (E11, model ecm1) and 64% (O26 and O15, model ecm3) larger than the benchmark presuming absence of error correction dynamics. The latter results are at odds with a presumption of cointegration linking the ratios of domestic saving and investment over GDP. In case of cointegration just regressing ΔI^*_{it} on ΔS^*_{it} would suffer from statistical inefficiency owing to the neglection of the long run equilibrium relationship.

IV. Conclusion

In this article we investigate the relation between domestic saving and investment for five cross sections covering the sample period 1971 to 2002. CV criteria are applied to compare different specifications of the SI relation. From static model performance we derive that the best performing parametric description of the SI relation is cross section specific. As such, SI relations might be also subject to other country specific economic conditions and policies than global or cross sectional capital mobility. Contrasting static and weakly dynamic model formalizations we find no hint at the necessity of a weakly dynamic model specification. This evidence might be due to individual effects governing investment ratios. Moreover, adding an error correction term in dynamic models does not improve model performance. Supporting evidence for a cointegration relation between domestic saving and investment ratios is not found. As an area of future research, it appears natural to investigate conditional features of the SI relation in the framework of static cross sectional model formalizations.

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Appendix

List of countries

- W97: Algeria; Argentina; Australia; Austria; Bangladesh; Barbados; Belgium; Benin; Botswana; Brazil; Burkina Faso; Burundi; Cameroon; Canada; Central African Republic; Chile; China; Colombia; Congo Dem. Rep.; Congo Rep.; Costa Rica; Denmark; Dominican Republic; Ecuador; Egypt Arab Rep.; El Salvador; Fiji; Finland; France; Gabon; Gambia; Germany; Ghana; Greece; Guatemala; Guyana; Haiti; Honduras; Hong Kong, China; Hungary; Iceland; India; Indonesia; Ireland; Israel; Italy; Ivory Coast; Jamaica; Japan; Kenya; Korea, Rep.; Kuwait;

Luxembourg; Madagascar; Malawi; Malaysia; Mali; Malta; Mauritania; Mexico; Morocco; Myanmar; Nepal; Netherlands; New Zealand; Niger; Nigeria; Norway; Pakistan; Paraguay; Peru; Philippines; Portugal; Rwanda; Saudi Arabia; Senegal; Singapore; South Africa; Spain; Sri Lanka; Suriname; Swaziland; Sweden; Switzerland; Syrian Arab Republic; Thailand; Togo; Trinidad and Tobago; Tunisia; Turkey; Uganda; United Kingdom; United States; Uruguay; Venezuela, RB; Zambia; Zimbabwe.

- O26: all OECD countries except Czech Republic, Poland, Slovak Republic and Luxembourg.
- L68: W97 minus O26, Luxembourg, Hong Kong (China) and Singapore.
- E11: Austria; Belgium; Finland; France; Germany; Greece; Ireland; Italy; Netherlands; Portugal; Spain.
- O15: O26 minus E11.