New Measures of Hours Worked in the OECD: Implications for Business Cycles, 1960 - 2010*

Lee E. Ohanian† UCLA

Andrea R. Raffo‡ Federal Reserve Board

Abstract

This paper constructs a new dataset for total hours worked at the quarterly frequency for 14 OECD countries over the last fifty years. We find that key cyclical features of labor markets across countries differ markedly from the empirical regularities reported in the literature based on just U.S. data or on international employment data. We document that total hours in many OECD countries are about as volatile as output, that the volatility of total hours relative to output volatility has increased over time in almost all countries, and a large fraction of labor market adjustment takes place along the intensive margin outside the United States. We also find a number of puzzles regarding labor wedges in Europe. In recessions, the cyclical labor wedges for European countries constructed using employment appear to be much too large, while the labor wedges constructed using hours

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†Corresponding authors: ohanian@econ.ucla.edu

‡Email: andrea.raffo@frb.gov

appear to be much too small. The Great Recession in many OECD countries represents a major puzzle in that both hours-based and employment-based labor wedges are roughly zero, while those in the U.S. Great Recession - and those in previous European recessions - are roughly an order of magnitude larger. This indicates that understanding many OECD recessions requires analyzing why and how their labor markets changed so much in the last few years, and why these labor markets during recessions appear to be inconsistent with theories of firing costs.

1 Introduction

Documenting and understanding cyclical changes in hours worked has been a primary focus of business cycle research since at least Kydland and Prescott (1982) and Hansen (1985), and the very different labor market outcomes observed during the 2008-09 recession across countries have generated renewed interest in the evolution of labor input during fluctuations. However, this research has often focused on the U.S. due to the very limited availability of systematic measures of aggreate hours worked in other countries, including other high income countries. Thus, what is known about cyclical changes in labor input and productivity in other countries is largely based on measures of employment (see for example Backus, Kehoe, and Kydland, [1995], BKK henceforth).

Studies of cyclical fluctuations in other countries largely abstract from documenting and analyzing changes in the intensive labor margin, which is an important limitation for a number of reasons. One reason is that it limits the extent that conclusions about cyclical changes in labor can be drawn across these countries. Another is that because it is generally accepted that hiring and firing costs are much higher in Europe than in the U.S., one would expect that the relative size of fluctuations in the intensive versus extensive margin may be very different. Since at least the influential work of Hopenhayn and Rogerson (1993), many economists argue that European labor markets provide an excellent setting for quantifying the impact of labor market distortions and policies, but this laboratory is significantly limited for addressing cyclical fluctuations due to data limitations on hours worked.

This paper addresses these shortcomings by first constructing a new dataset for total hours worked at the quarterly frequency which covers 14 OECD countries and spans the last fifty years. The dataset draws on a variety of international sources, including data from national statistical offices, establishment surveys, and household surveys. There are three contributions. One provides the most comprehensive, international database of total hours worked that can be used by other researchers. A second contribution documents and compares cyclical fluctuations in total hours between the U.S. and other countries. The third contribution addresses the Great Recession using these new data.

This paper addresses these issues by presenting quarterly measures of total hours worked for a number of OECD countries from 1960 to 2010. We construct these measures consistently across countries according to national income and product account constructs. We then use these measures to compare business cycle properties of total hours worked across OECD countries, including the U.S., focusing on three questions: (1) How sensitive are accepted business cycle features in OECD countries based on employment to using hours? That is, what fraction of fluctuations in labor input are due to hours per worker versus employment, and how have these features changed over time? (2) What fraction of fluctuations in output and labor across countries is accounted for by labor versus productivity wedges? (3) How does the Great Recession in other OECD countries, using hours versus employment, compare to that in the U.S.?

This last question is important, as Ohanian (2010) documents large differences in this recession between the U.S. and other advanced economies. He finds that productivity is close to trend in the US, and that the U.S. Great Recession is due to a very large decline in labor input and a historically large labor wedge (i.e. a large deviation of the marginal rate of substitution between consumption and leisure from the marginal product of labor). In the other G7 countries, the Great Recession is the consequence of large productivity declines, with only very small employment declines and no labor wedge. We use total hours to reassess Ohanian's analysis of the Great Recession, as the small changes in Western European employment may reflect large firing costs, and labor input may have declined considerably through declines in hours per worker.

Our main findings contrast with commonly held views in some cases, and raise significant puzzles in other cases. Specifically, we show that employment is a poor proxy for labor input in many OECD countries, as changes in hours per worker are about as large as changes in employment. We also find that employment-based labor wedges are much too large in Europe, given high European firing costs, while hours-based labor wedges are much too small. Finally, we find that the Great Recession is a substantial puzzle in Europe, as both employment-based and hours-based labor wedges are nearly zero in many European countries. This stands in sharp contrast to labor wedges in the U.S. during the Great Recession, or wedges in other European recessions, both of which are an order of magnitude larger.

The paper is organized as follows. Section 2 describes the data sources and the approach we use to construct the hours measures. Section 3 compares standard business cycle features, including the cyclical volatility of hours, employment, and productivity, and their correlation with output across countries. Section 4 uses the business cycle accounting approach developed by Cole and Ohanian (2002), and Chari, Kehoe, and McGrattan (2007), to construct labor and productivity wedges using both emloyment and hours for recessions since 1960, with a specific focus on assessing the relative importance of these wedges during the Great Recession. Section 5 concludes.

2 Data

We collect national accounts series for nominal output and its components from the OECD-Economic Outlook and deflate them using their specific price deflators. Throughout the paper, our measure of labor input is total hours worked (H), constructed as the product between hours worked per worker (h) and employment (E), normalized by the size of the population aged 16-64 years (P). That is

$$H = h * \frac{E}{P}$$

Similarly, we define labor productivity (LP) as the ratio between real output and labor input,

$$LP = \frac{Y}{H}$$

In measuring labor input, data on employment (E) and population aged 16-64 (P) are from national statistical offices and the OECD-Economic Outlook database. We next present our methodology to construct our measures of hours per worker (h), which represent one of the main contribution of the paper. The Appendix presents country-specific details and sources.

2.1 Construction of hours per worker

Official series for quarterly hours worked per worker in advanced economies are typically short and their comparability across countries is often considered problematic. In our sample, only theseries for the United States begins in 1960Q1, whereas they typically start sometimes in the mid-1970s for other countries. Moreover, the underlying surveys used to construct these series, whether using establishments or labor force surveys, are not uniform across countries and, in some cases, for the same country at two different dates.

Establishments surveys have been conducted in many countries at a quarterly or even monthly frequency since the 1960s, but they often collect hours paid and not hours actually worked. Thus, they do not account for differences across countries in important features of labor contracts such as paid vacation or sick days. In addition, these surveys do not sample all sectors of the economy. For instance, the government sector is often neglected by these surveys.

Labor force surveys tend to be more comprehensive since they directly sample individuals in the labor force, but they suffer from several shortcomings as well. First, it is well-known that these surveys present an upward bias for the estimated working time due to self-reporting. Second, there are methodological differences across countries in the construction of these surveys which might also affect the concept of working time measured, thus undermining their comparability[1]. Third, in many countries labor force surveys have been conducted primarily at a annual frequency until very recently.

[1]For instance, some countries do not include in their questionnaires a distinction between contractual hours and hours not worked because of illness or holidays.

Given all these data limitations, it is not suprising that the literature on international business cycle fluctuations has focused on employment as the summary statistics for labor market outcomes. One important contribution of this paper is to provide researchers with a dataset of total hours worked, thus including both the intensive and the extensive margin. Since labor market institutions, such as firing costs and the generosity of unemployment benefits, differ markedly across countries, likely affecting the incentives to adjust along these two margins, employment might not fully capture the overall adjustment in labor input over the cycle.

Our methodology to construct quarterly series of hours per worker consists of three elements. First, we obtain a dataset of hours worked per worker that has been adjusted to take into account cross-country variation in elements like sick days and holidays. The series contained in this dataset, however, are available only at annual frequency. Second, we construct a dataset of quarterly indicators for hours worked per worker composed by the official series extended using information from establishment surveys published by the International Labor Organization (ILO). Third, we implement a procedure to adjust our quarterly indicators to ensure that they inherit some of the properties of the better-quality annual series. We next provide more specific details about these three elements.

The Conference Board, in partnership with the Groningen Growth and Development Centre (GGDC), has produced estimates of hours worked per worker that are comparable across countries, but available only at annual frequency. These series, which are contained in their Total Economy Database (TED), are adjusted to reflect most sources of cross-country variation in hours worked (contracted length of the workweek, statutory holidays, paid vacation and sick days, days lost due to strikes...) and are consistent with aggregate measures of output. The TED dataset covers a large set of developed and developing countries, in many cases starting as early as 1950, and is currently the benchmark source of data for analysis of trends in total hours worked across countries (see, for instance, Rogerson [2006] and Ohanian *et al.* [2008]).

We construct a dataset of quarterly indicators of hours worked per worker as follows. For all countries in our sample, we first collect quarterly series of hours worked per worker that are consistent with the national accounts from national agencies[2]. We will refer to these data as the official series. Since these series do not cover the whole postwar period, we extend them to the early 1960s using measures of hours worked per worker collected from ILO and, in a few instances, the OECD Main Economic Indicators (MEI)[3]. Although both publications are based on information from establishment surveys, we opted for adopting primarily the ILO series for several reasons. First, the ILO series often measure total hours *actually worked,* and not just paid for. Second, the ILO series cover the non-agricultural sector (i.e. manufacturing, mining and quarrying, construction, commerce, transport and services) whereas the OECD-MEI series typically cover the manufacturing sector only. Third, the ILO series have statistical properties in terms of trends and variability closer to the official series, suggesting that the underlying surveys were primary sources used by the national agencies.

Our procedure to extend the official series to the 1960s consists of estimating a country-specific statistical relationship between the official and the ILO series and then backcasting the official series using the estimated model and the ILO data. To ensure that the estimated OLS coefficients are not affected by extreme values, we first remove outliers in the ILO series following the approach suggested by Iglewicz and Hoaglin (1993) in the *Engineering Statistics Handbook.* More specifically, we construct the test statistics

$$M_t = 0.6745\,\frac{x_t - \widehat{x}}{MAD}$$

where x_t is the first difference of the logarithm of the ILO series, $\widehat{x}$ is the median growth rate, and MAD is the median absolute deviation, that is $MAD = median\,(|x_t - \widehat{x}|)$.

[2] The Japanese series excludes the agriculture sector, so we construct an employment-weighted series using annual levels in this sector as estimated in the EU-Klems database.

[3] In particular, we used several historical issues of the ILO Bulletin of Labor Statistics and the ILO International Labour Review to import these data into electronic format. We generally used the latest available vintage of data for each series, smoothing breaks due to changes in the survey methodology using interpolation.

We identify as outliers those observations for which $|M_t| > 3.48$, which corresponds to a probability of 0.0005 in a standard normal distribution. Finally, we replace the outliers with an interpolation that uses the preceeding and following observations. Notably, our test statistics identifies at most 4 observations as outliers.[4]

After eliminating outliers in the ILO series, we estimate an econometric model of the level of the official series (h_t^i) as a function of a constant (c), current and lagged values of the ILO series $\left(\widetilde{h}_{t-k}^i\right)$, and a time trend:

$$h_t^i = c + \beta_0 \widetilde{h}_t^i + ...\beta_k \widetilde{h}_{t-k}^i + \gamma t + \varepsilon_t^i \qquad (1)$$

We estimate country-specific models using all the observations available for overlapping quarters up to 1984Q4, since there is overwhelming evidence that the volatility of output has declined significantly after 1984 (Great Moderation). In addition, since several authors have documented that, in the United States, the volatility of total hours has increased relative to the volatility of output, we do not include indicators of activity among the regressors in order to avoid imposing a tight relationship between output and labor input.

As for the model specification, we select the number of lags for the ILO series (k) using Akaike and Schwarz information criteria and perform Lagrange Multiplier tests on the residuals to test for serial correlation. Overall, this estimation produced adjusted R^2 between 0.55 (in the case of Australia, whose specification does not include a time trend) and 0.98 (in the case of France and Germany, with a time trend included only in the specification for Germany).

This estimation procedure is applied to Australia, Canada, France, Germany, Italy, Japan, Norway, and Sweden. Since the official series for Austria, Finland, Ireland, and Korea start after 1982, we use the entire sample to estimate our statistical model for these countries. No estimation is applied to the United States (the BLS series we use begins in 1947) and the United Kingdom (for which only the official series, which starts in 1971, is

[4]The Appendix reports the exact observations identified as outliers in each country

available)[5].

Our final step involves adjusting the quarterly indicators of hours per worker so that they conform with the annual series obtained from the TED dataset. We follow the method proposed in Denton [1971] since it is commonly implemented by national statistical offices.[6] This method involves minimizing the (weighted) adjustments imposed on our constructed quarterly indicators subject to the constraint that the sum of the quarterly adjusted series equals the value of the annual TED series. Formally,

$$\underset{x}{Min}(x-z)'A(x-z)$$

$$s.t. \quad \sum x = y$$

where y is the annual TED series, z is the quarterly indicators we construct using the official and the ILO series, x is the adjusted quarterly series that we will use inour analysis, and $A = D'D$ is a weghting matrix. One possible choice for the weighting matrix is the identity matrix, which would imply that the penalty function is minimized by distributing the discrepancy between the annual and (the sum of the) quarterly series evenly across quarterly observations. However, this would introduce discrete jumps at the turn of the year, thus spuriously altering the properties of the series. Denton shows that a penalty function based on the difference between the first difference of the two series $\left(\sum\left[\Delta(x-z)\right]^2\right)$ or the proportional first difference of the two series $\left(\sum\frac{1}{z}\left[\Delta(x-z)\right]^2\right)$ does not suffer from this shortcoming.[7] Since we did not find, quantitatively, significant differences between the two options, we decided to present results using the proportional first difference specification.

The table below presents the countries and their time periods considered in our sample.

[5] Eurostat produces a series of hours per worker in Spain which starts in 1995. However, we were not able to find consistent survey data covering the previous years. Thus, we opted to include Spain only in the analysis of the Great Recession.

[6] For instance, the BLS regularly uses this methodology to derive quarterly estimates of U.S. series (e.g. manufacturing output).

[7] For a more articulated discussion on the implications of alternative weighting matrix, see Denton (1971). For a broader discussion about interpolation methods, the reader is invited to check the Handbook of Quarterly National Accounts Compilation.

Table 1. Hours per Worker: Sample

Australia	1970-2010	Italy	1960-2010
Austria	1965-2010	Japan	1960-2010
Canada	1960-2010	Korea	1970-2009
Finland	1960-2010	Norway	1960-2010
France	1960-2010	Sweden	1975-2010
Germany	1960-2010	UK	1971-2010
Ireland	1960-2010	U.S.	1960-2010

2.2 Testing the methodology

This section tests the quality of the data construction procedure by comparing actual hours data in three countries for which there are official series (US, Germany, Japan) in the early years, to constructed hours data. Since the data for the United States cover the whole period of interest (1960Q1-2010Q4), we construct a US series by applying the procedure presented in Section 2.1. That is, we first collect U.S. hours per worker in the non-agricultural sector for the period 1960Q1-1984Q4 from the ILO and correct for outliers using the modified Z-score statistics. We next estimate a relationship, following equation (1), between the official (BLS) series and the ILO series over the period 1975Q1-1984Q4. We then use the estimated coefficients and the ILO series to backcast the official series from 1974Q4 to 1960Q1. Finally, we adjust this extended series, that now covers the whole sample 1960Q1-2010Q4, to conform with the TED annual data using Denton's procedure. Figure 1 plots the counterfactual series we constructed together with the official series.

[Insert Figure 1 here]

Our procedure produces a series for the United States that matches the official series very well. Denton's adjustment pins down accurately the level of the series whereas the ILO data reproduce the cyclical properties of the series. This suggests that most likely the establishment series reported by the ILO is an important input in the construction of the official BLS series. Table 2 provides more statistical evidence in support of this observation by comparing moments of the two U.S. series. In addition, we report moments for two counterfactual series created for Germany and Japan, since the official data for these countries begin in 1970Q1 and 1968Q1 respectively, thus allowing us to assume that we do not have data until 1974Q4.

[Insert Table 2 here]

Overall, we find that the standard deviation of the cyclical components of these counterfactual series is close to the standard deviation of the official series, especially when we transform the data using four-quarter changes and the HP filter. Similarly, the counterfactual and the official series are highly correlated. Thus, this evidence indicates that our procedure provides a very accurate description for the cyclical patterns of hours per worker across these countries.

3 Labor input and labor productivity over the business cycle

Using our newly-constructed dataset, we next present some business cycle facts about labor input - measured as total hours worked - and labor productivity - measured as real output divided by total hours worked - across countries and over time. Throughout the analysis, our statistics refer to the cyclical component of the data obtained after applying the HP filter to the (logaritm of the) series[8].

Notably, we find that, on average, labor input is almost as volatile as output, as changes in hours per worker are quantitatively more important than one might think, especially in Europe and Japan. Therefore, employment data do not provide an accurate description of labor market outcomes across countries. In addition, we find that the Great Moderation

[8] We also reproduced all the tables using the first difference operator, four-quarter changes, and the BP filter. Results are relatively robust to the various filtering procedure and are available upon request.

has been associated with a sharp increase in the volatility of labor input relative to the volatility of output. This finding, which is consistent with the evidence provided by Galì and Gambetti [2010] (GG hanceforth) and Galì and Van Rens [2011] (GVR henceforth) based on U.S. data only, suggests that the Great Moderation was not generated by a reduction of the variance of the shocks driving business cycles, as implied by a narrow view of the "good luck" explanation. However, since it applies to several advanced economies, our results also call for an explanation that is not specific to the United States. Finally, we document that our hours-based measure of labor productivity is systematically procyclical but negatively correlated with total hours of work across countries, whereas this is not the case when we use an employment-based measure of labor productivity. We argue that standard equilibrium models have difficulties in accounting for this correlation together with the large volatility observed in labor input, and future research should devote more attention to the role of labor markets in trasmitting business cycle fluctuations.

3.1 Total Hours: Volatility and Correlation

Figure 2 presents the standard deviation of total hours worked relative to the standard deviation output for all countries in our dataset over the entire sample period. Our data reveal that labor input is almost as volatile as output, with the average ratio around 0.9, although there is quite a bit of variation across countries. This fact about the volatility of labor input stands in sharp contrast with the typical description of labor fluctuations based on employment data as presented in the literature (see, for instance, BKK [1995]).

[Insert Figure 2 and Table 3 here]

As shown in the top panel of Table 3, BKK report that the volatility of labor input is, on average, nearly two-thirds as large as the volatility of output. Among G7 countries, the volatility of employment-based labor input is higher in Canada and in the U.K., but much lower in the Euro countries (an average of France, Germany, and Italy) and in Japan. Note that, as shown in the second row, standard general equilibrium models reproduce very little volatility in labor input compared to the employment data. For instance, in the benchmark two-country BKK model the volatility of labor input is about half as much of the volatility of output.

Using our measures of total hours worked over the pre-1984 period, a comparable sample period (middle panel of Table 3), we find that the volatility of labor input is about three-quarters as large as the volatility of output. Most importantly, the volatility of labor input in the Euro countries and Japan jumps up sharply, suggesting that hours per worker represent an important margin of adjustment for labor input in these countries. Indeed, the standard deviation of hours per worker in the Euro countries and in Japan is as large as the standard deviation of employment. These results contrast not only with employment-based statistics, but also with the typical features of labor market dynamics obtained by analyzing U.S. data, as presented, among others, in Kydland [1995], Cho and Cooley [1994], and Hall [2007], for which the volatility of hours per worker is about half the volatility of employment.[9] More generally, these findings are consistent with the idea that different labor market institutions, such as high firing costs, generous unemployment benefits, but also work-sharing arrangements, are likely to affect the extent to which European and Japanese firms adjust labor input along the extensive or the intensive margin.[10]

Turning to the bottom of Table 3, we find that, on average, the volatility of labor input has increased dramatically over the past 25 years, thus extending the findings of GG and GVR for the United States to a broader set of countries. This observation indicates that theories that explain the Great Moderation with a proportional reduction of the variance of

[9] Incidentally, we note that since we are reporting standard deviations (of HP residuals), the volatility of the intensive and the extensive margin do not sum up to the volatility of total hours worked. When we compute the variance of these series using the first difference operator, for which terms are additive up to a covariance term, we find that the two margins account for nearly 50 percent of the variance of total hours worked.

[10] Recent work by Fang and Rogerson [2010], for instance, shows that, in steady state, higher firing costs induce firms to cut employment and increase hours per worker as, from the perspective of the production function, the two margins are substitute inputs.

all shocks (strong version of the "good luck" story) would fail in reproducing this empirical regularity. On the other hand, GG and GVR interpret the U.S. evidence as consistent with an increase in labor market flexibility due to U.S.-specific changes in policies or institutions, whereas our findings suggest that this phenomenon calls for an explanation that applies to most high income countries.[11]

We next analyze how the cyclical properties of labor input vary across countries and over time in terms of comovement. Figure 3 presents the correlation of labor input with output over the whole sample (panel a) and in the pre- and post-1984 period (panel b). Labor input is procyclical, as typically implied by employment data as well as standard equilibrium models, but the magnitude of this correlation varies significantly across countries. In particular, labor input is strongly procyclical in Canada, U.K., and U.S., but less so in Euro countries and in Japan. Moreover, labor input has become, on average, more correlated with output in the post-1984 period, but this correlation has somewhat decreased in the United States, Euro countries, and Japan.[12]

[Insert Figure 3 here]

Panels (c) and (d) document the cyclical relationship between intensive and extensive margin. Notably, hours per worker and employment are, on average, only weakly correlated. This result is particularly strong for Euro countries, where this correlation is essentially zero over the years 1960-2007. In addition, this correlation has weakened significantly over time, approaching zero in Japan or becoming even negative in Euro countries. All told, these cyclical correlations suggest that labor input is highly synchronized with output in Canada, U.K. and U.S., but less so in Euro countries and Japan. This result points to the

[11] Barnichon [2010] argues that lower labor market frictions cannot account for the large increase in hours per worker, suggesting that other structural changes might be quantitatively responsible for this change in volatility.

[12] GG also document this observation for the U.S.

fact that labor market rigidities, which tend to be higher in the latter group of countries, affect the timing of adjustment along the two margins.

3.2 Labor Productivity: Volatility and Correlation

As shown in Table 4, labor productivity tends to be almost as volatile as output, except for Canada and U.S. where it is much less volatile than output. This observation does not change when we use an employment-based measure, as typically done in the literature on international fluctuations, instead of our hours-based measure of labor productivity. Over time, the volatility of labor productivity relative to output volatility in the United States has increased, going from 0.51 to 0.64. We also find that this is the case in Euro countries and in Japan, but not in Canada and U.K. The cross-country average of the distribution is modestly higher during the Great Moderation.[13] However, the employment-based of labor productivity depicts a very different picture. Except, for the U.S., when we use the emplpoyment-based measure of labor productivity we find that its volatility relative to output volatility has generally fallen, especially in European countries and in Japan.

[Insert Table 4 here]

In the U.S. data, it is a well-established fact that labor productivity and total hours are weakly correlated, a feature of the data that is difficult to account for in a standard real business cycle model à la Kydland and Prescott. Benhabib et al. [1991] account for this empirical regularity by incorporating shocks to a home production sector into the standard model. Christiano and Eichenbaum [1992], in contrast, argue that wealth effects associated with government spending shocks represent a key mechanism to account for this weak correlation. In addition, GG document that this correlation has been falling over time and

[13] GG also document that the absolute volatility of labor productivity in the United States has fallen significantly during the Great Moderation, but it has increased relative to output volatility. In our data, however, the increase in the volatility of U.S. labor productivity is less marked than in the GG's dataset. This difference might be due to the fact that GG use series that refer to the nonfarm business sector only.

the evidence provided in Barnichon [2010] is also consistent with this finding. GG concludes that the change in the productivity-hours correlation and in the volatility of hours over time are clearly inconsistent with a strong version of the good luck hypothesis to explain the Great Moderation (i.e. the variance of all shocks affecting the cycle has experienced a roughly proportional fall). Similarly, the cyclical properties of labor productivity vis-à-vis output bear important implications on the sources of fluctuations driving business cycles.[14] Thus, since the sign of these correlations and their time changes have received much attention, we explore what the international data have to say about these features using our measures of total hours of work. Figure 4 summarizes the evidence on these moments.

[Insert Figure 4 here]

As shown by the full bars in panel (a), labor productivity over the period 1960-2007 is generally procyclical, with an average correlation slightly above 0.5. For comparison, we report the same correlation for the employment-based measure of labor productivity, as typically done in the literature (crossing bars). Overall, the hours-based and the employment-based measures of labor productivity depict a very similar picture, with the former only somewhat less procyclical. Among G-7 countries, productivity tends to be strongly procyclical in Euro countries and Japan, whereas in Canada this correlation is much weaker. Panel (b) uses the hours-based measure of productivity to analyze changes in the magnitude of this correlation over time. Our data suggest that this correlation has generally weakend, thus confirming that the evidence provided in GG and GVR applies to a larger set of advanced economies. Yet, we observe important variations across countries, with the magnitude of this correlation falling significantly in the U.K. and the U.S., but remaining essentially unchanged in Euro countries and Japan. Nevertheless, we note that despite these changes, in the post-1984 sample labor productivity is still procyclical.

[14] Gali' and van Rens [2010] argue that a reduction in labor market frictions can account for these facts together with the increase in the volatility of real wages that occurred during the Great Moderation.

Panel (c) shows that the correlation between the hours-based measures of labor productivity and labor input (full bars) is weak and, on average, negative across countries. This result stands in sharp contrast with the evidence that would emerge if one were to use employment-based measures for these two series, represented by the crossing bars. According to the latter measures, labor productivity tends to be positively correlated with labor input, thus emphasizing one more time that different measurements of labor input might provided very different inference about empirical regularities. Finally, panel (d) shows that this correlation has declined sharply in the post-1984 period, in accordance with the U.S. evidence, where it has switched sign.

3.3 Summary: Facts about Labor Market across OECD Countries

The international business cycle literature has focused on (un)employment to summarize labor market outcomes across countries. This was due in part to data limitation, since hours per worker for OECD countries have become available only recently and do not cover the whole postwar period, and in part to the evidence produced using U.S. data, which suggests that the intensive margin accounts for about one third of the fluctuations in total hours worked.

Using our constructed dataset of total hours worked, we have documented some new stylized facts that are in sharp contrast with the conventional view about labor markets. We find that labor input, when measured using total hours of work, is as volatile as output, that its volatility has increased markedly over the past 25 years, and that the intensive margin is quantitatively as important as the extensive margin over the business cycle. Turning to labor productivity, our findings confirm that labor productivity is about as volatile as output and generally procyclical, negatively correlated with labor input, and even more so in during the Great Moderation.

These observations are difficult to reconcile using standard theories of the business cycle. For instance, international real business cycles models à la BKK reproduce about half of the volatility observed in the data. Similarly, indivisible labor models à la Hansen [1985] or preferences that introduce high short-run response of labor input to wages, as in Greenwood et al [1988][15], although able to generate larger volatility in labor input, deliver labor input volatility that is significantly short of what we find in the data while inducing a high correlation between labor input and labor productivity, which is counterfactual.

All told, these findings suggest that labor markets represent a key, and often overlooked, transmission mechanism of business cycle fluctuations. Since labor market institutions, such as firing costs and the generosity of unemployment benefits, vary to a great extent across countries, understanding business cycle fluctuations in labor input requires understanding how policies and institutions affects the incentives to adjust labor over the business cycle.

4 Business Cycle Diagnostics

4.1 The Diagnostic Framework

Cole and Ohanian (2002) and Chari, Kehoe, and McGrattan (2007) present a diagnostic methodology for broadly evaluating the classes of theories that may potentially account for fluctuations. This process has been used implicitly in one form or another by much of the real business cycle literature, including Kydland and Prescott (1982), and in general equilibrium analyses of fluctuations that focus on channels other than productivity, including Hall (1997), Cole and Ohanian (2004), Gali', Gertler, and Lopez-Salido (2007), Shimer (2009), and Mulligan (2010).

This process involves using time series data on output, consumption, investment, and labor input to measure wedges from the first order conditions in a parameterized optimal growth model, and then use those wedges as diagnostics for constructing economic theories of fluctuations. In this section, we use this analytical framework to measure such wedges in

[15] These preferences are commonly used in open economy models that study international business cycles. See, for instance, Raffo [2008].

two ways. For the sample of OECD countries considered, we first construct these wedges using the standard measure of employment as labor input, and we then compare them to wedges constructed using the measures of hours worked reported earlier in this paper as the measure of labor input.

The theoretical framework is given as follows. Preferences are:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \{\ln(C_t) + \phi \ln(1 - L_t)\}.$$

The technology, resource constraint and the law of motion for capital are given by:

$$AK_t^{\theta} L_t^{1-\theta} = Y_t = C_t + I_t + G_t,$$

$$(1 + g)K_{t+1} = (1 - \delta)K_t + I_t,$$

where the variables are, respectively, per-capita measures of consumption (C), fraction of time devoted to market activities (L), capital stock (K), real output (Y), investment (I), and government spending (G). The variable A denotes total factor productivity, and g is the exogenous growth rate of technology, respectively. All per-capita variables are detrended at a two percent annual rate. The appendix describes the sources and construction of these data.

The parameters are chosen as follows. We set β to 0.99, $\theta = 0.36$, $\delta = .0175, g = .005$, and ϕ is chosen so that steady state hours worked is 1/3 of the time endowment. Typically, this framework is used to construct four deviations, or wedges: (1) a productivity wedge, which is the ratio between output and the Cobb-Douglas aggregator of capital and hours worked(i.e. the Solow Residual), (2) a labor wedge, which is the difference between the marginal rate of substitution between consumption and leisure and the marginal product of labor, (3) a capital market wedge, which is the difference between the intertemporal marginal rate of substitution and the return to capital, and (4) a resource constraint wedge that measures changes in the allocation of output between consumption, investment, and government spending. We will focus on productivity and labor wedges as these are typically the most important quantitatively in terms of accounting for fluctuations. These deviations are given as:

$$Z_t = \frac{Y_t}{AK_t^{\theta}L_t^{1-\theta}}$$

$$X_t = \frac{(1-\theta)(Y_t/L_t)(1-L_t)}{\phi C_t}$$

For the U.S., we measure these wedges for all NBER recession dates from 1960 through 2007. For other countries, we measure the deviations using recession dates between 1960 and 2007 identified by the Economic Cycle Research Institute (ECRI), which uses a methodology to date recessions that is very similar to that of the NBER.

For the 2008-09 recession, we measure these wedges for all countries using common dating, from 2008:1 - through 2009:4, which is the hours trough of the U.S. recession. We use this trough dating convention because of our interest in the evolution of labor input, and because labor continues to decline significantly following the NBER trough date. (For other NBER recession trough dates, labor input is closer to its trough value).

This approach will allow us to compare our findings to those of Ohanian (2010), who measured these deviations in the U.S. using both hours and employment as labor input, but for the other G7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) used just employment as hours were unavailable. Note from these equations that the two alternative measures of labor input affect TFP, and in particular, the labor wedge.

We conduct separate analyses for the Great Recession, and for all other recessions. For each of these analyses, we make two comparisons. We first measure the size of labor and productivity distortions across countries using both employment and total hours worked. To understand the relative importance of these deviations for fluctuations, we compare their size to average trough recession levels of output and employment, and we then measure the relative contributions of productivity and labor deviations by simulating the model economy with each deviation individually, and measuring the fraction of output and labor change accounted for by each distortion.

4.2 Cross-Country Differences in Employment Protection and Implications for Diagnostics

Before turning to the findings, we note that this collection of countries has very different labor market institutions and regulations that are broadly defined as *employment protection legislation*. The OECD produces employment protection rankings for OECD countries that measures the strength of these policies, and we summarize the OECD's ranking here (OECD, 2004). The OECD index is based primarily on (i) the strength of protection of permanent workers against individual dismissal, (ii) the specific requirements for collective worker dismissal, and (iii) regulations on temporary employment contracts.

Several of the European countries studied here have relatively high levels of employment protection. Specifically, Spain ranks 4th highest in protection (out of 28 countries), while France is 6th, Sweden is 7th, Norway 8th, and Germany is 10th. At the other end of the scale, the UK is 27th out of 28 countries, and moreover has employment protection far below that of the other countries, and the U.S. has the least amount of employment protection, and is ranked 28th.

These large cross-country differences in employment protection indicate large differences in hiring and firing costs across countries, and thus provides an interesting way to interpret the findings we present below. Specifically, higher firing costs decrease the incentive to cut workers during recessions, and at the same time, increase incentives to reduce hours per worker in order to reduce labor input. This suggests we should observe particular cross-country patterns in these deviations, including that the difference between hours-based and employment-based labor deviations should be considerably larger for much of Western Europe than for the United States and the UK.

4.3 Cyclical Features of Labor and Productivity Wedges in OECD Countries: 1960 - 2007

This section presents statistics on cyclical labor and productivity wedges, measured using both total hours and employment as labor input. We use all data up to the Great Recession, as we treat the Great Recession separately in the following section. We begin by reporting the volatility of the cyclical components of the wedges relative to the volatility of output, and the correlation of the wedges with the cyclical output. This approach to reporting second moment statistics of macroeconomic variables is standard in the business cycle literature (see Prescott (1986)). We focus on HP filtered logged data to facilitate comparison with existing business cycle studies.[16] Following this second moment analysis, we examine in detail the behavior of these wedges during recessions as defined by the NBER for the U.S. and by the ECRI for other OECD countries.

Our main findings are that the wedges are large, they fluctuate significantly over the business cycle, they differ considerably depending on the measure of labor input, that their properties differ somewhat across countries. Our wedge analysis also identifies some significant puzzles about the nature of European fluctuations given the size of firing European firing costs and how those costs impact incentives.

[Insert Table 5 here]

Table 5, panel (a), shows the volatility of the two wedges relative to the volatility of output for the US and for Western Europe. For most countries, these measures differ depending on whether hours or employment is used as labor input, and there is considerable variation across countries. The table shows that for the US, the labor wedge measured using hours is about as volatile as output, while the employment-based measure is only about

[16] We also construct cyclical wedges using oother filters, such as first difference, four-quarter changes, and bannd-pass. Results are available upon request.

60 percent as volatile as output. The productivity wedge is less volatile than the labor wedge; the hours-based productivity wedge is about 40 percent as volatile as output, and the employment-based productivity wedge is about 50 percent as volatile as output.

The volatility of both wedges is higher in Europe and there are considerable differences across European countries. The hours-based labor wedge is more volatile than output in Euro countries (1.19), but is significantly more volatile that output in the UK (1.99), whereas it is less volatile than output in the US (0.97). The employment-based labor wedge is also more volatile than its US counterpart, ranging between 0.96 (Euro) to 1.45 (UK), compared to just 0.6 in the U.S.

European productivity wedges are also more volatile than US productivity wedges. The relative volatility of the hours-based productivity wedge is about 0.65 in Euro countries and UK, compared to about 0.40 for the US. The employment-based productivity wedges provides a very similar picture.

Table 5, panel (b), shows the cross-correlations between the wedges and output between 4 lags and 4 leads. For the US, the labor wedge is countercyclical, as the contemporaneous correlation is 0.67 for the hours-based wedge, and 0.57 for the employment based wedge, which means that the wedge between the marginal rate of substitution and the marginal product of labor widens when the economy is below trend, and narrows when the economy is above trend. The labor wedge-output correlations across all lags and leads range between 0.30 to 0.72 for hours and 0.21 to 0.68 for employment. Productivity is strongly contemporaneously procyclical, the correlation for the two measures of TFP is 0.84 and 0.90, respectively.

The cyclical correlation of the labor wedge with output is not as strong in Europe compared to the US, and also varies considerably across European countries. The correlation of the labor wedge with output in Euro countries is contemporaneoulsy much less correlated than in the U.S., with a correlation ranging between 0.23 for the hours-based wedge and 0.06 for the employment-based. There is, however, a stronger correlation between lagged output and the labor wedge in these countries. For example with output lagged two quarters, the correlations for both labor wedges range from about 0.3 to 0.4. In contrast, the cyclicality of the labor wedge in the UK is closer to that of the US, where the contemporaneous correlation is 0.52 (hours-based) and 0.31 (employment-based). As in the case of most of the other Euro countries, the correlation between the labor wedge and lagged output is larger than the contemporaneous correlation but this pattern is less pronounced.

The cyclical pattern of the productivity wedge in Europe is very similar to that in the US, and also very similar across countries in Europe. The correlation of the hours-based productivity wedge ranges between 0.83 to 0.87, and the correlation for the employment-based productivity wedge ranges between 0.90 to 0.92.

In summary, this analysis suggests that these wedges are larger in Europe than in the US, that the cylical pattern of the labor wedge is quite different in Europe, and that the cyclical pattern of productivity in Europe is similar to that in the US.

4.4 Wedges During US and European Recessions

We now examine these wedges during NBER (for the US) and ECRI (for Europe) identified recessions to gain additional information about their properties during standard definitions of economic downturns. We first compare the size of recessions across countries to help understand the relative size of the labor and productivity wedges we present below.

[Insert Table 6 here]

Table 6 shows average trough levels for real GDP and labor (both employment and hours) for several countries. The data indicate that US recessions were somewhat less volatile than European recessions before 1983, but that US recessions became much less volatile than European recessions afterwards. Specifically, the average US recession trough output level declined by more than half after 1984 (-5.1 percent before 1984, to -2.2 percent afterwards), but the average Western European trough output level was roughly unchanged over this period (-5.0 percent before 1984 and -5.2 percent afterwards). This suggest that, using output changes in recession as a metric, the Great Moderation was primarily a US phenomenon, rather than an international phenomenon.

We now present statistics on labor and productivity wedges at recession troughs. Table 7 shows the size of labor wedges for all recessions and also splits recessions into two groups, before the Great Moderation (1984 and before) and those for the Great Moderation (1985 - 2007). The most striking finding is that the European labor wedges at recession troughs do not conform to the hypothesized patterns based on both cross-country differences in hiring and firing costs and on the fact that the standard deviation of hours per worker is higher in most Western Eurpean economies than in the US.

[Insert Table 7 here]

We begin with the US, in which the labor wedges constructed using hours worked are about twice as large during recessions compared to those constructed using employment (-2.8 percent compared to -1.2 percent, measured using quarterly data from 1960 - 2007). The hours wedge is about three times as large before 1984 (-3 percent compared to -1.1 percent), and there is a small decline in the hours-based wedge during the Great Moderation.

The European wedges feature two surprising patterns. One is that the employment-based labor wedges are much larger than those in the U.S. Specifically, the size of these wedges should be relatively low, ceteris parabus, as high firing costs should limit employment loss during a recession. However, the European employment-based labor wedges are about four times higher than those in the United States both before and during the Great Moderation; the average for Western Europe for 1960 through 2007 is -5.0 percent, compared to -1.2 percent for the US. This five-fold difference is also large even after correcting for the fact that Western European recessions on average have been deeper than US recessions.

The second suprising feature of these labor wedges is that the size of the hours-based European wedges seem too small relative to the employment-based measures. To see this, recall that the hours-based wedges in the US are about twice as large as the employment-based wedges. This ratio should tend to be larger in Europe because high firing costs increase the incentive for European firms to adjust labor input more on the intensive margin than the extensive margin. Moreover, recall from Table 3 that the standard deviation of the cyclical component of hours per worker is higher in Europe than in the US, which is consistent with higher European firing costs.

In contrast, we do not observe this pattern among the European wedges. To see this, note that the hours-based labor wedge in Europe is moderately higher than the employment-based labor wedge between 1960-2007, -5.0 percent, versus -4.0 percent. This is particularly striking when compared with the US wedges, where the hours-based labor wedge is twice as large as the emplopyment-based. In addition, the employment-based and hours-based wedges are about the same after 1984 (-6.2 percent compared to -6.5 percent). This similarity between the two wedges is striking because the quantitative importance of the intensive margin has increased over time.

These European recession wedge results are puzzling, both from the perspective of the incentives associated with firing costs and the fact that the volatility of the cyclical changes in hours per worker is higher in Europe. The wedge statistics suggest that the reason that the European hours-based and employment-based wedges are similar is because the relative share of labor adjustment between hours and employment during recession episodes are different than during expansion episodes. Specifically, the standard deviation of the log change in the hours-based labor wedge in Western Europe measured during both recessions and expansions after 1984 is about 40 percent higher than the employment-based wedge, compared to a difference of about 18 percent in the U.S. This suggests that relatively less adjustment in labor input takes place on the intensive margin during ECRI-dated recessions than during other times.

[Insert Table 8 here]

Table 8 compares TFP wedges across countries. For the US, since hours are more variable than employment, TFP declines more during recessions for employment-based labor than for hours-based labor (-2.3 percent for hours-TFP compared to -2.8 percent for employment), and both measures decline considerably during the Great Moderation to -1.4 percent and -1.1 percent, respectively. These 50 percent declines in cyclical US TFP is consistent with the findings of Arias *et al.* [2007], who report a similar drop in TFP volatility.

In comparison with other countries, before 1984, Western Europe featured smaller recession TFP declines for both hours-based and employment-based measures of labor input, despite the fact that European recessions were somewhat deeper. However, this pattern of relatively small Western European TFP declines is reversed during the Great Moderation, as the large moderation in US TFP decline is not mirrored in Europe. Specifically, both hours-based and employment-based measures of European TFP are higher than their US counterparts after 1984 (-2.2 percent for hours, -2.3 percent for employment for Western Europe, compared to -1.1 percent and -1.4 percent, respectively). These statistics also indicate that the Great Moderation was primarily a US event, rather than a European event.

4.5 Labor and TFP Wedges During the Great Recession in OECD Countries

We now report these wedges for the Great Recession. We pursue this analysis since Ohanian (2010) finds that the productivity and labor wedges - measured using only employment as labor input - differ remarkably between the U.S. and the other advanced countries during the Great Recession. Specifically, Ohanian documented that the U.S. Great Recession is almost entirely due to a very large decline in labor input associated with an historically large labor wedge, and that productivity is on nearly on trend. In contrast, the recessions in other G7 countries are virtually the opposite of that in the US, as other G7 recessions have only relatively small employment declines, large productivity declines, and no quantitatively important labor wedges.

These very different patterns led Ohanian to suggest that the underlying source and/or propogation mechanisms for the Great Recession may have been very different between the US and the other G7 countries, and that these different patterns pose a challenge for the widely held view that all of these recessions were the result of similar banking crises that operated through the same economic channels. But Ohanian's findings are entirely based on using employment, rather than hours, as labor input. The fact that firing costs are higher in several of the other G7 strongly suggests that labor input adjustment should have taken place relatively more on the intensive margin, and that using employment would generate downward biased Solow Residuals, and upward biased labor wedges.

We therefore use total hours to determine whether the Great Recession is more similar across the G7 than reported by Ohanian. Our main finding is that the puzzle identified by Ohanian is perhaps even more anomalous, as using total hours, which should be a better measure of labor input given firing costs, doesnt materially change Ohanian's findings.

Table 9 shows output, labor, and labor and productivity wedges for the Great Recession across countries. The table shows that using hours as labor input instead of employment in constructing the labor wedge and productivity in other countries has very little impact on the size of labor wedges for Western Europe. Specifically, note that the US hours-labor wedge is about -10 percent at the trough of U.S. hours worked in the Great Recession, while the hours-labor wedge is only -0.8 percent on average for Western Europe, which is only modestly different from its value measured using employment (0.9 percent).

[Insert Table 9 here]

The table also shows that the European labor wedges - measured using either hours or employment - are remarkably small during the Great Recession when compared to their size during previous recessions described above. To see this, we compare the relative size of labor wedges and output loss during the Great recession to all other recessions. The average peak-to-trough hours-labor wedge for Western Europe between 1960 and 2007 was about 6 percent, while output fell about 5 percent, while these numbers for the Great Recession are about 1 percent, and 9 percent, respectively. This implies that if the pre-Great Recession relationship between the labor wedge and output was also operative during the Great Recession, then the hours-labor wedge would have been around 11 percent (given the 9 percent output decline), more than an order of magnitude bigger than it was.

Not surprisingly, the labor wedge accounts for very little of the Great Recession in Europe. Table 10 shows the percentage of trough output and labor accounted for by the model in response to the labor wedge and the productivity wedge, using both employment and hours worked as labor input. While the US hours-labor wedge accounts for almost all of US output, amd more than the full decline in hours worked, the European hours-labor wedge accounts for only about 6 percent of the drop in European output, and about 22 percent of the decline in hours. In contrast, the Table also shows the relative contribution of productivity for the US and Europe. Productivity explains only about 20 percent of the drop in output, and almost none of the drop in hours in the US, whereas productivity overaccounts for output and hours on average in Western Europe.

[Insert Table 10 here]

These large differences in the size of labor and productivity wedges, and their relative contributions to the Great Recession across countries, pose a challenge for the common view that the coincident recessions across countries in 2008-2009 were the consequence of very similar banking crises that depressed economies through very similar economic channels and forces. Instead, these results indicate considerably difference between the US and Western

Europe, and suggest that different economc forces were operative in the US compared to much of Western Europe.

Moreover, the fact that both hours and employment labor wedges are about an order of magnitude smaller than their normal recession size during the Great Recession in Europe raises an interesting puzzle: why were the dynamics of employment and hours per worker so much different during the worst postwar European recession of the last 50 years compared to other recessions?

While the results indeed indicate that the US is an outlier compared to much of Western Europe, Table 9 also shows labor and productivity wedges for some OECD countries that were not analyzed by Ohanian (2010). In particular, both Spain and Ireland have very large labor wedges (around -15 percent), measured using either hours or employment. This similarity between the US, Spain, and Ireland suggests a new avenue for understanding cross-country experiences. One possibility relates to the housing market. Specifically, some have argued that in the US, very large housing price declines, coupled with government policies designed to cushion the impact of falling prices on borrowers, including mortgage modification programs, changed the incentives for unemployed individuals to take new jobs or for homeowners to relocate from relatively depressed areas to areas with better job prospects (see Mulligan (2008), Herkenhoff and Ohanian (2011)).

While it is beyond the scope of this paper to pursue this idea in detail, we present some limited evidence on the relationship between the labor market and housing. Figure 5 shows changes in housing prices for the US and a number of other countries. It is interesting that two of the three countries which have large labor wedges - the US and Ireland - also have very large housing price declines. We discount somewhat the fact that the Spanish housing price series does not fall as much as those in Ireland and the US, as there are concerns about the measurement of the Spanish housing price series. These findings suggest an interesting avenue for future research by developing theories that relate a widening labor wedge to sectoral dislocation in construction.

5 Summary and Conclusions

Cyclical labor fluctuations are a central focus of business cycle research, but this research has been limited by the fact that typically only employment, rather than total hours worked, is available for many OECD countries. This paper has constructed quarterly time series of total hours worked for 17 OECD countries, with a focus on constructing hours that are consistent with national income and product account constructs. These hours measures provide new labor data for earlier years that can shed new light on a number of questions involving comparisons over time, including changes in the nature and sources of fluctuations over time, how changes in fiscal and monetary policy have impacted fluctuations over time, and how changes in labor market regulations have impacted fluctuations over time.

While these analyses extend well beyond the scope of our paper, the basic statistics we report here regarding these new hours data stand in sharp contrast to many common views about cyclical labor market dynamics. Specifically, we show that for several countries, employment is a poor proxy for cyclical labor input, and consequently provides poor measures of productivity, as about 50 percent of labor adjustment occurs along the intensive margin. Another finding is that employment fluctuations in much of Western Europe appear to be much too high compared to the US, given much higher hiring and firing costs in Europe. And given the large fluctuations in European hours, employment-based labor wedge fluctuations in Europe are too high, and hours-based labor wedge fluctuations are too low. Our findings also have implications for the international Great Recession. Specifically, there is a common view that the Great Recession across countries was the result of very similar responses to very similar banking crises. The findings presented here contrast with that view, as Western European recessions feature very small labor wedges compared to the US, measured either with employment or hours, and instead feature much larger productivity shocks than the US.

Future research should aim to address these puzzles, with a focus on understanding why the intensive margin adjustment is so small during European recessions, and why labor wedges are virtually non-existant in many European countries during the Great Recession, and why they are so large in the US.

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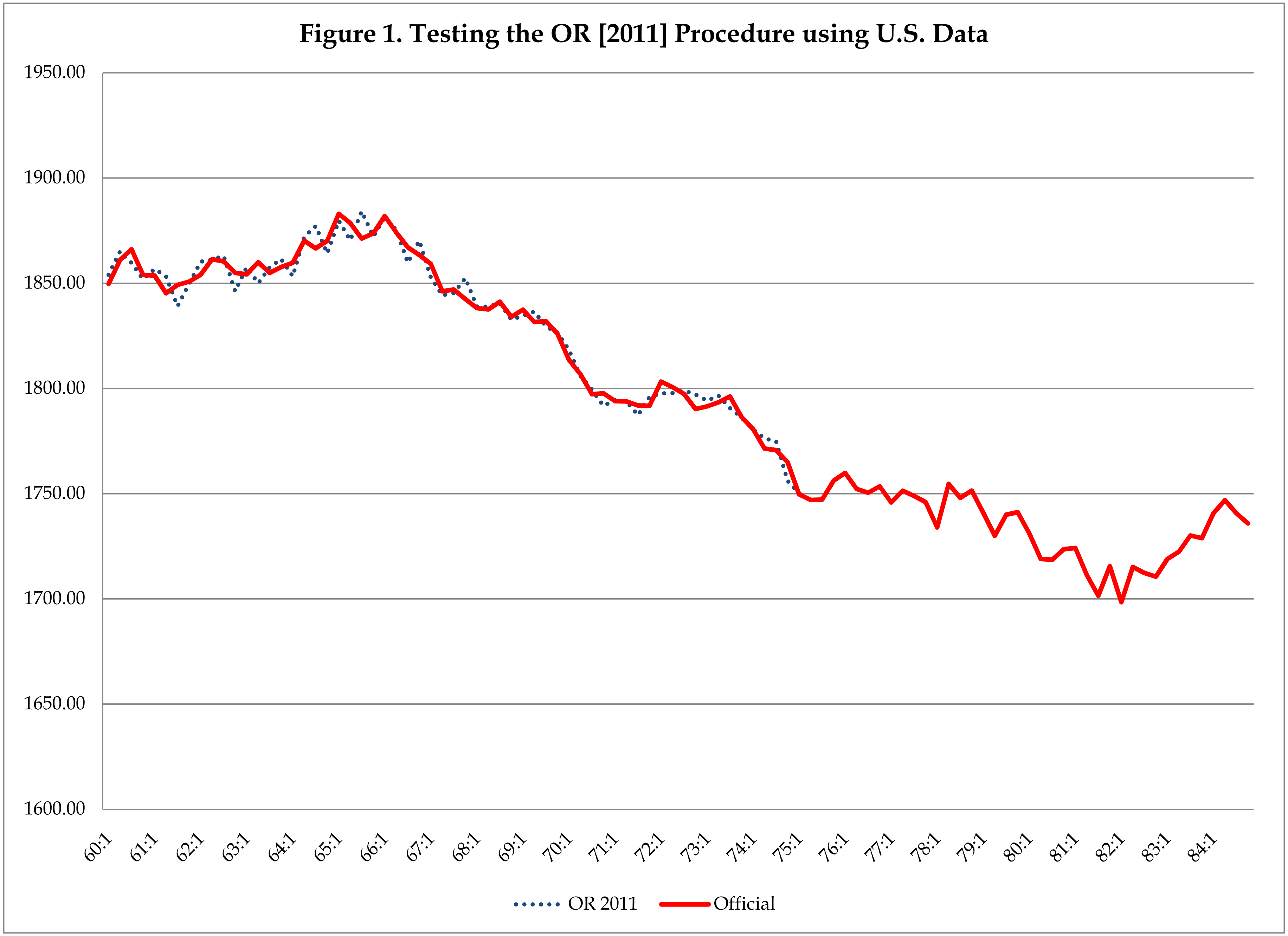


Figure 1. Testing the OR [2011] Procedure using U.S. Data
1950.00
1900.00
1850.00
1800.00
1750.00
1700.00
1650.00
1600.00
60:1
61:1
62:1
63:1
64:1
65:1
66:1
67:1
68:1
69:1
70:1
71:1
72:1
73:1
74:1
75:1
76:1
77:1
78:1
79:1
80:1
81:1
82:1
83:1
84:1
OR 2011
Official

Figure 2. Volatility of Labor Input (1960-2007)

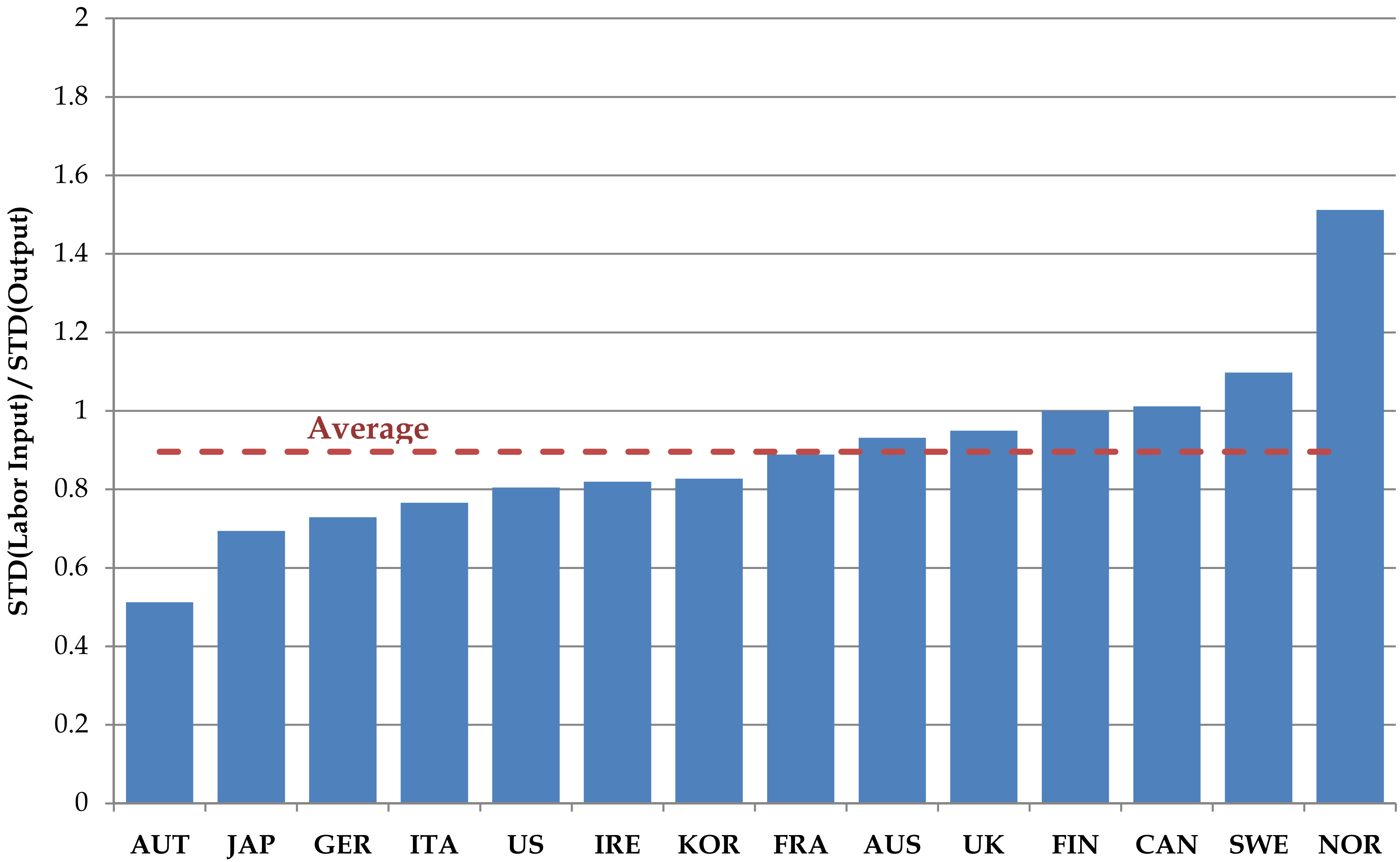


Figure 3. Cyclical Properties of Total Hours Worked

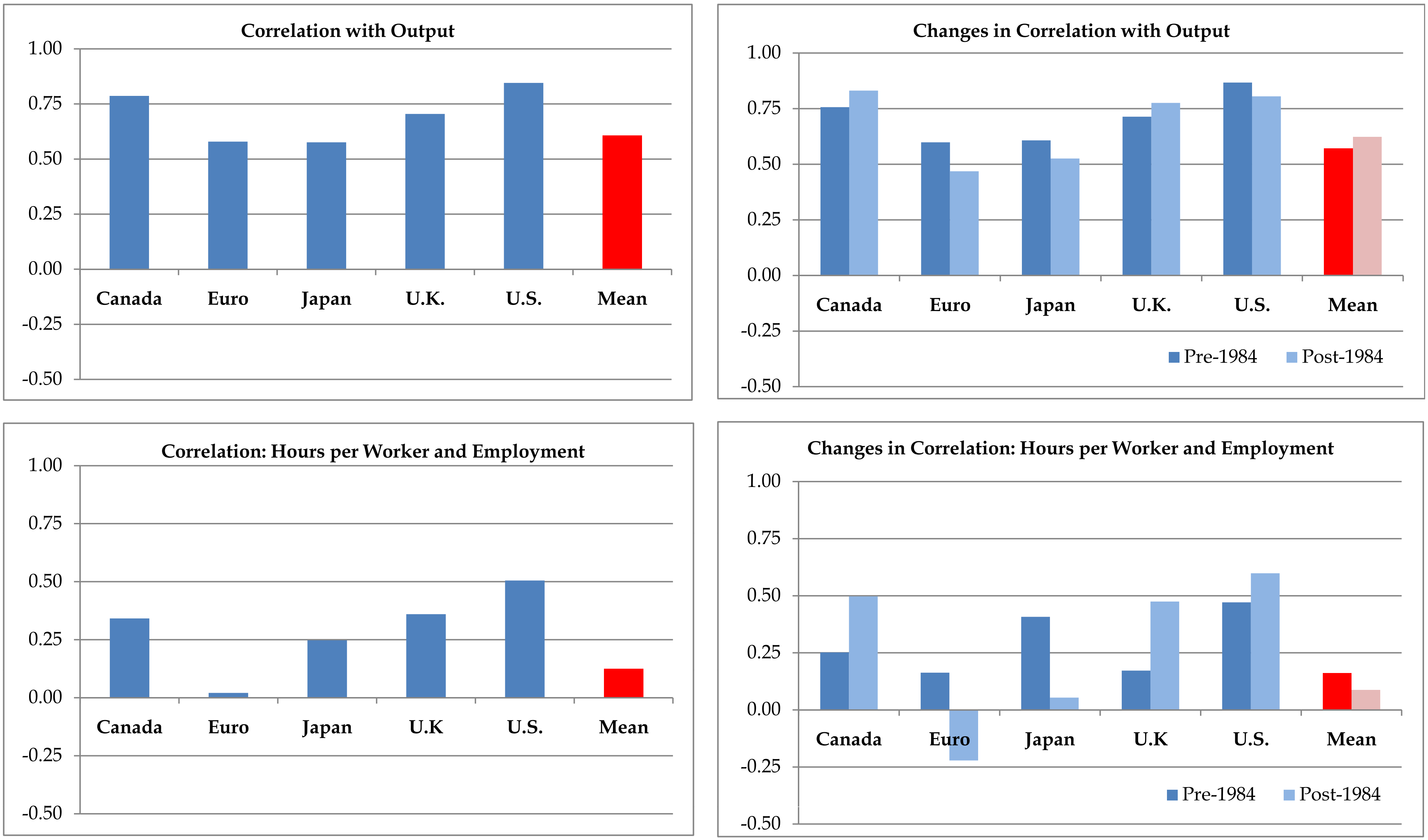


Figure 4. Cyclical Properties of Labor Productivity (1960-2007)

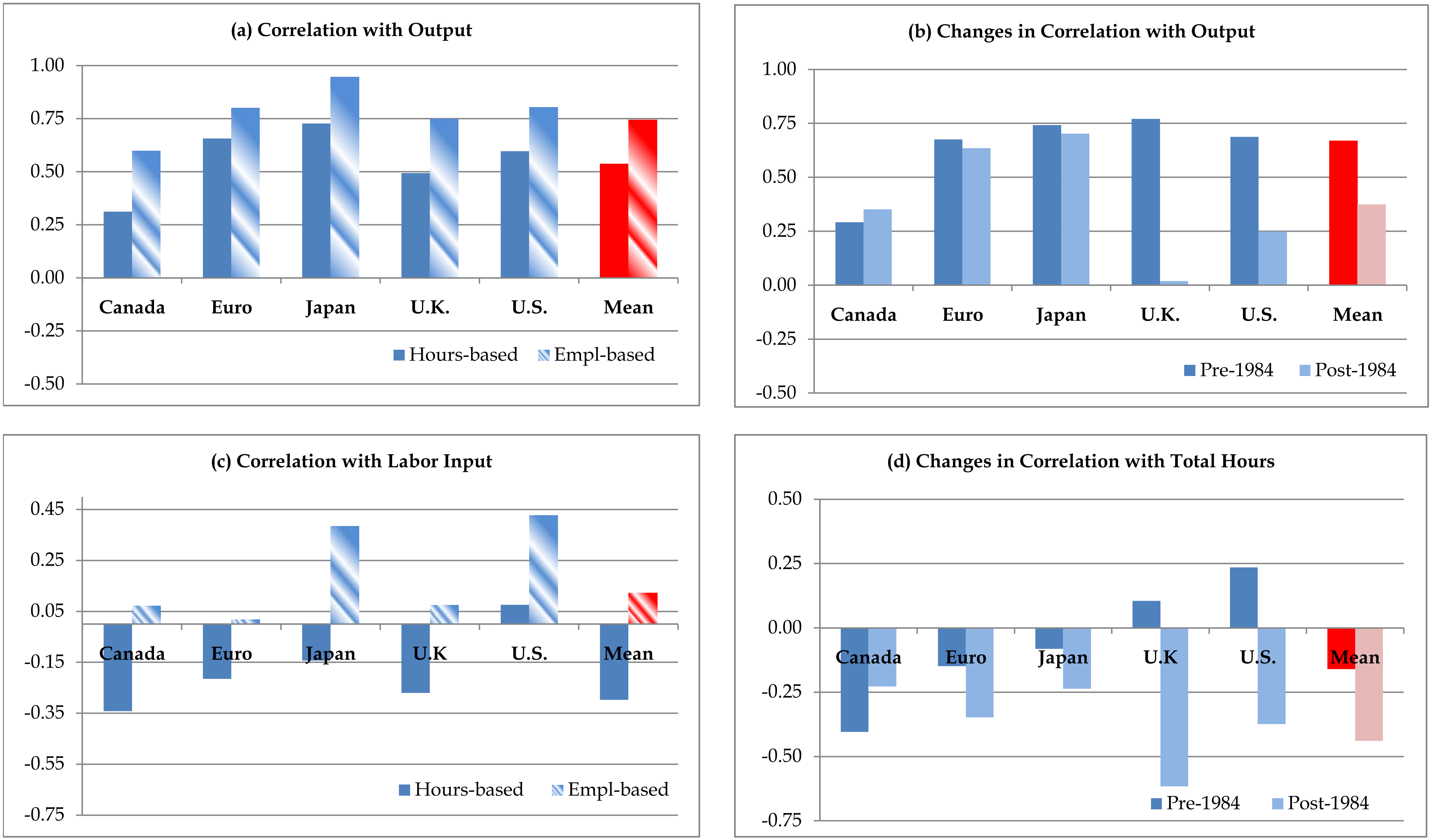
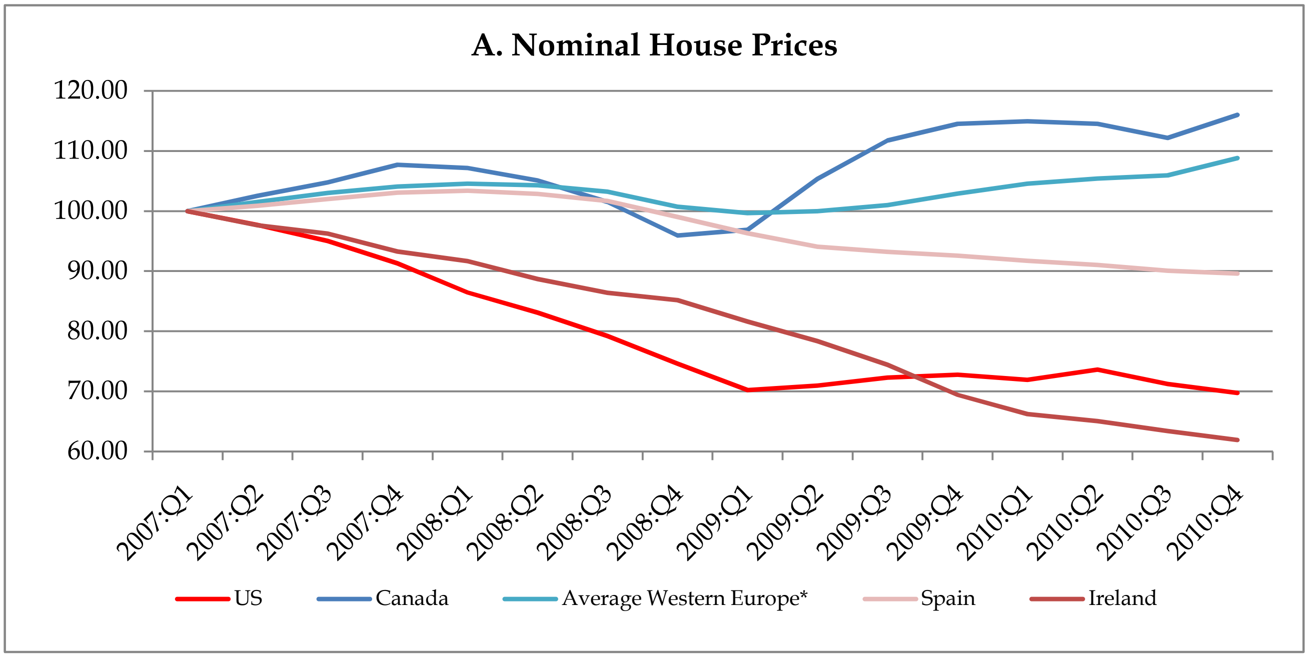
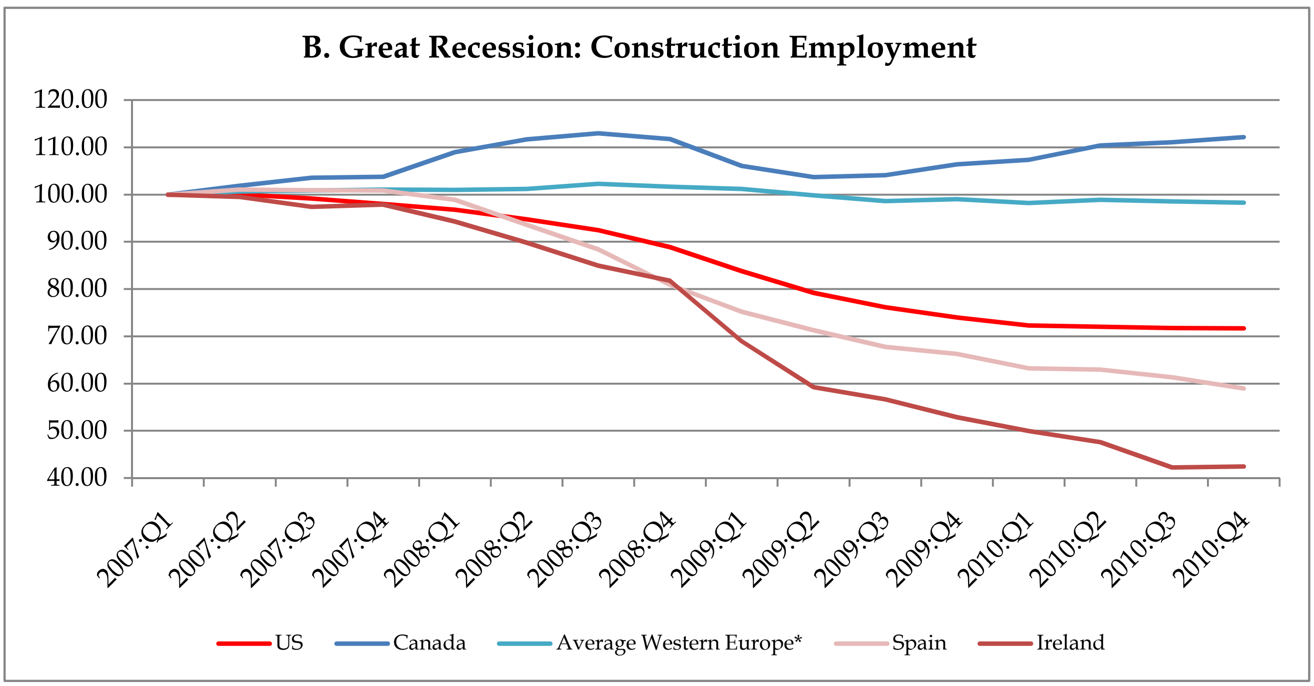


Figure 5. Housing Sector During the Great Recession





*Advanced Western Europe includes: Finland, France, Germany, Italy, Netherlands, Norway, Sweden, and U.K.

Table 2. Assessing OR [2011] Procedure

X: Hours per worker constructed following OR [2011] procedure

Y: Official series of hours per worker

		First Difference	*4-Quarter Changes*	*HP Residuals*
Relative Standard Deviation $\sigma(X)/\sigma(Y)$				
	U.S.	1.17	1.07	1.07
	Germany	0.86	0.99	0.96
	Japan	0.78	0.94	0.94
Correlation $\rho(X,Y)$				
	U.S.	0.70	0.93	0.93
	Germany	0.85	0.98	0.96
	Japan	0.79	0.97	0.96

NB. In all cases, series have been logged and adjusted using Denton [1971] procedure. Regressions are estimated over the sample 1975-1984. Statistics refer to the following country-specific samples: U.S. (1960Q1-1984Q4), Germany (1970Q1-1984Q4), and Japan (1968Q1-1984Q4).

Table 3. Volatility of Labor Input (Standard Deviation relative to Output)

		Canada	*Euro**	*Japan*	*UK*	*US*	*OECD Mean*
BKK [1995]							
	1970:Q1 - 1990:Q2						
	Data (Employment)	0.86	0.53	0.36	0.68	0.61	0.64
	Benchmark Model						0.49
OR [2011]							
	1960:Q1 - 1984:Q4						
	Total Hours	1.05	0.78	0.67	0.76	0.75	0.76
	Hours per Worker	0.31	0.49	0.43	0.36	0.26	0.44
	Employment	0.92	0.53	0.37	0.52	0.59	0.55
	1985:Q1 - 2007:Q4						
	Total Hours	0.96	0.83	0.73	1.27	1.04	1.05
	Hours per Worker	0.40	0.59	0.60	0.54	0.42	0.65
	Employment	0.70	0.69	0.39	0.92	0.74	0.76

Note. Statistics refer to residulas of HP filter (smoothg parameter 1600).

* Euro is the average of France, Germany, and Italy.

Table 4. Volatility of Labor Productivity

		CAN	EURO	JAP	UK	US	OECD Mean
Standard Deviation relative to Output							
1960:Q1 - 2007:Q4	*Hours-based**	0.66	0.84	0.83	0.77	0.54	0.84
	*Empl-based***	0.65	0.79	0.90	0.83	0.62	0.81
1960:Q1 - 1984:Q4	*Hours-based**	0.71	0.80	0.80	0.84	0.51	0.84
	*Empl-based***	0.66	0.81	0.91	0.88	0.61	0.84
1985:Q1 - 2007:Q4	*Hours-based**	0.57	0.94	0.88	0.80	0.64	0.88
	*Empl-based***	0.65	0.77	0.86	0.69	0.67	0.78

NB. Statistics refer to residuals of the HP-filter (smoothing parameter is 1600).
* *Hours-based* labor productivity is real output divided by total hours of work.
** *Empl-based* labor productivity is real output divided by employment.

Table 5. Properties of the Labor and Productivity Wedges

(a) Standard Deviation relative to Output

	Canada	EURO	Japan	UK	US
Hour-based Labor Wedge		1.19		1.99	0.97
Empl.-based Labor Wedge		0.96		1.45	0.62
Hour-based Productivity Wedge		0.65		0.64	0.39
Empl.-based Productivity Wedge		0.74		0.74	0.53

(b) Cross-Correlation with Output

		-4	-3	-2	-1	0	1	2	3	4
Canada	*labor wedge, hours*									
	labor wedge, empl									
	productivity wedge, hours									
	productivity wedge, empl									
Euro	*labor wedge, hours*	0.30	0.35	0.33	0.29	0.23	0.23	0.19	0.14	0.08
	labor wedge, empl	0.38	0.39	0.32	0.23	0.06	0.12	0.07	0.06	0.00
	productivity wedge, hours	-0.03	0.16	0.38	0.59	0.87	0.69	0.55	0.38	0.21
	productivity wedge, empl	-0.04	0.15	0.39	0.62	0.92	0.73	0.59	0.40	0.24
UK	*labor wedge, hours*	0.64	0.69	0.69	0.62	0.52	0.44	0.31	0.17	0.01
	labor wedge, empl	0.54	0.55	0.50	0.42	0.31	0.25	0.13	0.01	-0.10
	productivity wedge, hours	-0.15	0.08	0.30	0.55	0.83	0.71	0.61	0.50	0.33
	productivity wedge, empl	-0.07	0.16	0.38	0.61	0.90	0.76	0.66	0.55	0.38
US	*labor wedge, hours*	0.30	0.51	0.64	0.72	0.67	0.64	0.53	0.43	0.32
	labor wedge, empl	0.43	0.60	0.68	0.68	0.57	0.54	0.43	0.32	0.21
	productivity wedge, hours	-0.12	0.03	0.28	0.55	0.84	0.79	0.67	0.46	0.28
	productivity wedge, empl	-0.11	0.07	0.34	0.62	0.90	0.84	0.71	0.52	0.34

NB. Statistics refer to residuals of the HP-filter (smoothing parameter is 1600).

Table 6. Output, Hours, and Employment at Trough, Average Deviation from Peak

(1) US (NBER recessions)

	Output	*Hours*	*Empl.*
All recessions (except Great Recession)	-4.3	-2.9	-2.1
Pre-1984 recessions	-5.1	-3.2	-2.3
Post-1984 recessions (except Great Recession)	-2.2	-2.2	-1.6

(2) Other high income countries (ECRI recessions)

	Output			*Hours*			*Empl.*		
	Canada	**Euro**	**UK**	**Canada**	**Euro**	**UK**	**Canada**	**Euro**	**UK**
All recessions (except Great Recession)	-9.1	-4.3	-7.0	-7.3	-3.9	-5.3	-6.0	-2.6	-3.0
Pre-1984 recessions	-9.5	-4.3	-7.7	-8.0	-4.6	-4.4	-6.9	-2.5	-2.3
Post-1984 recessions (except Great Recession)	-8.6	-4.2	-5.6	-6.6	-2.8	-7.1	-5.1	-3.1	-4.5

(3) Average Western Europe: France, Germany, Italy, UK, Austria, Sweden (ECRI recessions)*

	Output	**Hours**	*Empl.*
All recessions (except Great Recession)	-5.1	-4.1	-3.2
Pre-1984 recessions	-5.0	-3.6	-2.2
Post-1984 recessions (except Great Recession)	-5.2	-4.6	-4.4

(4) Japan, Korea (ECRI recessions)**

	Output		*Hours*		*Empl.*	
	Japan	**Korea**	**Japan**	**Korea**	**Japan**	**Korea**
All recessions (except Great Recession)	-4.8	-7.3	-4.2	-7.0	-1.2	-4.0
Pre-1984 recessions	-5.8	-11.1	-6.5	-4.8	-3.3	-2.9
Post-1984 recessions (except Great Recession)	-4.5	-5.4	-3.5	-8.2	-0.5	-4.5

*Note: ECRI recession dates only available for the above countries

**Note: Data available from 1990 onwards for Korea

Table 7. Labor Wedge at Trough, Average Deviation from Peak

(1) US (NBER recessions)

	Hours	*Empl.*
All recessions (except Great Recession)	-2.8	-1.2
Pre-1984 recessions	-3.0	-1.1
Post-1984 recessions (except Great Recession)	-2.3	-1.4

(2) Other high income countries (ECRI recessions)

	Hours			*Empl.*		
	Canada	**Euro**	**UK**	**Canada**	**Euro**	**UK**
All recessions (except Great Recession)	-8.9	-4.4	-6.4	-7.7	-2.7	-3.4
Pre-1984 recessions	-9.6	-5.2	-4.2	-8.7	-2.4	-1.3
Post-1984 recessions (except Great Recession)	-8.3	-3.8	-10.7	-6.7	-4.6	-7.7

(3) Average Western Europe: France, Germany, Italy, UK, Austria, Spain, Sweden (ECRI recessions)*

	Hours	*Empl.*
All recessions (except Great Recession)	-5.0	-4.0
Pre-1984 recessions	-4.2	-2.3
Post-1984 recessions (except Great Recession)	-6.2	-6.5

(4) Japan, Korea (ECRI recessions)**

	Hours		*Empl.*	
	Japan	**Korea**	**Japan**	**Korea**
All recessions (except Great Recession)	-5.0	-11.1	-0.4	-5.9
Pre-1984 recessions	-8.4	-0.8	-3.5	3.0
Post-1984 recessions (except Great Recession)	-3.8	-16.3	0.6	-10.4

* Note: ECRI recession dates only available for the above countries. Euro is the average of France, Germany, and Italy.

** Note: Data available from 1990 onwards for Korea

Table 8. Productivity Wedge at Trough, Average Deviation from Peak

(1) US (NBER recessions)

	Hours	*Empl.*
All recessions (except Great Recession)	-2.3	-2.8
Pre-1984 recessions	-2.8	-3.4
Post-1984 recessions (except Great Recession)	-1.1	-1.4

(2) Other high income countries (ECRI recessions)

	Hours			*Empl.*		
	Canada	**Euro**	**UK**	**Canada**	**Euro**	**UK**
All recessions (except Great Recession)	-4.7	-1.7	-3.8	-5.5	-2.6	-5.2
Pre-1984 recessions	-4.9	-1.3	-4.8	-5.6	-2.7	-6.2
Post-1984 recessions (except Great Recession)	-4.5	-2.4	-1.6	-5.5	-2.2	-3.3

(3) Average Western Europe: France, Germany, Italy, UK, Austria, Spain, Sweden (ECRI recessions)*

	Hours	*Empl.*
All recessions (except Great Recession)	-2.4	-2.9
Pre-1984 recessions	-2.6	-3.5
Post-1984 recessions (except Great Recession)	-2.2	-2.3

(4) Japan, Korea (ECRI recessions)**

	Hours		*Empl.*	
	Japan	**Korea**	**Japan**	**Korea**
All recessions (except Great Recession)	-3.0	-4.9	-5.0	-6.9
Pre-1984 recessions	-3.9	-12.5	-5.9	-13.5
Post-1984 recessions (except Great Recession)	-2.8	-1.1	-4.6	-3.5

*Note: ECRI recession dates only available for the above countries. Euro is the average of France, Germany, and Italy.

**Note: Data available from 1990 onwards for Korea

Table 9. Great Recession, Deviation from Peak (US hours trough)

	Data			Labor wedge		Productivity wedge	
	Output	*Hours*	*Empl.*	*Hours*	*Empl.*	*Hours*	*Empl.*
US	-7.2	-8.6	-7.0	-10.3	-8.9	-1.2	-2.3
Canada	-8.1	-4.8	-2.9	-2.8	-0.5	-5.6	-6.7
Euro	-8.1	-2.7	-1.1	0.4	2.5	-6.2	-7.1
UK	-9.7	-3.5	-2.6	-2.7	-1.9	-7.7	-8.3
Average Western Europe*	-9.1	-3.6	-2.1	-0.8	0.9	-6.9	-7.8
Spain	-9.0	-8.9	-10.0	-14.0	-16.4	-4.1	-3.3
Ireland	-16.2	-15.9	-12.9	-18.6	-15.2	-6.8	-8.9
Japan	-7.6	-4.7	-0.7	-2.0	4.0	-4.1	-6.6
Korea	-2.7	-5.1	-1.2	-8.4	-2.3	-0.1	-2.6

*France, Germany, Italy, UK, Austria, Finland, Netherlands, Norway, Sweden

Table 10. Great Recession, Deviation from Peak (Hours Trough)

	Data			Predicted, Model 1		Predicted, Model 2		Predicted, Model 3		Predicted, Model 4	
	Output	*Hours*	*Empl.*	*Output*	*Hours*	*Output*	*Empl.*	*Output*	*Hours*	*Output*	*Empl.*
US	-7.2	-8.6	-7.0	-6.7	-9.8	-5.8	-8.5	-2.0	-0.3	-3.5	-0.8
Canada	-8.1	-4.8	-2.9	-1.8	-2.6	-0.3	-0.5	-8.3	-2.6	-9.9	-3.0
Euro	-8.1	-2.7	-1.1	0.2	0.2	1.5	2.1	-9.2	-3.0	-10.5	-3.2
UK	-9.7	-3.5	-2.6	-1.7	-2.5	-1.2	-1.7	-11.5	-3.8	-12.2	-3.8
Average Western Europe*	-9.1	-3.6	-2.1	-0.5	-0.8	0.6	0.7	-10.4	-3.3	-11.5	-3.6
Spain											
Ireland	-16.2	-15.9	-12.9	-12.8	-18.6	-10.3	-15.0	-10.3	-3.1	-13.3	-4.0
Japan	-7.6	-4.7	-0.7	-1.3	-1.8	2.5	3.5	-6.1	-1.8	-9.7	-2.8
Korea	-2.7	-5.1	-1.2	-5.6	-7.8	-1.5	-2.1	-0.2	0.1	-3.9	-0.9

NB. Euro is the average of France, Germany, and Italy.

*France, Germany, Italy, UK, Austria, Finland, Netherlands, Norway, Sweden

** Model 1 = labor wedge, hours; Model 2 = labor wedge, employment; Model 3 = productivity wedge, hours; Model 4 = productivity wedge, employment