Output and Consumption in the Global Business Cycle, 1870-2006: A Dynamic Factor Approach*

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Abstract

This paper presents evidence on the international components of output and consumption since the 1870s, using dynamic factor techniques. We find that the overall explanatory power of international factors for national consumption levels has not increased since the 1870s, and lingers around thirty percent. This also holds true for most individual countries. International integration of output and consumption was strongest in the interwar period, substituting for earlier regional integration. Consistent with recent research on regionalization of business cycles, we find a slight reversal of this trend for the postwar period. Our research confirms the evidence on international consumption puzzles for historical periods, and casts doubt on the idea that the interwar years were a time of deglobalization.

Keywords: Globalization, Integration, Business Cycles, Common Components, Dynamic Factor Analysis

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1 Introduction

Has globalization been beneficial or harmful? One way to ask this question is to think of globalization as increased exposure to international shocks, or conversely, as increased international insurance against domestic shocks. Under full globalization, international shocks would fully pass through to national consumption levels. Macroeconomists have observed for some time that this is not fully the case, which gives rise to a set of macroeconomic puzzles (see Obstfeld and Rogoff, 2000).

Measurement of the international component of macroeconomic fluctuations is a major empirical issue in this context. Given the broad set of countries for which appropriate data are available, conventional VAR methods would face overparameterization problems, as would standard frequency domain approaches. For post-war data on output and consumption, Kose, Otrok, and Whiteman (2003), Kose, Otrok, and Prasad (2008) employed factor analysis to identify common components, and found that regional integration has dominated globalization. Barro and Ursúa (2008) examined international evidence on output and private consumption back to the 1870s to study the response of consumption to output shocks. Their preliminary findings suggest that consumption reacted rather strongly to output shocks when compared to the prediction of consumption asset pricing models. However, their methodology does not provide for measurement of multivariate cross-country effects of macroeconomic shocks on national consumption levels.

In this paper, we follow the dynamic factor approach set out in Kose, Otrok, and Whiteman (2003) and employ Dynamic Factor Analysis with suitable restrictions to identify common international components in the variation of output and consumption. Factor models establish a series of linear regressions from each individual time series on a common component. The latter is itself a latent variable and has to be estimated. Even in the simplest case where the regression coefficients, or factor loadings, and the factors themselves are normal distributed, this leads to nonstandard joint distributions. Our estimation approach is a Bayesian one. We employ Monte Carlo Markov chain (MCMC) techniques to infer the posterior distributions. This estimation approach is particularly robust under identifying restrictions on the factor loadings matrix, which would make maximum likelihood estimation computationally difficult.

The novelty of the paper is to take this type of analysis back to the 1870s, employing the collection of recent Historical National Accounts (HNA) data on national output and private consumption from Barro and Ursúa (2008). Data of this kind exist rest on extrapolations from narrow economic aggregates that can be more easily observed for historical periods than the broad aggregates required for GDP. Such extrapolations from narrow to big aggregates have been criticized for introducing excess volatility into reconstructed national accounts, see Romer (1986) for the case of the U.S. Evidence from factor techniques very similar to the ones in the present paper lends support to this criticism (see Ritschl, Sarferaz, and Uebele (2008) but confirms standard business cycle chronologies implicit in existing HNA estimates for the U.S. HNA estimates in international comparison must therefore be used with a caveat. However, our findings suggest that the impact of mismeasurement in the data is probably quite limited.

The rest of this paper is organized as follows. The next section briefly expounds the model and provides intuition on the estimation approach. Section 3 explains the identifying restrictions. Section 4 provides the main results. Section 5 concludes.

2 The Model

The goal of our analysis is to decompose the variation in each time series into one or more common components and an individual component. Dynamic Factor Analysis maps the unobserved common components of large panels of time series panels into synthetic series or factors. Under suitable identifying restrictions, these factors can be given a structural interpretation. This is achieved by restricting the coefficients, or factor loadings, to specific subsets of the series, e.g. regional groups.

Data Y_t span the cross section dimension N and an observation period of length T, and are assumed to be linked by the following observation equation:

$$Y_t = C + \Lambda f_t + U_t \tag{1}$$

Here, f_t is a $K \times 1$ vector containing the latent factors, U_t is a $N \times 1$ vector of series-specific idiosyncratic components, C is an $N \times 1$ vector of constant terms and Λ is the $N \times K$ coefficient matrix that kinks the K common factors to the i-th series. The law of motion for the latent factors or common components is a k-dimensional VAR with q lags:

$$f_t = \phi_1 f_{t-1} + \cdots + \phi_q f_{t-q} + v_t, \tag{2}$$

with $v_t \sim \mathcal{N}(0, \Sigma)$. The idiosyncratic components U_t are assumed to follow an AR(p) process:

$$U_t = \Theta_1 U_{t-1} + \ldots + \Theta_p U_{t-p} + \chi_t \tag{3}$$

where $\Theta_1, \ldots, \Theta_p$ are $N \times N$ diagonal matrices and $\chi_t \sim \mathcal{N}(0_{N\times 1}, \Omega_\chi)$ with

$$\Omega_\chi = \begin{bmatrix} \sigma_{1,\chi} & 0 & \cdots & 0 \\ 0 & \sigma_{2,\chi} & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{N,\chi} \end{bmatrix}$$

We *quasi difference* equation (1) . Accordingly we multiply equation (1) by $(\mathcal{I} - \Theta(L))$, where $\Theta(L) = \Theta_1 + \cdots + \Theta_p$ and $\mathcal{I}$ is the identity matrix. This leads to the more compact expression:

$$Y_t^* = C^* + \Lambda^* f_t + \chi_t, \tag{4}$$

where $Y_t^* = (\mathcal{I} - \Theta(L))Y_t$, $\Lambda^* = (\mathcal{I} - \Theta(L))\Lambda$ and $C^* = (\mathcal{I} - \Theta(L))C$.

Prior Specification

For the AR-Parameters of the idiosyncratic components $\Theta_1, \Theta_2, \ldots, \Theta_p$ we specified the following prior:

$$\theta^{prior} \sim \mathcal{N}(\underline{\theta}, \underline{V}_\theta)$$

where $\underline{\theta} = 0_{p\times 1}$ and

$$\left[\underline{V}_\theta\right] = \tau_1 \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & \frac{1}{2} & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \frac{1}{p} \end{bmatrix}$$

We choose $\tau_1 = 0.2$. The prior we specified implies that we punish more distant lags. This is applied by progressively decreasing the uncertainty about the mean prior belief that the parameters are zero for increasing lag values.
For each of the factor loadings we specified the following prior:

$$\lambda^{prior} \sim \mathcal{N}(\underline{\lambda}, \underline{V}_\lambda)$$

where $\underline{\lambda} = 0$ and $\underline{V}_\lambda = 100$. For each of the variances of the disturbances in χ_t we specified the following prior:

$$\sigma_\chi^{prior} \sim \mathcal{IG}\left(\frac{\alpha_\chi}{2}, \frac{\delta_\chi}{2}\right)$$

where we choose $\alpha_\chi = 6$ and $\delta_\chi = 0.001$, which implies a fairly loose prior. $\mathcal{IG}$ denotes the inverted gamma distribution.

For the parameters of the factor equation (2) we follow Bernanke, Boivin, and Eliasz (2005) and impose the Kadiyala and Karlsson (1997) Minnesota-type prior on the VAR parameters. Then, the prior distribution of the covariance matrix Σ and the VAR parameters Φ can be expressed by:

$$\Sigma_{prior} \sim \mathcal{IW}(\underline{\Sigma}, K+2),$$

with $\mathcal{IW}$ representing the inverse Wishart distribution and

$$vec(\Phi_{prior}) \sim \mathcal{N}(0, \Sigma_{prior} \otimes \underline{G}),$$

where $\underline{G}$ imposes less weight on more distant lags .

3 Identifying Restrictions

We specify two groups of factors, one international and common to all series, the others regional and mutually exclusive. This gives matrix Λ the following structure:

The transposed factor loading matrix Λ' then takes the form:

$$\begin{bmatrix} 1 & \lambda_2^w & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \lambda_N^w \\ 0 & 1 & \lambda_1^1 & \dots & \lambda_h^1 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ & & & & & 1 & \dots & \lambda^2 i & 0 & \cdots & 0 & 0 & 0 \\ \vdots & & & & & & & & & \cdots & \vdots & \vdots & \vdots \\ 0 & \dots & & & & & & & & & 1 & \dots & \lambda_j^k \end{bmatrix}_{[K\times N]} = \Lambda' \qquad (5)$$

This (transposed) matrix has K rows, equal to the number of factors, and N columns, equal to the number of data series. The first row includes the loadings on the world factor, which are nonzero for all series. Factor loadings for the regional factors in the rows below are identified by exclusion restrictions. To identify each factor, the coefficient on the first time series is set to be equal to unity. the first factor, however, loads on all series. For this factor to be identified, too, one series is exclusive to this factor, and thus does not form not part of any regional group.

4 Results

In this section we report the results from two specifications, chosen appropriately to deal with data limitations. In the Barro et al (2008) data set, series on both GDP and private consumption are available from 1870 for the U.S. and eleven European countries. Our first specification of the factor model is based on this narrow dataset. Data from 1875 are available for a wider group of countries. This wider dataset is the basis of our second specification[1].

For the first specification, the factor groupings are:

World Factor	=	{US GDP; all others}
Empire & Scand. Factor	=	{UK GDP; N; Dk; S; SF; UK Cons; US Cons.}
WCentr. Europe Factor	=	{D GDP; F; NL; CH; D Cons.}
Sth. Europe Factor	=	{I GDP; E; I Cons.}

By this choice of factors, we anchor the world factor to U.S. GDP. There is considerable comovement between this series and the "World" factor, which justifies this choice. The "Empire" factor is centered on UK output. Inclusion of Scandinavia in this factor is motivated by stronger comovement of these countries' activity with

[1]Consumption data for a significantly wider set of countries are only available for the postwar period.

the UK than with Germany, although the evidence is not very strong and this choice is somewhat arbitrary. The "West Central Europe" factor is identified by German GDP, while the "Southern Europe" factor is identified by Italian GDP. Again, these choices are to some extent arbitrary; experimenting with slight variations does not appear to alter the results.

From 1875, data are available for a wider set of countries, with 28 output and 15 consumption series. This gives rise to a second specification, with the following factor groupings:

World Factor	=	{US GDP; all others}
NW Europe Factor	=	{D GDP; N; Dk; S; SF; ICE GDP; UK; F; B GDP; NL; CH; A GDP; D Cons.}
Sth. Europe Factor	=	{I GDP; P GDP; E; HE GDP; I Cons.}
Asia Factor	=	{J GDP; AUS GDP; NZ GDP; Ind GDP; SL GDP; J Cons.}
America Factor	=	{ARG GDP; BZL GDP; CHL GDP; UR GDP; CDN; USA Cons.}

(The wider set of countries (for most of which we have output but lack consumption data back to 1875) allows us to specify factors for Asia and the Americas separately. As before, two factors are specified to group activity in Europe suitable, and again, the grouping is somewhat arbitrary.

Our main interest focuses on the variance decomposition of the observation equation (1):

$$Var(Y_i) = Var(\hat{Y}) + Var(\hat{u}_i)$$

where $Var(\hat{Y})$ is the part of the variance that is explained by the factors.

We estimated our specifications separately by three relevant subperiods, with the two World Wars as the obvious dividing lines. Table 1 reports summary results for the first specification.

(Table 1 about here)

Table 1 decomposes the variance of national output and consumption (measured in deviations from a HP 6.25 trend) into two common components (World and Regional) and one idiosyncratic, unexplained component. Detailed results are presented in Appendix Table A.1.

Results bear out several clear tendencies. First, the unexplained, idiosyncratic component of output is lower in the postwar period than in the prewar period. This would be consistent with globalization having made progress since the 1870s. The sames conclusion is also supported by a gradual increase in the explanatory share of the world factor for output. We also see, however, that international comovments of output reached their maximum, not in the postwar but actually in the interwar period. This is of course due to the strong common shock of the Great Depression. But it indicates that counter to popular perceptions, the interwar years were a period of high economic integration, at least with regard to the exposure to international risk.

As Table 1 also shows, national output on average is more responsive to international shocks than consumption: for every subperiod, the idiosyncratic component of its variance is lower than for the consumption series. This seems disturbing, as international diversification should reduce the exposure of consumption to idiosyncratic shocks relative to output. We also see that there is no clear downward trend in the idiosyncratic component of consumption. The impact of global fluctuations on consumption before 1913 as about as strong as it has been in the postwar period. Again, we also find that the internationalization of consumption was strongest in the interwar period. Clearly, consumption is less well integrated internationally than theory would predict. And there is no evidence of integration increasing over time.

We repeated this experiment with the wider dataset running from 1875 on. Table 2 provides summary results. Details are reported in Appendix Table A.2.

(Table 2 about here)

Again, the wider dataset bears out lower degrees of integration for consumption than for output: for consumption, the idiosyncratic component of the variance (which is not explained by international factors) is higher throughout than for output. The data also bear out the absence of a trend in the international component to both. Clearly, there is no increase in second-moment globalization in either output or consumption since the 1870s. We also find, again, that the interwar period saw more international comovement of output and consumption than both the prewar and the postwar.

5 Conclusion

This short paper has studied second-moment globalization of national output and consumption for a panel of countries since the 1870s. We followed the lead of Kose, Otrok, and Whiteman (2003) in using factor analysis to identify international and regional common components in the movement of national time series. We apply similar techniques to historical data panels of 12 and 25 countries put together by Barro and Ursúa (2008). The dynamic factor approach allows us to study the effects of variations in the common components on individual output and consumption series. We find only very weak evidence of increased international comovement of consumption and output. Counter to theoretical prediction, consumption is even less integrated internationally than output. We also observe that contrary to conventional wisdom, the interwar period comes out as one of high international integration, caused in no small part by the tremendous worldwide shock of the Great Depression. Our findings add a long-term dimension to the international macroeconomics puzzles identified by Obstfeld and Rogoff (2000).

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Table 1: Variance Decomposition of Output and Consumption, 24 series

		Avg-Y	Avg-C
Prewar	World	**0.131**	**0.097**
	Regional	**0.245**	**0.218**
	Idiosyncr	**0.565**	**0.685**
Interwar	World	**0.164**	**0.178**
	Regional	**0.417**	**0.281**
	Idiosyncr	**0.338**	**0.541**
Postwar	World	**0.196**	**0.168**
	Regional	**0.301**	**0.178**
	Idiosyncr	**0.475**	**0.654**

		Avg-Y	Avg-C
Interwar/Prewar	Int'l	**1.255**	**1.828**
	Regional	**1.701**	**1.289**
	Idiosyncr	**0.598**	**0.790**
Postwar/Interwar	Int'l	**1.199**	**0.947**
	Regional	**0.722**	**0.633**
	Idiosyncr	**1.405**	**1.208**
Postwar/Prewar	Int'l	**1.505**	**1.731**
	Regional	**1.229**	**0.816**
	Idiosyncr	**0.840**	**0.955**

Table 2: Variance Decomposition of Output and Consumption, 42 series

		Avg-Y	Avg-C
Prewar	World	**0.134**	**0.112**
	Regional	**0.166**	**0.199**
	Idiosyncr	**0.672**	**0.688**
Interwar	World	**0.263**	**0.202**
	Regional	**0.118**	**0.115**
	Idiosyncr	**0.616**	**0.683**
Postwar	World	**0.222**	**0.185**
	Regional	**0.083**	**0.113**
	Idiosyncr	**0.664**	**0.702**

		Avg-Y	Avg-C
Interwar/Prewar	Int'l	**2.322**	**1.973**
	Regional	**0.659**	**0.712**
	Idiosyncr	**0.877**	**0.917**
Postwar/Interwar	Int'l	**0.747**	**0.843**
	Regional	**0.852**	**0.704**
	Idiosyncr	**1.113**	**1.077**
Postwar/Prewar	Int'l	**1.733**	**1.663**
	Regional	**0.561**	**0.501**
	Idiosyncr	**0.975**	**0.988**