

# Asymmetric shocks among U.S. states

Marco Del Negro\*

Instituto Tecnológico Autónomo de México

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## Abstract

The paper uses a factor analysis model to study co-movements in non-durable consumption and output among the fifty U.S. states from 1969 to 1995. The paper finds that asymmetric shocks in output are, on average, large, i.e., of the same magnitude of U.S. business cycle fluctuations. Regional business cycles and state-specific shocks are equally important sources of asymmetries in output. Asymmetric shocks in consumption, excluding disturbances due to measurement error, are, on average, as large as asymmetric shocks to output, suggesting a lack of inter-state smoothing.

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\*Marco Del Negro, Centro de Investigación Económica, ITAM, Camino Sta. Teresa 930, Mexico D.F. 10700, Telephone: (+525) 628 4197, Fax: (+525) 628 4058, E-mail: delnegro@master.ster.itam.mx. The author acknowledges financial support from *ISFSE (CNR)*.

# 1 Introduction

Are intranational business cycles different from international business cycles? Is there more risk sharing within a country or among countries? The trend towards trade and capital market integration observed in the past twenty years makes these questions very relevant for international macroeconomics. Indeed, the study of intranational business cycles may shed light on the future patterns of international co-movements, assuming that such a trend will continue. As a result, a growing body of literature has investigated these questions since the beginning of the nineties.<sup>1</sup>

The policy implications of this literature are far reaching. If risk sharing is one of the beneficial effects of a global capital market, opening internal capital markets to foreign capital may increase macroeconomic stability in the long run. For Europe in particular, the comparison between an established monetary union (United States) and a nascent one (EMU) is often used as a tool to judge the likelihood of success of the latter.<sup>2</sup>

Hess and Shin (1998) provide an interesting study of intranational business cycles within the United States.<sup>3</sup> Using data on retail sales of non-durables for nineteen U.S. states from 1978 to 1992 they show that the so-called “quantity anomaly”, i.e., the finding that de-trended consumption is less correlated across countries than output (see Backus et al. 1992), holds true at the intranational level as well. This result is interpreted as evidence of lack of risk sharing among U.S. states, since under perfect risk sharing consumption should be perfectly correlated across states.

This paper represents a contribution to the study of intranational business cycles in the United States. The paper extends the analysis of Hess and Shin (1998) by expanding the data set both cross-sectionally and in the time dimension. Using a different source of data for consumption of non-durables the paper analyzes co-movements in per capita output and consumption for all fifty states from 1969 to 1995. The inclusion of thirty-one additional states changes the picture of inter-state co-movements, particularly in terms of output correlation, as these states are generally subject to more risk than the nineteen considered by Hess and Shin.

The paper uses a factor analysis model as a tool to study co-movements in output and consumption among U.S. states. The model is used to attribute fluctuations in consumption and output to national, regional, and state-specific business cycles. The factor analysis model offers a methodology for addressing issues of inter-state smoothing which has two advantages over the approaches adopted by the previous literature (see Asdrubali et al. 1996, Crucini 1998, Méltiz and Zúmer 1999). Firstly, the decomposition of consumption fluctuations in national, regional, and state specific business cycles can be helpful in identifying the sources of imperfect risk sharing. Secondly, the estimates from the factor analysis model contain information on the amount of smoothing for each state (unlike in the panel estimation of Asdrubali et al. and Méltiz and Zúmer), and at the same time are derived from a joint cross sectional analysis (unlike in Crucini).

The factor analysis model also presents an advantage over the analysis based on correlations. The study of cross correlations creates serious limitation, especially when applied to state level data. Given that consumption data is likely to be measured with error, cross-state consumption correlations may be low for reasons other than lack of risk sharing. This paper makes an attempt to isolate the effect of measurement error, as it uses the factor model to separate those shocks to consumption that are due to national, regional, or state-specific business cycles from those that are purely idiosyncratic and presumably reflect measurement error or preference shocks.

The paper focuses on asymmetric shocks, that is, shocks that affect consumption and output in a given state differently than the aggregate. Contrary to the results of previous work on inter-state smoothing, the paper finds little evidence that asymmetric shocks to output are smoothed across U.S. states. This result is mainly due to the lack of smoothing with respect to regional business cycle shocks.

Finally, the paper shows that asymmetric shocks to output and consumption within U.S. states are roughly of the same magnitude of U.S. business cycle fluctuations. A comparison with the European case shows that asymmetric shocks in Europe are on average of smaller magnitude. This finding goes against the conventional wisdom.

The remaining of the paper is as follows. Section 2 discusses the model. Section 3 illustrates the data. Section 4 describes some features of inter-state business cycles, while section 5 focuses on the “quantity anomaly”, and section 6 provides a comparison with Europe. Section 7 concludes.

## 2 The model

The factor analysis model considered here differs from the standard factor analysis model due to the restrictions imposed in order to identify the model. The restrictions are as follows: for each state, de-trended output and consumption are assumed to depend on a national factor (U.S. business cycle), on a regional factor (regional business cycle), on a state-specific factor (state-specific business cycle). In addition, consumption fluctuations depend on a purely idiosyncratic component, which reflects preference shocks and/or measurement error. The identification restrictions therefore consist of a set of zero restrictions on the matrix of coefficients: the impact of a regional business cycle shock in a given region is constrained to be zero for states which do not belong to that region, and the impact of a state-specific shock on the consumption or output of other states is also zero by assumption.<sup>4</sup> This set of restrictions based on geographic proximity may not necessarily be the best one: one can think of grouping different states on the basis of different criteria, such as the productive structure, or the level of income (see Sørensen and Yosha 1997b). However, geographic proximity may in some cases be a proxy for some of these features, as geography plays an important role in defining the productive structure of a given area (see Krugman 1991).

The model can be described as follows. Let the variables  $c_{it}$  and  $y_{it}$  represent de-trended and de-measured per capita consumption and output for state  $i$  in period  $t$  ( $i = 1, \dots, n$ ,  $t = 1, \dots, T$ ). If state  $i$  belongs to region  $r$  ( $r = 1, \dots, \bar{r}$ ),  $c_{it}$  and  $y_{it}$  are affected by the nation wide shock  $f_t^{us}$ , by the regional shock  $f_t^r$ , and by the state-specific shock  $f_t^i$ . In addition, consumption is affected by a purely idiosyncratic shock. Consumption and output in each state can be affected differently by national, regional, and state specific-shocks, i.e., the exposures are not constrained to be the same. Formally, the

model is as follows:

$$\begin{aligned}
 y_{it} &= \beta_{yi}^{us} f_t^{us} + \sum_{r=1}^{\bar{r}} \beta_{yi}^r f_t^r + \sum_{j=1}^n \beta_{yi}^j f_t^j \\
 c_{it} &= \beta_{ci}^{us} f_t^{us} + \sum_{r=1}^{\bar{r}} \beta_{ci}^r f_t^r + \sum_{j=1}^n \beta_{ci}^j f_t^j + \varepsilon_{it},
 \end{aligned} \tag{1}$$

where

$$\begin{aligned}
 \beta_{yi}^r &= \beta_{ci}^r = 0 \text{ if state } i \text{ does not belong to region } r \\
 \beta_{yi}^j &= \beta_{ci}^j = 0 \text{ for all } j \neq i.
 \end{aligned} \tag{2}$$

The model does not allow for measurement error in output. The state-specific factor indeed coincides with the shocks to output in state  $i$ , after taking into account national and regional business cycle shocks. This assumption is made because with only two observations for each state (consumption and output) it is not possible to separately identify state-specific and idiosyncratic shocks in output. Furthermore, for reasons discussed in section 3 it is likely that measurement error in consumption is larger in relative terms than measurement error in output.<sup>5</sup>

The factors are by construction uncorrelated with each other and with the idiosyncratic shocks, and the idiosyncratic shocks are also uncorrelated with each other:

$$\begin{aligned}
 E[f_t^{us} f_t^r] &= E[f_t^{us} f_t^i] = E[f_t^{us} \varepsilon_{it}] = 0, \\
 E[f_t^r f_t^s] &= E[f_t^r f_t^i] = E[f_t^r \varepsilon_{it}] = 0, \\
 E[f_t^i f_t^j] &= E[\varepsilon_{it} \varepsilon_{jt}] = 0,
 \end{aligned} \tag{3}$$

for all  $t$ , all  $r$ , all  $i$ , all  $s \neq r$ , all  $j \neq i$ . It is also assumed, as in the standard factor analysis model, that all variables are normally distributed. In particular, for all  $t$ ,  $r$ , and  $i$ ,

$$f_t^{us} \rightarrow N(0, 1), f_t^r \rightarrow N(0, 1), f_t^i \rightarrow N(0, 1), \varepsilon_{it} \rightarrow N(0, \phi_i^2), \tag{4}$$

Note that the assumption that factors have unitary variance is purely a normalization assumption: the different variances of U.S., regional, and state-specific business cycles are reflected in the different magnitudes of the parameters  $\beta$ 's. The maximum likelihood estimates of the model (1) can be found using the EM algorithm (see Del Negro 1998b).

Using the factor analysis model, one can decompose asymmetric shocks to output and consumption in a given state into four components: differences in the exposure to the U.S. business cycle shocks, regional shocks, state specific shocks, and purely idiosyncratic shocks:

$$\begin{aligned} y_{it} - y_t^{us} &= (\beta_{yi}^{us} - \beta_{y,us}^{us})f_t^{us} + \sum_{r=1}^{\bar{r}} (\beta_{yi}^r - \beta_{y,us}^r)f_t^r + \beta_{yi}^i f_t^i, \\ c_{it} - c_t^{us} &= (\beta_{ci}^{us} - \beta_{c,us}^{us})f_t^{us} + \sum_{r=1}^{\bar{r}} (\beta_{ci}^r - \beta_{c,us}^r)f_t^r + \beta_{ci}^i f_t^i + \varepsilon_{it}. \end{aligned} \quad (5)$$

where  $\beta_{y,us}^{us}$ ,  $\beta_{c,us}^{us}$ ,  $\beta_{y,us}^r$ ,  $\beta_{c,us}^r$  are the exposures of de-trended per capita U.S. output and consumption to U.S. business cycle shocks and regional shocks respectively. In Eq. (5) I use the fact that de-trended U.S. per capita output and consumption can be approximated as a weighted average of de-trended per capita output and consumption in each state:

$$\begin{aligned} y_t^{us} &= \sum_i w_i y_{it} = \left( \sum_i w_i \beta_{yi}^{us} \right) f_t^{us} + \sum_{r=1}^{\bar{r}} \left( \sum_i w_i \beta_{yi}^r \right) f_t^r, \\ c_t^{us} &= \sum_i w_i c_{it} = \left( \sum_i w_i \beta_{ci}^{us} \right) f_t^{us} + \sum_{r=1}^{\bar{r}} \left( \sum_i w_i \beta_{ci}^r \right) f_t^r, \end{aligned} \quad (6)$$

where the weights are given by the share of each state in total U.S. GDP.<sup>6</sup> The approximation therefore implies that the exposures of per capita U.S. output and consumption to U.S. business cycle shocks and regional shocks are defined as  $\beta_{y,us}^{us} \equiv \sum_i w_i \beta_{yi}^{us}$ ,  $\beta_{y,us}^r \equiv \sum_i w_i \beta_{yi}^r$ ,  $\beta_{c,us}^{us} \equiv \sum_i w_i \beta_{ci}^{us}$ ,  $\beta_{c,us}^r \equiv \sum_i w_i \beta_{ci}^r$ . On the ground that the weight of most states is small, it is assumed that state-specific and idiosyncratic shocks average out, and do not affect per capita U.S. output and consumption, that is  $\sum_i w_i \beta_{ci}^i f_{it}^i \rightarrow 0$ ,  $\sum_i w_i \beta_{yi}^i f_{it}^i \rightarrow 0$ ,  $\sum_i w_i \varepsilon_{it} \rightarrow 0$ . Note that regional shocks are not assumed to average out.

The standard deviation of asymmetric shocks can then be written as:

$$\begin{aligned} stdev(y_{it} - y_t^{us}) &= \sqrt{(\beta_{yi}^{us} - \beta_{y,us}^{us})^2 + \sum_{r=1}^{\bar{r}} (\beta_{yi}^r - \beta_{y,us}^r)^2 + \beta_{yi}^i{}^2}, \\ stdev(c_{it} - c_t^{us}) &= \sqrt{(\beta_{ci}^{us} - \beta_{c,us}^{us})^2 + \sum_{r=1}^{\bar{r}} (\beta_{ci}^r - \beta_{c,us}^r)^2 + \beta_{ci}^i{}^2 + \phi_i^2}. \end{aligned} \quad (7)$$

There is an advantage to using (6) in order to approximate aggregate variables. Namely, one is able to determine the fraction of asymmetric shocks due to different exposures to the U.S. business cycle, to regional business cycles, to state-specific business cycles and, in the case of consumption, to purely idiosyncratic shocks.

The model developed in this section presents a number of advantages over simple correlations as a tool for studying co-movements among output and consumption across states. First of all, this methodology makes it possible to quantify the size of asymmetric shocks. The correlation between two variables only conveys information on the extent to which the shocks affecting the variables are orthogonal to each other, but says nothing of the magnitude of the shocks.

Secondly, by means of the factor model one is able to disentangle asymmetries in consumption due to shocks in output, and asymmetries due to measurement error or preference shocks. It is well known that one implication of complete markets when agents' preferences display constant relative risk aversion is the following (see for instance Obstfeld 1994):

$$c_{it} = c_t^{us} + \theta_{it} \quad (8)$$

where  $c_{it}$  and  $c_t^{us}$  represent the growth rates of consumption in state  $i$  and in the aggregate, respectively, and the term  $\theta_{it}$  represents preference shocks. Because of preference shocks the correlation in consumption growth rates between states  $i$  and  $j$  may be less than one even under perfect risk sharing (see also Stockman and Tesar 1995). In the model, idiosyncratic shocks are by construction orthogonal with respect to national, regional, or state specific business cycles. This implies that a plausible explanation for idiosyncratic shocks in consumption is either measurement error, or preference shocks, or both.<sup>7</sup> The advantage of using Eq. (7) over the analysis based on correlations is that asymmetries due to the idiosyncratic component can be distinguished from asymmetries due to output shocks.

Finally, the factor analysis model offers the possibility of attributing the deviations from perfect risk sharing to national, regional, and state-specific shocks. This in turn leads to a deeper understanding of the sources of imperfect risk sharing.

The approach adopted in this paper also differs from the one followed by Stockman (1988), who estimates a similar model using dummy variables. This approach has two advantages over Stockman's. Firstly, it is more economical in terms of the number of parameters that need to be estimated.<sup>8</sup> Secondly, Stockman's method does not allow for the same factor to have a different impact on different states, or a different impact on consumption and output in same state. This would have been a major impediment in addressing questions regarding the relative variability of consumption and output, and the fraction of variability that can be attributed to each factor.

Two important assumptions underlie the model. The first assumption is that the model is not dynamic, in that the factors are assumed to be uncorrelated over time. Several papers (see Stockman 1988, and Costello 1993) neglect serial correlation when dealing with annual data. Table 1 shows that the first order serial correlation in consumption is on average close to zero, and that the first order serial correlation in output is on average between .22 and .27, depending on the de-trending method.<sup>9</sup> The second assumption is that the parameters are not time-varying. As the productive structure of the states has changed over time, so have in principle the exposures to national, regional, and state-specific business cycles. The limited time series dimension of the sample (26 observations) makes it hard to deal with this issue. Therefore, I follow most previous work, and do not allow for time-varying parameters.

### **3 The data**

The data on real output are obtained by deflating the data on nominal gross state product (gsp) from the Bureau of Economic Analysis (BEA) by state CPI. Data on nominal gsp are available from 1963 to 1997. The CPI series are constructed using American Chamber of Commerce Association data on Cost of Living by metropolitan areas, as well as other sources, and are weighted for each state using BEA data on population by metropolitan area. The CPI data are constructed from 1969 to 1995, which implies that the real output series are available for this period only. Details on the construction of the CPI series can be found in Del Negro (1998b).

Hess and Shin use data on real gsp from the BEA. These data are available since 1978 only. The real gsp data are obtained by deflating nominal gsp by a gsp deflator. The latter is a weighted average of national producer prices, where the weight of each commodity is given by its production share in each state. In Del Negro (1998b) I compare the properties of the CPI deflated output and the real gsp from the BEA, and find the two data sets to be highly correlated.

In terms of the consumption data, Hess and Shin argue that evidence on the quantity anomaly should be obtained using data on consumption of non-durables, as this variable is a better empirical counterpart to the theoretical definition of consumption used in Backus et al. (1992) than total consumption, which includes consumption of durables. Hess and Shin's data on real non-durable consumption are constructed by deflating the nominal data on retail sales of non-durables from the Bureau of the Census by the gsp deflator from the BEA. The data on retail sales of non-durables from the Bureau of the Census are available only from 1978 to 1995 for nineteen states, and are no longer produced. It is important to note that the use of the gsp deflator introduces measurement error in the real consumption data for two reasons. First, the prices used in the deflator are national prices, and do not take into account price differences within the United States.<sup>10</sup> Secondly, the share of any particular commodity in production is likely to be different from the share in consumption, particularly for oil producing and agricultural states.

In this paper, the data on real non-durable consumption are constructed by deflating the nominal data on retail sales of non-durables by the state CPI series mentioned above. Data for retail sales of non-durables are constructed as the difference between total retail sales and retail sales of automobiles, furniture, building materials and hardware. The data are obtained from Sales&Marketing Management, which is the same source for the data on total consumption used in Asdrubali et al. (1996) (the data are proprietary, and I am grateful to Sales&Marketing Management for giving me permission to use them). All the data are transformed in per capita terms using the population data from the BEA.

As mentioned above, state non-durable consumption is measured as retail sales of non-durables, given that no data for state level consumption is available. In doing so, the paper follows the previous literature on risk sharing among U.S. states. Retail sales is an imprecise measure of consumption, both because it does not incorporate consumption of services, and because it may include purchases made by residents of other states.<sup>11</sup> However, Hess and Shin (1998) show that at the aggregate level retail sales are a good proxy for consumption, especially at the annual frequency. The source for retail sales data is different from the one used by Hess and Shin. In Del Negro (1998b) I compare the two data sets for the nineteen states for which both are available. In particular, I use a bivariate factor model of the form:

$$\begin{aligned} c_{it}^{S\&M} &= c_{it}^* + \theta_{it}^{S\&M} \\ c_{it}^C &= c_{it}^* + \theta_{it}^C \end{aligned}$$

where  $c_{it}^{S\&M}$  and  $c_{it}^C$  are the proxies for de-trended consumption of non-durables in state  $i$  obtained from Sale&Marketing Management and the Census, respectively,  $c_{it}^*$  represents the “true” measure of consumption, which is not observed, and  $\theta_{it}^{S\&M}$  and  $\theta_{it}^C$  represent the measurement error for each proxy. The comparison between the standard deviation of  $\theta_{it}^{S\&M}$  and  $\theta_{it}^C$  reveals that for the majority of states the Census measures are more precise. However, for none of the nineteen states am I able to reject the hypothesis that the two standard deviations are different at the 10% significance level.

For the United States, regions are based on the BEA definition of regions. The BEA regions are New England, Mid East, Great Lakes, Plains, South East, South West, Rocky Mountains, and Far West.

In the application to European countries, the data for real consumption of non-durables are obtained from the United Nations, and are calculated, following van Wincoop (1994), as total private consumption minus consumption of clothing and footwear, furniture and household equipment, and personal transportation, all in constant prices. These data are obtained for the period 1973-1990 for nine countries: Belgium, Denmark, France, West Germany, Greece, the Netherlands, Italy, Ireland, and the UK.<sup>12</sup> The data for total private consumption, which were collected for eleven countries (the

nine mentioned above plus Spain and Portugal), are obtained from the OECD Main Aggregates (nominal) and are deflated using the CPI from the International Financial Statistics. The output data for European countries are from the United Nations (constant prices), and are available since 1970. Although the data are available up to 1993, I follow Sorensen and Yosha (1997a) and cut the sample in 1990 to avoid problems with the German reunification. All the data are transformed in per capita terms using the population data from the International Financial Statistics.

The identifying assumptions for Europe, in terms of regions, are such that Belgium, Denmark, France, West Germany, and the Netherlands belong to one region (which can be called the Deutsche Mark area), Greece, Italy, Spain, and Portugal belong to a different region (which can be called the Club Med region), while Ireland and the UK are unassigned.

The data are de-trended using two different methods: log-differences (growth rates) and Hodrick-Prescott (HP) filtering. Given that the frequency of the data is annual, in applying the HP filter the smoothing parameter is set to 10 (see Baxter and King 1995). All the tables show the results under both de-trending methods. Given that the results are not qualitatively different, the figures shown in the paper are obtained using the log-differenced data only.

## **4 National, regional, and state-specific business cycles**

The discussion of the results begins with an analysis of the relative importance of national, regional, and state-specific business cycles for US states.<sup>13</sup> Table 2 indicates that the relative importance of the factors is different for consumption and for output. Idiosyncratic shocks are the predominant source of movements in consumption, as they explain on average more than 50% of the variance. The second most important source of fluctuations for consumption is represented by regional business cycles, which explain roughly one third of the variance. U.S. and state-specific business cycles have a negligible impact on consumption, as they explain less than 5% of the variance. By

construction, idiosyncratic shocks are orthogonal with respect to national, regional, or state-specific business cycles. Consequently, a plausible explanation for idiosyncratic shocks in consumption may be either measurement error or preference shocks. If this is the case, the results suggest that comparing cross-state correlations in consumption and output is not a good method for assessing the degree of risk sharing. If correlations in consumption are lower than correlations in output, that may be because of preference shocks or measurement error, rather than because of lack of risk sharing.

The results of the variance decomposition for output are quite different. National business cycles are the most important source of fluctuations for state output, as they explain more than 50% of the variance. The remaining fraction is split equally between regional and state-specific business cycles. These results imply that the U.S. business cycle is the main driving force for movements in output across states. This is consistent with the finding of Hess and Shin (1998) that cross sectional correlations in output are on average quite high. Table 2 does not say whether the impact of U.S. business cycles is the same across states, or whether some states are affected by national business cycles differently than others.

Fig. 1 conveys some information in this respect, as it shows the cross sectional distribution of the exposures to national, regional, and state-specific business cycles. The exposures are divided by the standard deviation of U.S. output in the sample, which is 3.1% for the case of growth rates (that is, the figure displays the cross sectional distribution of the quantities  $\beta_{pi}^q / stdev(y_t^{us})$ , where  $q = us, r, s$  and  $p = c, y$ ). The figures on the horizontal axis can therefore be interpreted as the responses of state output and consumption to a 3.1% shock in each of the factors. The mean and the standard deviation of the distributions are also shown.

The distribution of the exposures of state output with respect to the U.S. business cycle is centered around one, not surprisingly.<sup>14</sup> Perhaps more interestingly, there is a wide cross sectional dispersion (the standard deviation is .6). Some states are strongly pro-cyclical, others are a-cyclical, and one (Alaska) is strongly counter-cyclical. The distribution of the exposures of state consumption to the U.S. business cycle is cen-

tered around zero, confirming the finding from Table 2 that shocks in the national factor have little impact on consumption. It is interesting to note that not only is the mean exposure for consumption lower than the mean exposure for output, but also the dispersion is lower. One interpretation of this finding is that states share shocks to the U.S. business cycle, although other interpretations based on consumption smoothing via investment or via borrowing and lending from other states are also possible.

A second interesting feature of Fig. 1 is that the exposure of consumption to regional shocks is on average larger than the exposure of output. This finding is at odds with the prediction from perfect risk sharing at the national level: to the extent that regional shocks average out, under complete markets at the national level these shocks should have no impact on state consumption.

Does the exposure to the U.S. business cycle reflect particular characteristics of individual states? Fig. 2 shows the geographical distribution of the exposures to U.S. business cycles for output (top) and consumption (bottom). With respect to output, the figure shows that the “rust belt” states, like Michigan, are among the most pro-cyclical, together with the “sun belt” states. Oil producing states, like Alaska, Texas, Oklahoma, and Louisiana, are either counter-cyclical or a-cyclical. Most of agricultural states of the Midwest are also less pro-cyclical than the average. This observation suggests that the states’ productive structure, which in the U.S. follows a geographical pattern, plays a role in affecting the exposure to U.S. business cycles.<sup>15</sup> The bottom map confirms that the dispersion of the exposures to U.S. business cycle shocks for consumption is milder than for output. It is interesting to observe that Michigan and Alaska, which are respectively the most pro-cyclical and the most counter-cyclical state in terms of output, have roughly the same exposure in terms of consumption.

## 5 The “quantity anomaly” within the United States

Fig. 3 displays the cross-correlations of output and consumption of non-durables across U.S. states. More specifically, the two plots in Fig. 3 display all the pairs  $(Corr(y_{it}, y_{jt}), Corr(c_{it}, c_{jt}))$ , with output correlations on the horizontal axis, and consumption corre-

lations on the vertical axis. In the top plot, the data for consumption of non-durables and for real output are obtained from the same source of Hess and Shin.<sup>16</sup> In the bottom plot, the data for consumption of non-durables are obtained from Sales&Marketing Management and the data for real output are obtained by deflating nominal output by the state CPI. Table 3 displays the average correlation of consumption and output, the difference between the two, and the percentage of observations for which the correlation in output is larger than the correlation in consumption.

The top plot in Fig. 3 shows that for the nineteen states included in the data set of Hess and Shin the “quantity anomaly” holds: 94% of the observations are below the 45 degree line, implying that for almost all states consumption correlations are lower than output correlations. The average consumption correlation is between .3 and .33, and the average output correlation is between .7 and .78, depending on the de-trending method. These figures are roughly the same ones reported by Hess and Shin. The bottom plot in Fig. 3 shows that the inclusion of all fifty states in the analysis makes a difference. While in the top plot only about 5% of the observations lie above the 45 degree line, in the bottom plot more than 20% of the observations are above the 45 degree line. The average difference between consumption and output correlation is almost halved, from  $-.4$  to  $-.215$  for growth rates, and from  $-.45$  to  $-.28$  for HP de-trended data. The reason for this change is a .2 decrease in the average output correlation: the introduction of thirty-one more states in the sample, many of which are agricultural and oil producing, causes a decrease in output correlations. It is important to notice that consumption correlations are unchanged. If output correlations are smaller only because of a decrease in the average size of the states in the sample, consumption correlation should also be smaller. This is not the case, which suggests that the decrease in output correlations is due to characteristics of the newly added states other than size (perhaps their productive structure).

The overall conclusion from the analysis of cross-state correlations in consumption and output, however, is not different from the one reached by Hess and Shin: the “quantity anomaly” holds for U.S. states as well as for countries. The discussion in the previous section, however, indicates that almost 60% of movements in consumption can

possibly be attributed to preference shocks or measurement error. If low consumption correlations are due to preference shocks or measurement error, no meaningful inference can be made about risk sharing. The model described in section 2 provides a better tool to analyze the data, as it makes it possible to separate out the idiosyncratic component of consumption.

Fig. 4 plots the pairs of standard deviations of asymmetric shocks for non-durable consumption and output for all 50 states. The difference between the top and the bottom plot on Fig. 4 is that in the top plot the standard deviations of asymmetric shocks for non-durable consumption include the idiosyncratic component of consumption, while in the bottom plot they exclude it. For all the observations that lie below the 45 degree line the standard deviation of asymmetric shocks in consumption is larger than the standard deviation of asymmetric shocks in output. The starred observations are those for which the two are different at the 5% significance level. Table 4 displays the average standard deviations of asymmetric shocks in consumption and output across states, the difference between the two, and the percentage of observations for which the standard deviation of asymmetric shocks in consumption is larger than the standard deviation of asymmetric shocks in output. The first line in Table 4 shows that when the idiosyncratic component of consumption is included, the standard deviation of asymmetric shocks in consumption is larger than the standard deviation of asymmetric shocks in output for 94% of the states. The average standard deviation of asymmetric shocks in consumption is 5% for growth rates, that is, almost 2% larger than the average standard deviation of asymmetric shocks in output, which is 3% (roughly the same standard deviation of the growth rate of U.S. per capita output in the sample). For HP de-trended data the average standard deviation of asymmetric shocks in consumption is 3.2%, 1.3% larger than the average standard deviation of asymmetric shocks in output, which is 1.9% (the standard deviation of HP de-trended per capita U.S. output in the sample is 2.1%).

When the idiosyncratic component of the fluctuations in consumption is included the findings are consistent with the analysis of cross state correlations. When the idiosyncratic component of the fluctuations in consumption is excluded the results are

strikingly different. The average standard deviation of asymmetric shocks in output and consumption are roughly the same, although for almost 60% of states the standard deviation of asymmetric shocks in consumption is still larger than the standard deviation of asymmetric shocks in output.

An additional advantage of the methodology used in this paper is that it makes it possible to determine the fraction of asymmetric shocks in output and consumption due to differences in the exposures to U.S. business cycles, to regional business cycles, and to state-specific shocks. Table 5 shows that depending on the de-trending method 13%-20% of asymmetric shocks in output are due to different exposures to the U.S. business cycle, 36%-42% are due to regional shocks, and 44%-45% to state-specific shocks. For consumption, 58%-60% of asymmetric shocks are due to the idiosyncratic component, and almost 80% of what remains is due to the impact of regional shocks.

Which states have the highest standard deviation in asymmetric shocks in consumption and output? For which states is the difference between the two the highest? Fig. 5 addresses these questions. The figure shows that asymmetric standard deviations in output are the largest for oil producing and agricultural states, and for Michigan. They are small, below 2%, for California and most East Coast states. The asymmetric standard deviations in consumption, excluding the idiosyncratic component, are the largest for North-Western agricultural states, for New England states (excluding Massachusetts), and for South-Eastern states. The standard deviation of asymmetric shocks in consumption is larger than the standard deviation of asymmetric shocks in output by more than 1.5% for many East Coast states. For most oil producing and agricultural states of the Mid-West the standard deviation of asymmetric shocks in output is larger than the standard deviation of asymmetric shocks in consumption.

The results can be summarized as follows. Asymmetric shocks to output are of about the same magnitude of U.S. business cycles fluctuations. The two most important sources of asymmetric shocks to output are regional and state-specific business cycles. Differences in the exposures to U.S. business cycles play a less important, but still non negligible, role. Only a small fraction of state-specific shocks in output, and

of differences in the exposure to U.S. business cycles, translate into asymmetric shocks in consumption. Regional business cycles, however, have a large impact on consumption. Asymmetric shocks in consumption, excluding the idiosyncratic component, have the same magnitude of U.S. business cycle fluctuations. This amounts to substantial evidence against perfect risk sharing at the national level.

These results are quite different from the ones found in much of the previous literature on inter-state smoothing. Note that asymmetric shocks to consumption, when purged from measurement error and/or preference shocks, are by construction related to shocks in output. Since the magnitude of asymmetric shocks to output is equal to the magnitude of asymmetric shocks in consumption, the results indicate lack of inter-state smoothing.

## 6 A comparison with Europe

This section compares the findings for intranational data with the results obtained using international data. Given that the comparison between the amount of asymmetries within an established monetary union (United States) and a new one (EMU) is relevant for the policy debate in Europe, the section focuses on European countries.<sup>17</sup>

The model for Europe is analogous to the one used for U.S. states. Co-movements in output and consumption are assumed to be due to a common factor, called the European factor, to regional business cycles, and to country-specific shocks. Consumption is also allowed to have a purely idiosyncratic component. Based on the “two speed Europe” hypothesis, the regions for Europe coincide with the so called “Deuscthe Mark Area”, formed by Germany and its neighbors, and with the “Club Med”, composed of southern European countries (see section 3).

Table 6 is the analogous of Table 3 for Europe. The table displays the average correlation of consumption and output across European countries, the difference between the two, and the percentage of observations for which the correlation in output is larger than the correlation in consumption. The table displays information on total consump-

tion, as well as on consumption of non-durables, since data on non-durable consumption are not available for Spain and Portugal for the whole sample period. The table shows that the average correlation in output, regardless of the de-trending method, is .2 lower among European countries than among U.S. states. The average correlation in non durable consumption within Europe is also lower than within the US, but by a smaller amount. The average correlation in output is still larger than the average correlation in non-durable consumption, but the difference between the two is smaller than in the United States. For only 61%-63% of countries the correlation in output is larger than the correlation in consumption. The corresponding figure for the U.S. is almost 80%.

The analysis of correlation does not say whether asymmetric shocks in Europe are larger than in the United States. Table 7, which is the analogous of Table 4, addresses this issue. The table displays the average standard deviations of asymmetric shocks for consumption and output across European countries, the difference between the two, and the percentage of observations for which the standard deviation of asymmetric shocks in consumption is larger than the standard deviation of asymmetric shocks in output. The results indicate that asymmetric shocks in both consumption and output are lower than in the US. In particular, the average standard deviation of asymmetric shocks in non durable consumption, excluding the idiosyncratic component, is .2% to .7% lower, depending on the de-trending method. Given the substantial cross-sectional variability one cannot conclude that asymmetric standard deviations in consumption are in general lower for European countries than for U.S. states. However, the evidence strongly suggests that European countries are not more asymmetric than U.S. states in regard to both consumption and output. This findings contradicts the conventional wisdom (see for instance the IMF World Economic Outlook, 1997), which is often based on the analysis of correlations. As pointed out above, correlations do not convey much information on the magnitude of asymmetric shocks.<sup>18</sup>

The results also indicate that asymmetries in non durable consumption and output are of the same magnitude, after taking the idiosyncratic component into account. Depending on the de-trending method, asymmetric shocks to consumption are larger than asymmetric shocks to output for 44% to 54% of European countries.

Table 8 addresses the issue of the source of asymmetries in Europe. The table shows that for output the large majority of asymmetric shocks stems from country-specific disturbances. It is interesting to note that regional shocks do not have a large impact on output. This finding provides little support for the “two speed Europe” hypothesis. Country-specific shocks are in general the most important source of asymmetries for consumption as well, apart from the idiosyncratic component. A large fraction of asymmetric shocks in consumption are also due to regional shocks, and to the different exposures to the European factor. For non-durable consumption, under the HP de-trending method, the latter is indeed the most important source of asymmetries.

To summarize, the comparison between U.S. states and European countries suggests that there is no evidence that asymmetries within Europe are larger than within the United States. This is the case for both consumption and output. If anything, the evidence goes in the other direction. The relative magnitude of asymmetric shocks to non durable consumption and output is roughly the same in Europe, suggesting absence of smoothing across European countries.

## 7 Conclusions

The paper contributes to the literature in intranational macroeconomics by analyzing co-movements in de-trended per capita non-durable consumption and output among the fifty U.S. states from 1969 to 1995. The evidence presented in the paper is based on the analysis of cross-correlations as well as on the results of a factor analysis model.

The factor analysis model is used to attribute fluctuations in consumption and output to national, regional, and state-specific business cycles. The model is also used to isolate the component of consumption fluctuations due to purely idiosyncratic disturbances, which presumably reflect measurement error or preference shocks. The paper focuses in particular on asymmetric shocks, that is, shocks that affect consumption and output in a given state differently than the aggregate.

The paper finds that asymmetric shocks to output across U.S. states are large: on average the standard deviation of asymmetric shocks to output is of the same magnitude of U.S. business cycle fluctuations. While the component of asymmetric output shocks due to state-specific business cycles has little impact on consumption, the component due to regional business cycles has a strong effect on consumption. On average the standard deviation of asymmetric shocks to consumption, excluding disturbances due to measurement error, is of the same magnitude of asymmetric shocks to output. This result suggests that very little smoothing occurs within U.S. states, contrary to the results in previous literature (Asdrubali et al. 1996). The comparison with Europe indicates that asymmetric shocks to both consumption and output in Europe are of smaller magnitude than in the United States. Furthermore, there is little evidence of smoothing within Europe as well.

An important implication of these results is that goods and capital market integration may not lead to the disappearance of asymmetric shocks. In particular, the fact that a large fraction of asymmetries in output are due to regional business cycles provides some support for Krugman's hypothesis that economic integration leads to regional specialization (see Krugman 1991, 1993). The finding that there is little inter-state smoothing of asymmetric shocks in output is consistent with the direct and indirect evidence of financial market segmentation within the United States provided by recent works of Coval and Moskowitz (1997), Huberman (1999), and Hess and Shin (1999). This finding suggests that lowering barriers to capital markets may not help to achieve greater macroeconomic stability.

The results indicate that some asymmetric shocks, like those due to differences in the exposures to U.S. business cycles, or to state-specific business cycles, are smoothed across states, while others, like regional business cycles, are not. Is this finding due to the nature of market incompleteness? Or to federal and/or state-level policies? These questions are left for future research.

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## Notes

<sup>1</sup>See Asdrubali et al. (1996), Athanasoulis and van Wincoop (1997a) (1997b), Atkeson and Bayoumi (1993), Bayoumi and Klein (1995), Crucini (1998), Crucini and Hess (1999), Del Negro (1998a), Hess and Shin (1997) (1998), Mélitz and Zúmer (1999), Sørensen and Yosha (1997a) (1997b), van Wincoop (1995).

<sup>2</sup>See Eichengreen (1990) among several others, and Frenkel and Rose (1997) for a critique of this literature.

<sup>3</sup>A number of papers (e.g. Clark, 1998; Ghosh and Wolf, 1997; Kollmann, 1995; Norrbin and Schlagenhaut, 1988) study the relative importance of regional and sectoral shocks within U.S. states or regions. These studies focus on fluctuations in employment, industrial production, and productivity. This literature is reviewed in Clark and Shin (1999). Carlino and Sill (1998) and Wynne and Koo (1999) analyze co-movements across U.S. regions in per capita income and output, respectively.

<sup>4</sup>In standard factor analysis identification is obtained by means of the so called canonical restrictions, which have no economic content.

<sup>5</sup>The assumption of no measurement error in output is implicitly made in some of the previous literature as well (Asdrubali et al. and Mélitz and Zúmer). As they use output as a regressor, the presence of substantial measurement error in output would indeed imply that their estimates contain a bias.

<sup>6</sup>For growth rates, this approximation follows from a first order expansion of the logarithm of per capita US GDP. In the practical application I use as weights the shares of each state in total U.S. GDP at the beginning of the sample.

<sup>7</sup>In principle, movements in consumption may also reflect changes in future output that are not correlated with changes in current output. From a practical point of view, however, this does not seem to be a very relevant case for U.S. states.

<sup>8</sup>Stockman uses a dummy variable for each factor in each time period: since there are 59 factors and 26 time periods, that would have meant estimating  $26 \times 59 = 1508$  parameters instead of 400.

<sup>9</sup>Kose et al. (1999) and Forni and Reichlin (1998) however estimate a dynamic factor analysis model with annual data. Another example of estimation of a dynamic factor analysis model is Gregory et al. (1997).

<sup>10</sup>See Friedenber and Beemiller (1997).

<sup>11</sup>The District of Columbia is not included in the analysis precisely for this reason.

<sup>12</sup>For Ireland, the change in the base year in 1982 is calculated using the CPI from the IMF International Financial Statistics, and for the Netherlands the data for consumption in personal transportation in 1983 and 1984 are obtained deflating the nominal data from the same source (United Nations) with the CPI.

<sup>13</sup>Tables describing the maximum likelihood estimates for all the parameters, and their respective standard errors, are not included in the paper for expositional reasons, as the model involves a large number of parameters. The tables are available upon request.

<sup>14</sup>The mean is slightly below one. This is because it is computed giving the same weight to all states. The actual weight of the larger states in U.S. output is however bigger than the one of smaller states (like Alaska).

<sup>15</sup>Garcia-Mila and McGuire (1993) (1994) present further evidence on the relationship between state employment variability and productive structure. Davis et al. (1997) discuss the importance of oil shocks for state business cycles.

<sup>16</sup>However, differently from Hess and Shin, for reasons discussed in section 3 the data for consumption are deflated using the state CPI rather than the gsp deflator.

<sup>17</sup>Bayoumi and Eichengreen (1993) and Ballabriga et a. (1999) study asymmetric output shocks in Europe, and focus on the decomposition between demand and supply shocks. Forni and Reichlin (1999) present an analysis of long run income risk in Europe. Finally, Von Hagen and Hammond (1995) discuss possible arrangements for risk sharing of asymmetric shocks within Europe.

<sup>18</sup>Wynne and Koo (1999) find that the cross sectional standard deviation of detrended output across the Federal Reserve districts in the U.S. is only slightly lower than the cross sectional volatility across European countries.

## Tables

Table 1: Autocorrelation of consumption and output

	consumption	output
growth rates	-0.0547 (0.106)	0.221 (0.158)
HP filter	0.0601 ( 0.1)	0.276 (0.176)

Note: Averages across states. Cross sectional standard errors in parenthesis.

Table 2: Variance decomposition for consumption and output

	consumption				output		
	U.S.	Reg.	St.	Id.	U.S.	Reg.	St.
growth rates	5%	33%	4.8%	58%	54%	23%	23%
HP filter	8.7%	32%	5.4%	54%	65%	16%	19%

Note: The table shows the percentage of the variation in consumption and output explained by the national (U.S.), regional (Reg.), state specific (St.) factor, and by the idiosyncratic component (Id.). In particular, the columns show the averages across states of the values  $\beta_{ci}^{us\ 2}/var(c_{it})$ ,  $\beta_{ci}^{r\ 2}/var(c_{it})$ ,  $\beta_{ci}^{s\ 2}/var(c_{it})$ ,  $var(\varepsilon_{it})/var(c_{it})$ ,  $\beta_{yi}^{us\ 2}/var(y_{it})$ ,  $\beta_{yi}^{r\ 2}/var(y_{it})$ ,  $\beta_{yi}^{s\ 2}/var(y_{it})$  respectively, where the parameters  $\beta$  are the maximum likelihood estimates of (1).

Table 3: Cross correlation of consumption and output

		consumption	output	difference	%
growth	Census	0.302 (0.236)	0.703 (0.186)	-0.401	94.2
rates	Sales&Marketing	0.314 (0.219)	0.529 (0.341)	-0.215	76.2
HP	Census	0.33 (0.25)	0.776 (0.181)	-0.446	94.7
filter	Sales&Marketing	0.295 (0.243)	0.58 (0.387)	-0.285	78.9

Note: The first and second columns show the average correlation of consumption and output, respectively. The third column shows the difference between the two, and the fourth column shows the percentage of observations for which the correlation in output is larger than the correlation in consumption. Cross sectional standard errors in parenthesis.

Table 4: Standard deviations of asymmetric shocks in consumption and output

		consumption	output	difference	%
growth	with idiosyncratic component	0.049 (0.0146)	0.0302 (0.0228)	0.0189	94
rates	without idiosyncratic component	0.0298 (0.0122)	0.0302 (0.0228)	-0.000352	56
HP	with idiosyncratic component	0.0321 (0.0105)	0.0192 (0.016)	0.0129	94
filter	without idiosyncratic component	0.0203 (0.0101)	0.0192 (0.016)	0.00111	58

Note: The first and second columns show the average across states of the standard deviation of asymmetric shocks in consumption and output, respectively. The third column shows the difference between the two, and the fourth column shows the percentage of observations for which the correlation in output is larger than the correlation in consumption. In the second and fourth line the standard deviation of asymmetric shocks in consumption is computed without including the idiosyncratic component, i.e., the term  $\phi_i^2$  in Eq. (7). Cross sectional standard errors in parenthesis.

Table 5: Variance decomposition of asymmetric shocks

	consumption				output		
	U.S.	Reg.	St.	Id.	U.S.	Reg.	St.
growth rates	4.1%	31%	4.8%	60%	13%	42%	45%
HP filter	5.6%	31%	5.5%	58%	20%	36%	44%

Note: The table shows the percentage of the variation of asymmetric shocks in consumption and output due to the national (US), regional (Reg.), state specific (St.) factor, and to the idiosyncratic component (Id.). In particular, the columns show the averages across states of the values  $(\beta_{ci}^{us} - \beta_{c,us}^{us})^2 / \text{var}(c_{it} - c_t^{us})$ ,  $\sum_r (\beta_{ci}^r - \beta_{c,us}^r)^2 / \text{var}(c_{it} - c_t^{us})$ ,  $\beta_{ci}^s{}^2 / \text{var}(c_{it} - c_t^{us})$ ,  $\phi_i^2 / \text{var}(c_{it} - c_t^{us})$ ,  $(\beta_{yi}^{us} - \beta_{y,us}^{us})^2 / \text{var}(y_{it} - y_t^{us})$ ,  $\sum_r (\beta_{yi}^r - \beta_{y,us}^r)^2 / \text{var}(y_{it} - y_t^{us})$ ,  $\beta_{yi}^s{}^2 / \text{var}(y_{it} - y_t^{us})$  respectively.

Table 6: Cross correlation of consumption and output, Europe

		consumption	output	difference	%
growth	total cons.	0.37 (0.224)	0.374 (0.227)	-0.00422	47.3
rates	non durables	0.178 (0.289)	0.313 (0.275)	-0.135	63.9
HP	total cons.	0.32 (0.296)	0.395 (0.24)	-0.0747	52.7
filter	non durables	0.214 (0.37)	0.363 (0.276)	-0.149	61.1

Note: The first and second columns show the average correlation of consumption and output, respectively. The third column shows the difference between the two, and the fourth column shows the percentage of observations for which the correlation in output is larger than the correlation in consumption. Cross sectional standard errors in parenthesis.

Table 7: Standard deviations of asymmetric shocks in consumption and output, Europe

			consumption	output	difference	%
	total	with idiosyncratic component	0.022 (0.01)	0.0187 (0.0075)	0.0032	72.7
growth	cons.	w/o idiosyncratic component	0.0142 (0.0065)	0.0187 (0.0075)	-0.0045	36.4
rates	non	with idiosyncratic component	0.0353 (0.0341)	0.0172 (0.0072)	0.018	66.7
	durables	w/o idiosyncratic component	0.0229 (0.0207)	0.0172 (0.0072)	0.0057	55.6
	total	with idiosyncratic component	0.0154 (0.0075)	0.0126 (0.0055)	0.0028	63.6
HP	cons.	w/o idiosyncratic component	0.0119 (0.0062)	0.0126 (0.0055)	-0.0008	45.5
filter	non	with idiosyncratic component	0.0245 (0.023)	0.0117 (0.0037)	0.0127	66.7
	durables	w/o idiosyncratic component	0.0181 (0.016)	0.0117 (0.0037)	0.0064	44.4

Note: The first and second columns show the average across European countries of the standard deviation of asymmetric shocks in consumption and output, respectively. The third column shows the difference between the two, and the fourth column shows the percentage of observations for which the correlation in output is larger than the correlation in consumption. In the second and fourth line the standard deviation of asymmetric shocks in consumption is computed without including the idiosyncratic component, i.e., the term  $\phi_i^2$  in Eq. (7). Cross sectional standard errors in parenthesis.

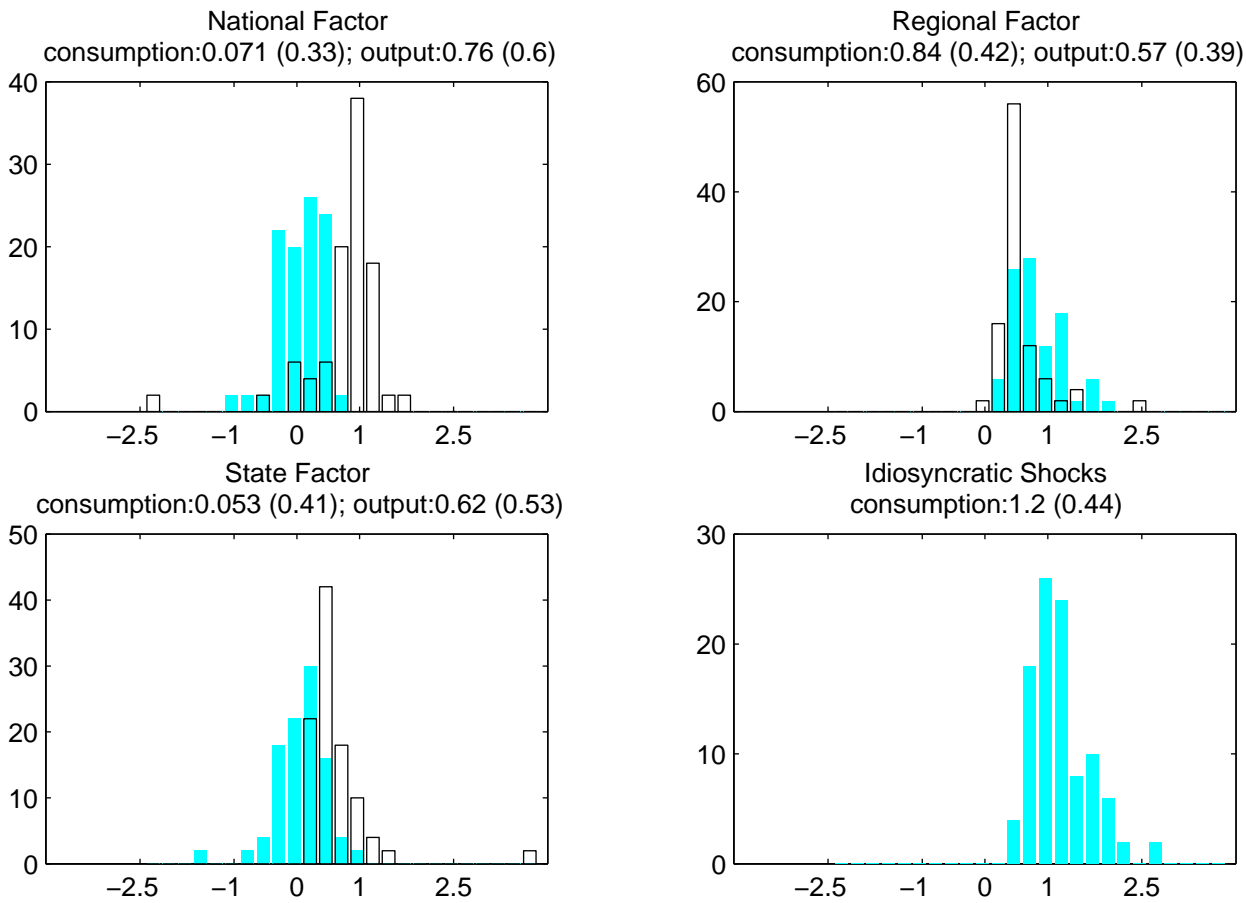
Table 8: Variance decomposition of asymmetric shocks, Europe

		consumption				output		
		Eu	Reg.	Co.	Id.	Eu	Reg.	Co.
growth	total consumption	9.6%	15%	23%	52%	6.3%	18%	76%
rates	non durables	15%	14%	25%	46%	10%	5.1%	85%
HP	total consumption	13%	20%	28%	39%	16%	21%	63%
filtered	non durables	34%	14%	16%	37%	14%	7.5%	78%

Note: The table shows the percentage of the variation of asymmetric shocks in consumption and output due to the European (Eu), regional (Reg.), country specific (Co.) factor, and by the idiosyncratic component (Id.). In particular, the columns show the averages across European countries of the values  $(\beta_{c_i}^{Eu} - \beta_{c_i, Eu}^{Eu})^2 / \text{var}(c_{it} - c_t^{Eu})$ ,  $\sum_r (\beta_{c_i}^r - \beta_{c_i, Eu}^r)^2 / \text{var}(c_{it} - c_t^{Eu})$ ,  $\beta_{c_i}^{s,2} / \text{var}(c_{it} - c_t^{Eu})$ ,  $\phi_i^2 / \text{var}(c_{it} - c_t^{Eu})$ ,  $(\beta_{y_i}^{Eu} - \beta_{y_i, Eu}^{Eu})^2 / \text{var}(y_{it} - y_t^{Eu})$ ,  $\sum_r (\beta_{y_i}^r - \beta_{y_i, Eu}^r)^2 / \text{var}(y_{it} - y_t^{Eu})$ ,  $\beta_{y_i}^{s,2} / \text{var}(y_{it} - y_t^{Eu})$  respectively.

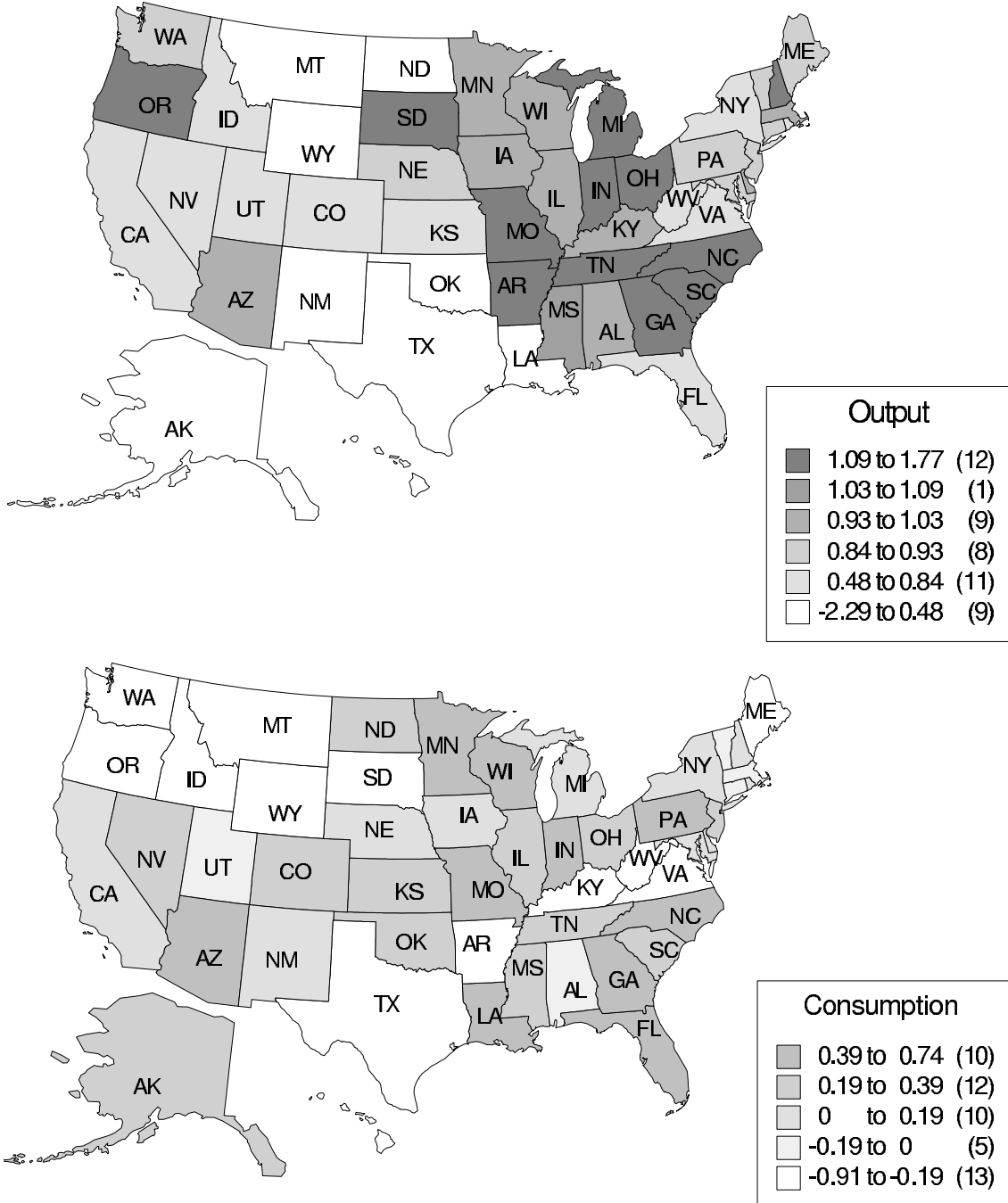
## Figures

Figure 1: Distribution of the exposures to the national, regional, and state specific business cycles, and to idiosyncratic shocks, for output and non-durable consumption



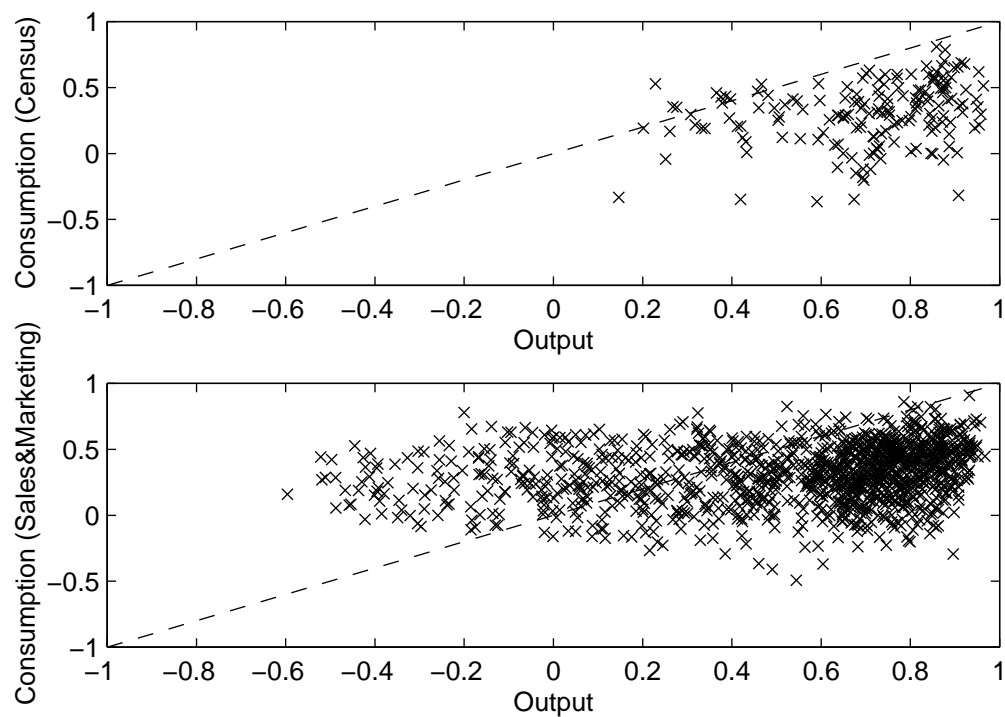
Note: The figure shows the distribution of the exposures to the national ( $\beta_i^{us}$ ), regional ( $\beta_i^r$ ), and state specific ( $\beta_i^s$ ) business cycles, and to idiosyncratic shocks ( $\phi_i$ ), for output (solid line) and non-durable consumption (shaded). The exposures are expressed as a fraction of the standard deviation of U.S. gdp, that is, are divided by  $stdev(y_i^{us})$ . The mean and the standard deviation (in parenthesis) of the distribution are displayed on top of each plot. The figure shows the results for the model estimated in growth rates.

Figure 2: Geographical distribution of the exposures to U.S. business cycle



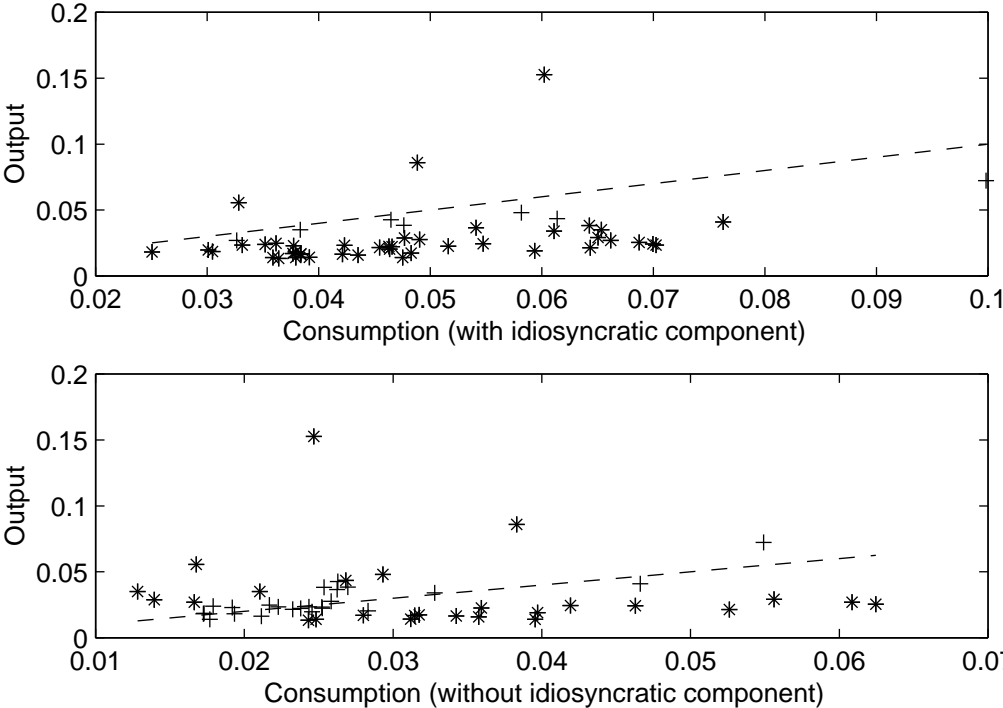
Note: The maps show the geographical distribution of the exposures to the national factor ( $\beta_i^{us}$ ), expressed as a fraction of the standard deviation of U.S. gdp, for output (top) and consumption (bottom). The figure shows the results for the model estimated in growth rates.

Figure 3: Cross correlation of output and non-durable consumption across states



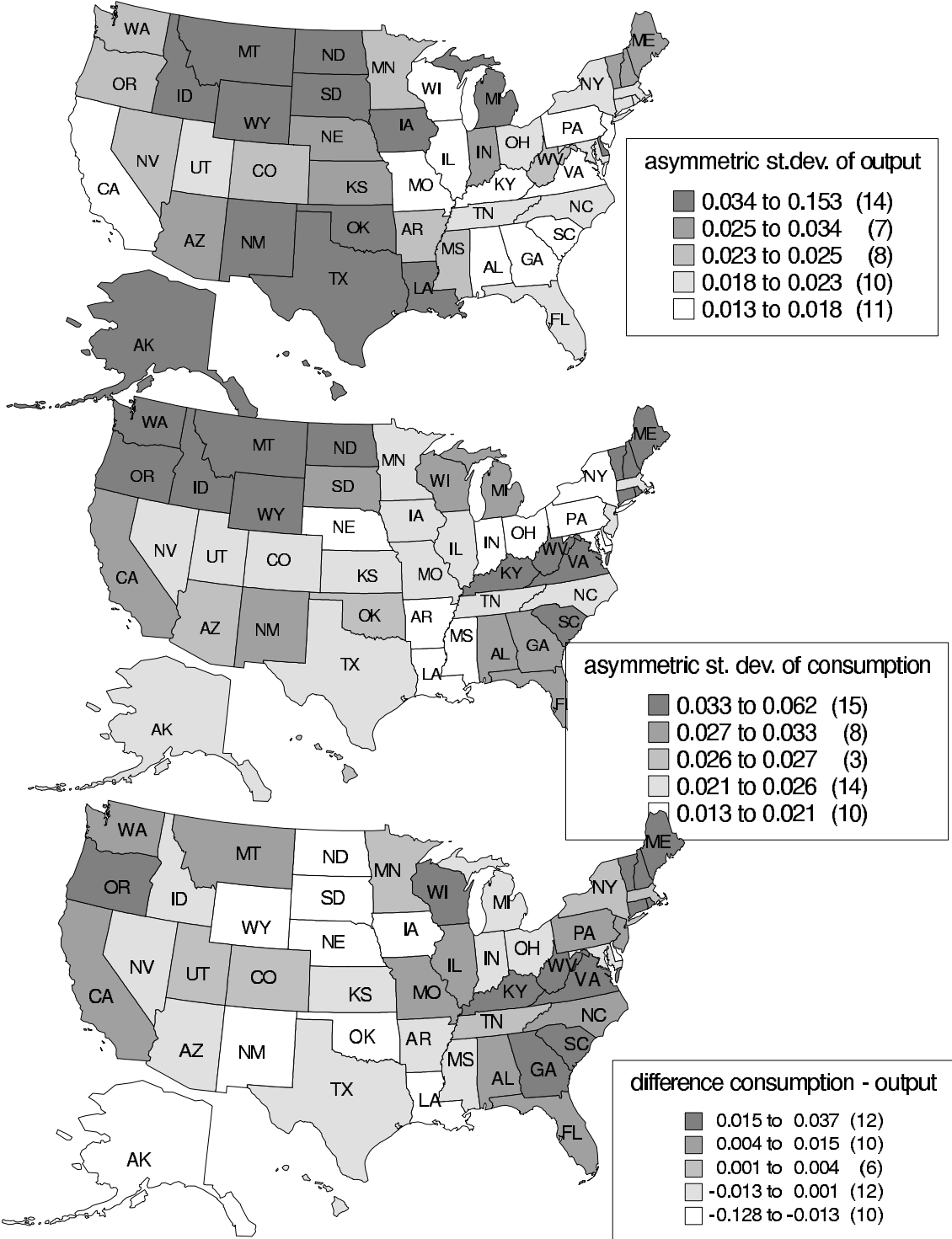
Note: The figures plot the pairs  $(Corr(y_i, y_j), Corr(c_i, c_j))$ , where  $y_i$  and  $c_i$  represent de-trended output and consumption in state  $i$  respectively. In the top plot the source for non-durable consumption data is the Bureau of the Census (19 states, 1978-1995) and the source for real output data is the Bureau of Economic Analysis. In the bottom plot the source for non-durable consumption data is Sales&marketing Management (50 states, 1969-1995) and real output data is obtained by deflating nominal output (source: Bureau of Economic Analysis) by state CPI (own source). The figure shows the results for the model estimated in growth rates.

Figure 4: Standard deviations of asymmetric shocks to output and non-durable consumption



Note: The figures plot the pairs  $(stdev(y_{it} - y_t^{us}), stdev(c_{it} - c_t^{us}))$ . In the bottom plot the standard deviation of asymmetric shocks in consumption is computed without including the idiosyncratic component, i.e., the term  $\phi_i^2$  in Eq. (7). The figure shows the results for the model estimated in growth rates.

Figure 5: Geographic distribution of the standard deviations of asymmetric shocks to output and non-durable consumption



Note: The maps show the geographical distribution of the standard deviations of asymmetric shocks to output (top) and non-durable consumption (middle), and of the difference between the two (bottom). The standard deviations of asymmetric shocks in consumption is computed without including the idiosyncratic component, i.e., the term  $\phi_i^2$  in Eq. (7). The figure shows the results for the model estimated in growth rates.