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Trends in Aggregate Employment, Hours Worked per Worker, and the Long-Run Labor Wedge*

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Abstract

Hours worked are fundamentally important for aggregate economic activity, yet canonical macroeconomic models fail dramatically at tracking its long run trends. We develop an intuitive and tractable extension of the canonical model that decomposes trend hours into extensive and intensive margins via household-side employment-attainment costs and firm-side employment adjustment costs. Its predictions track very well the trend behavior of hours, and its two underlying margins, in the United States and a host of OECD countries. Our framework is relevant for analyzing the long run labor-market effects of a number of factors such as productivity growth, and tax or labor-market reforms.
JEL Codes: E60, H20, J20. **Keywords**: CLM model; DLM model; Europe; hours worked per population; labor-market policy; long-run labor wedge; OECD countries; taxes; United States; U.S. tax puzzle.

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1 Introduction

Hours worked per population are fundamentally important for aggregate economic activity. The contemporary canonical (dynamic, micro founded, representative agent) macroeconomic model is broadly established as a common benchmark that can get at the basic forces associated with the behavior of hours worked per population—which we denote by H—at *business cycle frequency*.[1]. As is well known, this canonical model can explain some, but not all, of the short-run behavior of H. Yet, the existence of such a common framework has allowed the macroeconomics literature to succinctly identify a series of key factors that are critical—*beyond these basic forces*—for successfully and with great tractability explaining the *business cycle* behavior of H within the representative-agent paradigm. These factors include, among others, search frictions and indivisible labor.[2]

The objective of this paper is to develop and propose a tractable benchmark model that can serve as a common reference for modeling the *trend/long-run* behavior of H. Absent such framework, it is not possible to identify the fundamental basic forces that are relevant for answering a series of timely questions of crucial importance and general interest. For instance, how should we expect trends in H to respond to the following developments: a slowdown in global output, which is a critical issue amid the ongoing convergence of the growth rate of the Chinese economy to that of advanced economies; changes in demographics, which is a critical issue in light of the aging of the population in advanced economies; economic policy, such as tax policy, labor market reforms, and pension reforms, which are critical in light of fairly recent policy developments in Europe in the wake of the Global Financial Crisis and amid the European Sovereign Debt Crisis.

In light of the above questions, the motivation behind our research objective is the following. In the macroeconomics literature, in contrast to the short-run behavior of H, an understanding of the *trend* behavior of H within the representative-agent

[1] Of course, the benchmark reference for these models is Kydland and Prescott (1982).

[2] Diamond (1982) and Mortensen and Pissarides (1994) are key references regarding search frictions, and Hansen (1985) and Rogerson (1988) are so regarding indivisible labor.

paradigm is considerably limited. In particular, a common, widely accepted, and tractable benchmark model that can get at the basic forces associated with the trend behavior of H, and, critically, that can explain to a considerable degree the trend behavior of H, remains elusive.

Importantly, as is well known, for all purposes the canonical macroeconomic model can explain *none* of the *trend/long-run* behavior of H. This results in the model yielding a prominent long-run labor wedge, that is, the long-run difference between model-predicted H and empirical H.[3] That said, a critical advancement in the understanding of the trend behavior of H in a representative-agent context took place with Prescott (2004), who proposed taxes as an intuitive variable that could help narrow the (long-run) labor wedge. However, Figure 1, which plots empirical H and model-predicted H by tax-inclusive and -exclusive versions of the canonical model shows the following. While on average taxes narrow the labor wedge in Europe substantially, they dramatically widen the labor wedge in the United States. We refer to this as the "U.S. tax puzzle."[4]

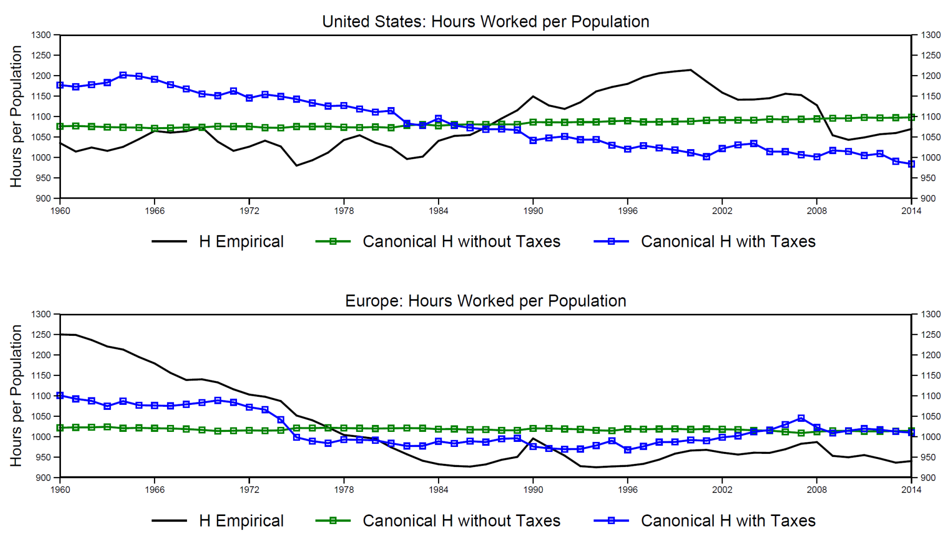

Figure 1: Empirical hours worked per population and predictions from CLM model with and without taxes for Europe (top panel) and the US (bottom panel).[5]

[3]More technically, the (long-run) labor wedge captures the extent to which, in the long run, the marginal product of labor differs from the marginal rate of substitution of consumption for leisure.

[4]This result is endemic to this tax-related literature, which also includes, amont others, Ohanian et al. (2008) and McDaniel (2011).

[5]Notes: All data are at yearly frequency. Total work hours are from the Conference Board's

The model that we propose is an intuitive and tractable extension of the canonical macroeconomic model. Our model is Walrasian and representative-agent in nature, and nests the canonical model. Two key features distinguish our model from the canonical one. First, the presence of employment-attainment costs on the household side, which enter the model in the form of disutility. Second, the presence of firm-side employment adjustment costs.

While these two modeling ingredients are not novel from the conceptual standpoint, the technical way in which our model incorporates these ingredients is indeed novel. Critically, the way in which our model incorporates these two ingredients results in an intuitive and straightforward disentanglement of the two margins of labor—hours worked per worker, which we denote by h, and the employment-population ratio, which we denote by e—on both the household and firm side. This is in contrast to the canonical macroeconomic model, where the only endogenous labor-market variable predicted by the model is H itself—we refer to this class of model as "*combined labor margin (CLM) models.*" As such, our model's prediction of H is built from the bottom up, with the model predicting both h and e, the product of which is of course H. Therefore, we refer to our model as the "*dual labor margins (DLM) model.*"

Clearly, there are many ways by which the two margins of labor can be disentangled. An advantage of our DLM model relative to alternative frameworks is that household-side employment-attainment costs allow our framework to remain within the representative-agent paradigm. Moreover, in contrast to labor search theory, where there is involuntary unemployment, our modeling methodology is such that *any existing nonemployment is voluntary.* Both of these features are critical for allowing our framework to nest the canonical macroeconomic model in straightforward fashion. Moreover, as noted below, the particular way in which our DLM model disentangles the two margins of labor allows it to speak directly to the U.S. tax puzzle.

Total Economy Database, employment is from the OECD, population data are from the UN, tax data are from McDaniel (2007), and consumption and output data are from the Penn Word Tables. "Europe" refers to the simple average of European countries in our sample. Sample countries, which are standard in related literature, and data span are limited by the availability of time series on taxes. Details are in the paper's data and theory sections.

In addition, the way in which our DLM framework incorporates firm-side employment-adjustment costs is such that it generates, in straightforward and intuitive fashion, the following two relationships: a positive and contemporaneous relationship between e and capital taxes and also between H and capital taxes, and no relationship between h and capital taxes. Importantly, we document that these relationships exist in the data—*a set of novel facts*—which lends validity to our framework. Moreover, while the empirical positive relationship between e and capital taxes is in principle puzzling, our DLM model implies that *this relationship is not causal.* It is instead an observed *outcome* stemming from forward-looking optimal employment demand, and from this vantage point, in line with intuition, *higher capital taxes put downward pressure on employment demand.*

In line with related literature that studies the trend behavior of H, we operationalize our model using a business cycle accounting approach.[6] We show that our model can account for the trend behavior of h (the equilibrium condition for which is static in our model) and e (the equilibrium condition for which is a novel *dynamic* expression) very well in *both* Europe *and the United States.* Therefore, our model can account very well for the trend behavior of H across countries. As such, our model is an important step forward in understanding the trend behavior of H relative to the canonical macroeconomic model and, therefore, in addressing the U.S. tax puzzle.

Our work results in the following three contributions. First, our DLM model itself. Indeed, the extent to which our DLM framework is successful in explaining the trend behavior of h, e, and therefore H across countries suggests that our model can justifiably be proposed as a benchmark for analyzing the trend behavior of these variables. Second, we further validate the role that taxes play as related to the trend behavior of H as highlighted by earlier literature starting with Prescott (2004), *even though an endemic feature of this literature is the existence of the U.S. tax puzzle* In particular and for instance, while our DLM model highlights that productivity is a major driving force associated with the trend behavior of H in the United States—

[6] Key references are, for example, Prescott (2004) and Chari, Kehoe, and McGrattan (2007) among others.

which is something not highlighted by earlier directly-related literature—taxes are more important for long-run *contours* in the trend behavior of H. Moreover, as related to taxes, our DLM framework also shows that a positive relationship between e and capital taxes and H and capital taxes observed in the data (*a novel stylized fact that we document*) has no causal implications. Instead, these relationships are an ex-post outcome stemming from capital taxes putting downward pressure—in line with intuition—on forward-looking employment demand. *This has not been highlighted by earlier literature.*

Third, since our DLM model does very well in explaining the trend behavior of H in the United States, our DLM model thoroughly contributes to resolving the U.S. tax puzzle, for which our results imply that disentangling the two margins of labor is crucial. Of note, our DLM model's equation for h, which is rigorously micro founded, is *exactly the same* as the canonical model's equation for H. Our DLM results therefore imply that in terms of trends, the canonical model will give the *impression* of correctly predicting trends in H if these trends are driven by h (as we review later in the paper, this is the case empirically on average in Europe, where as noted above the tax-inclusive canonical model is successful—*in appearance*). In contrast, the canonical model will give the *impression* of failing to predict trends in H if these trends are driven by trends in e (as we review later in the paper, this is the case empirically in the United States, where as noted above the canonical model predicts *counterfactual* H). Ultimately, this implies that a large fraction of the long-run labor wedge that remains after accounting for taxes is employment itself.

Of course, it is well known that the canonical macroeconomic model faces important limitations in accounting for the behavior of H at business cycle frequency given an underlying lack of explanatory power over the behavior of e (hence, for instance and as noted earlier, the relevance of labor search and indivisible labor theories). However, that this also be the case at the trend level is surprising. Indeed, to the extent that the macroeconomic conceptual framework for modeling the long run is correct, then, with perfectly competitive markets and fully variable inputs, why would the long-run behavior of H depend notably on anything else except the long-run behavior of the marginal rate of substitution of consumption for leisure and the long-run behavior of the marginal product of labor?

This paper proceeds as follows. Section 2 reviews related literature. Section 3 details the data we use in our analysis. Section 4 focuses on theory and Section 5 discusses its operationalization. Section 6 presents results. Section 7 concludes.

2 Related Literature

Our DLM framework begins as a full-fledged general equilibrium labor search model. This is so in order to thoroughly ground the key elements of our framework, which intuition-wise trace back to search theory. As such, we build on a vast related literature, including, among others, Diamond (1982), Mortensen and Pissarides (1994), and Merz (1995). *That said, our baseline DLM specification is purged of all frictions that render the labor market noncompetitive, meaning that our baseline specification is Walrasian: all markets are competitive.* Thus, our work is also related to existing studies that consider the extensive margin of labor in such frameworks, such as Hansen (1985), Rogerson (1987), Bils and Cho (1994), Cho and Cooley (1994), Mulligan (2001), Krusell et al. (2008), Llosa et al. (2014), and Erosa (2016), among others. Our DLM model contributes to these literatures by showing how accounting for household employment-attainment costs and firm-side employment adjustment costs are a means through which the extensive and intensive margins of labor can be easily disentangled in a representative-agent Walrasian framework.[7]

There is a large literature on the labor wedge—which is technically defined as the extent to which, in equilibrium, the marginal product of labor differs from the marginal rate of substitution of consumption for leisure. This literature includes, among others, Hall (2009), Shimer (2009), Pescatori and Tasci (2011), Karabarbounis (2014a and 2014b), Cheremukhin and Restrepo-Echavarria (2014), Cociuba and Ueberfeldt

[7] In our DLM framework, the way in which employment adjustment costs are introduced yields an intuitive relationship between employment and capital taxes. The broader relevance of adjustment costs is emphasized in a vast literature that includes, for instance, Cooper and Willis (2004), Caballero and Engel (2004), Cooper and Willis (2008), and Mumtaz and Zanetti (2014).

(2015), Gourio and Rudanko (2014), and Hou and Johri (2018). Focusing on hours worked per population, Prescott (2004) highlights that taxes are a natural candidate to help explain the *long-run* labor wedge.

Regarding the long-run labor wedge and taxes, Prescott (2004), Ohanian et al. (2008), and McDaniel (2011) are particular instances in which fairly standard tax-inclusive versions of CLM models are used for the purposes of analysis. In all cases CLM models yield counterfactual predictions for U.S. hours worked per population (to greater or lesser degree), but successful predictions for hours worked per population for European countries. This means that even after accounting for taxes, the *long-run* U.S. labor wedge remains. Importantly, Ohanian et al. (2008) note explicitly that the discrepancy between empirical hours worked per population in the United States and hours predicted for the United States by CLM models are so stark that it is a crucial question for future research in macroeconomics. Yet, in very broad terms, the literature that studies the relationship between trends in taxes and trends in hours worked per population ends with McDaniel (2011). This impasse in the literature is perhaps the result of it being the case that obvious resolutions to the U.S. tax puzzle are not evident within CLM modeling frameworks.

We contribute broadly to the labor wedge literature beyond taxes by showing that in CLM frameworks a large portion of the *long-run* labor wedge stems from deficiencies in the ability of canonical models to account for the behavior of the extensive margin of labor. As noted in the Introduction, this deficiency is well known at business cycle frequency. However, as also noted in the Introduction, it is extremely surprising that this limitation is also present in the long run.

Importantly, our DLM model highlights that the U.S. tax puzzle can be successfully addressed within a Walrasian representative-agent modeling framework, that is, *within the same framework in which the U.S. tax puzzle is originally observed*. This stands in contrast with papers that highlight heterogeneity as critical for addressing the puzzle, such as Cociuba and Ueberfeldt (2015), who stress the role of gender and marital status. As such, our DLM model shows that heterogeneity is, in fact, not a critical factor for resolving the U.S. tax puzzle.

Finally, we highlight a literature that centers on the fact that, while a positive long-run relationship between productivity and equilibrium is intuitive and empirically relevant, a definitive theory that links these two variables is lacking. See, for instance, Layard, Nickell, and Jackman (1991), Blanchard (2007), who surveys the literature on traditional models of aggregate labor markets and concludes that in these models there is long-run neutrality of unemployment to productivity growth, Shimer (2010), and Elsby and Shapiro (2012). Complementing this literature our DLM model suggests that a direct link between changes in total factor productivity (TFP) and equilibrium employment can exist by TFP potentially affecting job-formation costs. Our structural estimation suggests that this is indeed the case and, moreover, that higher TFP lower job-formation costs, which establishes a long-run positive link between TFP and employment.

3 Data

Given our focus on the trend behavior of labor market variables, in line with related literature our analysis makes use of data at yearly frequency. The countries in our sample are those for which, in line with related literature, there is extensive time series data on taxes. These countries are the United States and the following eleven european countries: Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. Our analysis spans the years 1960 - 2014, since at the time of writing this paper those are the years over which tax data, which we need to operationalize our model, are available for these twelve countries—in line with related literature, our main tax data are average taxes from McDaniel (2007). These data are at yearly frequency and publicly available from the author's website.[8]

Regarding the additional data we need, following related literature we use data on consumption, output, and total factor productivity from the Penn World Tables (Feenstra et al., 2015), which are hosted by the Groningen Growth and Development

[8] http://www.caramcdaniel.com/

Center.[9] Data on the working-age population (ages 15-64) come from the United Nations[10], while data on aggregate work hours and aggregate employment come from the Conference Board's Total Economy Database.[11]

Of note, the McDaniel tax series are *average* taxes (see the Appendix for details). For the United States, we are able to assess the sensitivity of results from using these data by comparing them to results obtained using a series on *average marginal* taxes available from the NBER.[12] To the best of our knowledge, there are no comparable tax series for the european countries in our sample. We show that results are similar in terms of trends, but the ability of our DLM model to track contours of the empirical data improves substantially. The main difference between the two labor tax series being that, as shown in Figure 3 below, *the McDaniel series do not fully capture the impact of the Reagan tax reforms (1981 through 1986).*[13] This has a impact on the extent to which our DLM model can match the contour of H, but is fairly irrelevant for our DLM model's ability to match the trend behavior of H.

Table 1 presents the notation we use for empirical data through the remainder of paper. In turn, Figures 2, 3, and 4 show the behavior of these data over our sample period. For brevity, in the main text we present *graphical results* for the United States and Europe, only, where "Europe" refers to the simple average of the eleven european

[9]These data are available for download at https://www.rug.nl/ggdc/productivity/pwt/. Regarding TFP, these data feature, for each country, a TFP index, which is TFP relative to the United States in each period. Of course, then, U.S. TFP is normalized to 1 in all periods. Therefore, we construct U.S. TFP using a standard Solow residual approach and then use the Penn World Tables TFP indices to back out implied TFP levels for all other countries in our sample.

[10]These data are publicly available at https://esa.un.org/unpd/wpp/Download/Standard/Population/

[11]These data can be found at https://www.conference-board.org/data/economydatabase/ While these data are publicly available, at the time of writing this paper accessing the data requires creating an account, which is free of charge.

[12]Tables 1 and 3 from http://users.nber.org/~taxsim/marginal-tax-rates/

[13]NBER tax series is available for a bit shorter time horizon.

countries in our sample.[14]

Table 1: Notation for Empirical Variables

Notation	Meaning
C/Y	Consumption-output ratio
$1+C\ tax$	Return-adjusted consumption tax, $1-\tau^c$ (McDaniel, 2007)
$1-L\ tax$	Return-adjusted labor tax, $1-\tau^l$ (McDaniel, 2007)
$1-K\ tax$	Return-adjusted capital tax, $1-\tau^k$ (McDaniel, 2007)
$1-NBER\ L\ tax$	Return-adjusted NBER labor tax
TFP	Total factor productivity
$d\ln(x)$	Growth rate of variable x
H *empirical*	Hours worked per population
H *fix* h	H holding h fixed at 1960 level $(h_{1960} \cdot e_t)$
H *fix* e	H holding e fixed at 1960 level $(h_t \cdot e_{1960})$
h *empirical*	Hours worked per worker
e *empirical*	Employment-population ratio

Some highlights follow. First, Figure 2 shows that over the last several decades the main driving force behind the behavior of H in the United states is e, with h being relatively flat.[15] The exact opposite is true of Europe, but with the behavior of e being virtually flat in absolute terms. Figure 3 shows that in the United States C/Y rose, τ^k decreased, τ^c was fairly flat, and τ^l rose. In Europe, C/Y, decreased, τ^k rose, τ^c rose somewhat as well, and there was a large secular increase in τ^l. Finally, Figure 4 shows that that TFP in the United States and Europe has followed a similar secular increase, with TFP growth slowing in Europe only towards the end of our sample (in this figure Europe's TFP in 1960 is relative to that of the United States, which is normalized to 100).

[14]On average the patterns for Europe reflect those across the European countries in our sample, so no single country drives the average. Also, results are robust to the averaging methodology including, for instance, GDP-weighted averages.

[15]Rogerson (2006) and Blundell et al. (2011) also broadly highlight these facts.

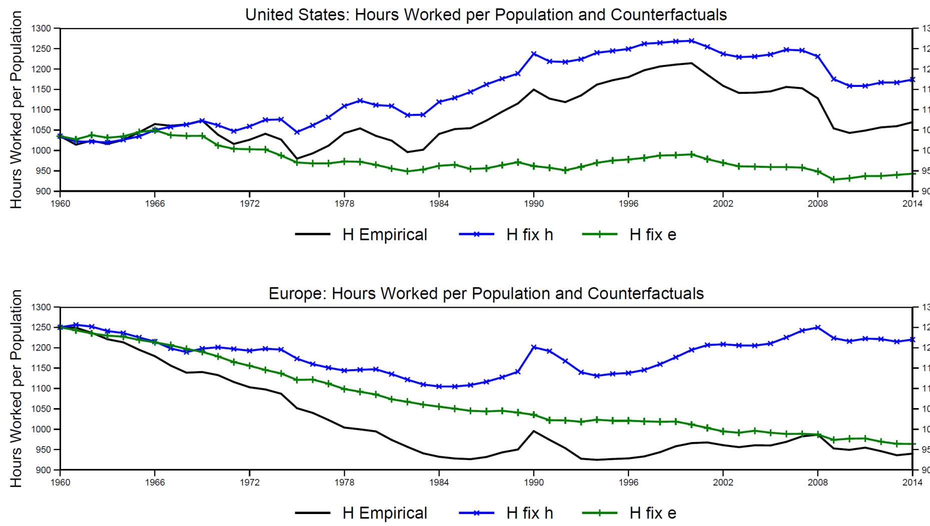

Figure 2: Hours worked per population, per worker, and the employment-population ratio in Europe (bottom panel) and the US (top panel).[16]

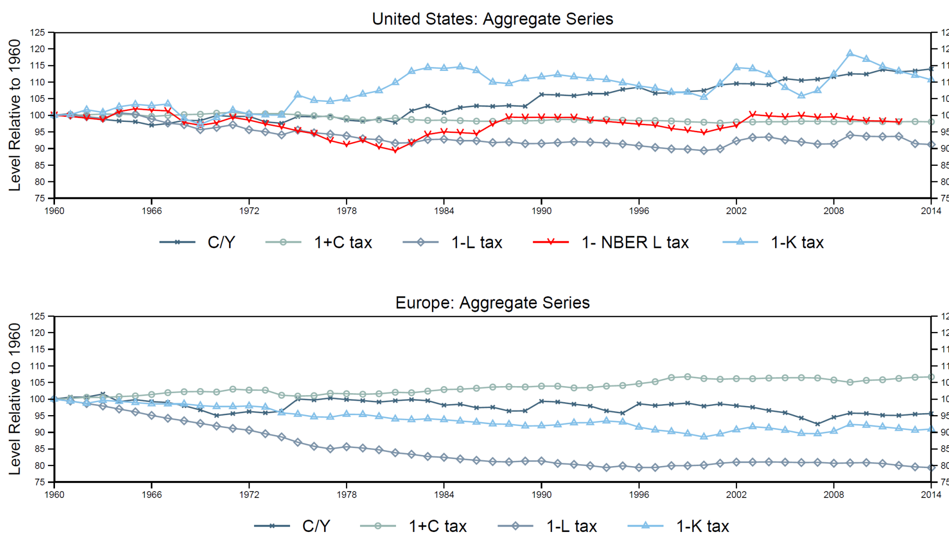

Figure 3: Empirical macroeconomic series for Europe (bottom panel) and the US (top panel).[17]

[16]Note: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the UN.

[17]Notes: data on total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, population data are from the UN, tax data from McDaniel (2007), and output and consumption from the Penn Word Tables.

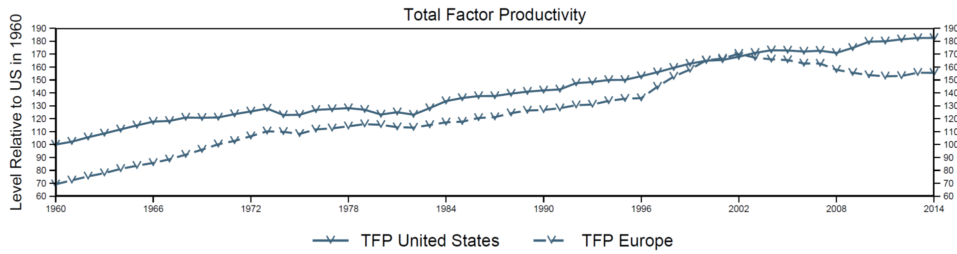

Figure 4: Total factor productivity in Europe and the US.[18]

Table 2 shows results from running a panel regression with all countries in our sample, where the left-hand side variable is, alternatively, $d\ln(e_t)$, $d\ln(h_t)$, and $d\ln(H_t)$. The regressands are the contemporaneous growth rates of return-adjusted taxes (τ^i is the investment tax). For each left-hand side variable this regression is run with and without a business cycle control: the growth rate of output per population, $d\ln(Y_t)$. Consumption taxes are insignificant, labor taxes have the correct sign (higher τ^l puts downward pressure on labor market variables) throughout and are significant on net, and investment taxes are not significant.

Finally, note that capital taxes are contemporaneously positively and significantly associated with e and H, but not with h. *To the best of our knowledge, this is a new stylized fact*, which implies that the association of H with capital taxes seeps in via the association of e with capital taxes. *As shown below, our DLM model suggests that this contemporaneous positive relationship between capital taxes and e and H is not causal.* Instead, our DLM model implies that these relationships should be *observed as an ex-post outcome* of forward looking employment demand from previous periods, with, in line with intuition, expected increases in *capital taxes putting downward pressure on employment demand (we elaborate on this relationship later).*

[18]Notes: data are from the Penn World tables.

Table 2: Panel Regression of Labor Market Variables[19]

Variable	$d\ln(e_t)$	$d\ln(e_t)$	$d\ln(h_t)$	$d\ln(h_t)$	$d\ln(H_t)$	$d\ln(H_t)$
$d\ln(1+\tau_t^c)$	0.02	-0.33	0.08	0.01	0.10	-0.32
	(0.61)	(0.34)	(0.13)	(0.08)	(0.71)	(0.37)
$d\ln(1-\tau_t^l)$	0.22^{**}	0.16^{**}	0.07^{*}	0.05	0.29^{***}	0.21^{***}
	(0.09)	(0.07)	(0.03)	(0.03)	(0.07)	(0.06)
$d\ln(1-\tau_t^k)$	-0.18^{**}	-0.14^{**}	-0.05	-0.04	-0.23^{***}	-0.17^{***}
	(0.07)	(0.06)	(0.04)	(0.03)	(0.06)	(0.04)
$d\ln(1+\tau_t^i)$	0.01	0.59	-0.11	0.00	-0.10	0.59
	(1.09)	(0.53)	(0.22)	(0.11)	(1.29)	(0.62)
$d\ln(Y_t)$		0.29^{***}		0.06^{***}		0.35^{***}
		(0.04)		(0.01)		(0.04)
Country fix. eff.	yes	yes	yes	yes	yes	yes
Obs.	648	648	648	648	648	648

4 Theory

Our DLM model begins as a full-fledged general equilibrium labor search model. Among other benefits, this approach allows for a disciplined and well-grounded theoretical justification for the presence of household-side search effort and the way in which we incorporate firm-side employment adjustment costs. *However, the baseline specification of our DLM model is purged of certain elements of standard search theory. Amid this backdrop, in our baseline DLM model all markets are competitive, including the labor market.* The modeling decision to purge our bottom-line DLM specification of certain search elements is specifically guided by the principle of making our DLM model easily comparable to the CLM model and, moreover, making our DLM model a tractable and intuitive extension of the CLM model.

The aggregate population consists of a unit mass, and a household (*not social*) planner solves the household's optimization problem. In contrast to related literature, the economy's population is entirely selfish, atomistic, and autonomous. "Autonomous" in this paper means that each ("atomistic") household member has the power to renege on the household planner's solution if it is not incentive compatible.

[19] Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, population data are from the UN, output is from the Penn World Tables, and tax data are from McDaniel (2007).

The resources of all economic agents that are in the household are pooled.

We assume that the household owns the economy's final-goods producing firm, and, without loss of generality, that the firm owns the economy's capital stock. Households can purchase corporate bonds and firms can issue debt. Corporate bonds and debt mature one period after being issued. Therefore, within any period the inflow of new bonds and debt is equivalent to the total stock of bonds and debt. The inclusion of debt guarantees that firms are able to pay any incurred vacancy-adjustment costs, which, as we show, ultimately link capital taxes to employment.

Mathematical details regarding all of the following can be found in the Appendix. Moving forward, all non-price variables are normalized by the aggregate population. Moreover, all price variables are normalized by the price of consumption.

4.1 The Household

In line with standard labor-search theory from the household's point of view employment evolves as follows:

$$e_t = (1-\rho)\, e_{t-1} + F(\chi_t)\, p_t s_t. \tag{1}$$

Above e_t denotes employment, ρ is the exogenous job destruction probability, and s_t is the endogenous mass of job searchers. $F(\chi_t)\, p_t$ is the household's *effective job finding probability.* $p_t \in [0,1]$ is exogenous, and χ_t is household-controlled search effort. $F' \geq 0$, $F'' \leq 0$, $F(0) = 0$, and $F_t \rightarrow 1$ as $\chi_t \rightarrow \infty$.[20] These diminishing returns to search effort are justified both theoretically and empirically (see, for instance, Pissarides, 2000, and Chirinko, 1984). All told, equation (1) says that period-t employment is equal to the sum of all individuals who were employed last period whose jobs were not destroyed, $(1-\rho)e_{t-1}$, and the mass of successful contemporaneous searchers, $F(\chi_t)\, p_t s_t$.[21] *This equation is a constraint in the household's problem.*

Also in line with standard labor-search theory we assume that *in equilibrium* all individuals participate in the labor market. Therefore, in equilibrium the mass of contemporary searchers is equal to the sum of all individuals who did not find a job

[20] These assumptions guarantee that the effective job finding probability is never greater than 1, as should be the case.

[21] We follow the timing convention in Arseneau and Chugh (20120).

in the previous period, $1 - e_{t-1}$, and the mass of all individuals whose jobs were destroyed at the end of the previous period, ρe_{t-1}. As such,

$$s_t = (1 - e_{t-1}) + \rho e_{t-1}. \tag{2}$$

Given the timing of the model in each period t there are three employment states. These states are newly employed workers (those who flow into employment in period t, $F(\chi_t) p_t s_t$), "old" employed workers (those whose jobs were not destroyed at the end of the previous period, $(1-\rho)e_{t-1}$), and searchers who did not find jobs in this same period $(1 - F(\chi_t))p_t s_t$—*nonemployed individuals*.

The household's lifetime utility $\mathbf{U}_t$ is equal to the infinite sum of the weighted sum of the instantaneous utility of individuals in each employment state. As such,

$$\mathbf{U}_t \equiv \mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left\{ \begin{array}{c} e_s^{old} \overbrace{\left[u(C_s^{e,old}) - G(h_s^{old})\right]}^{\equiv v_s^{e,O}} + e_s^{new} \overbrace{\left[u(C_s^{e,new}) - G(h_s^{new}) - D(\chi_t)\right]}^{\equiv v_s^{e,N}} \\ + (1 - e_s) \overbrace{\left[u(C_s^n) - D(\chi_t)\right]}^{\equiv v_s^n} \end{array} \right\},$$

where β is the exogenous subjective discount factor, e_s^{old} denotes old employed individuals, e_s^{new} denotes new employed individuals, and $1 - e_s$ is the mass of period-s unsuccessful searchers (*nonemployed individuals*). $v_s^{e,old}$, $v_s^{e,new}$, and v_s^n are, respectively, the instantaneous utilities of each of these individuals, and $C_s^{e,old}$, $C_s^{e,new}$, and C_s^n denote the consumption these individuals.[22] We assume that these consumptions are, respectively, a fraction $\kappa_s^{e,old}$, $\kappa_s^{e,new}$, and $1 - \kappa_s^{e,old} - \kappa_s^{e,new}$ of aggregate consumption C_s. Also, h_s^{old} is hours worked per old employed individual and h_s^{new} is hours worked per newly employed individual. Finally, u is utility from consumption ($u' > 0$ and $u'' < 0$), G is disutility from work hours ($G' > 0$ and $G'' > 0$), and D is disutility from search effort ($D' > 0$, $D'' > 0$, and $D_t \to \infty$ as $\chi \to \infty$, where these last two assumptions are consistent with the assumptions on F).

As noted earlier, the economy's population is assumed to be atomistic, autonomous, and selfish. Therefore the household planner faces a series of *incentive compatibility*

[22] The instantaneous utility of individuals in old employment does not include disutility from search effort since they do not search in the current period. In contrast, both newly employed individuals and unsuccesful searchers expend contemporaneous search effort, which of course is the same in equilibrium.

(participation) constraints. First, $v_t^{e,old} \geq v_t^{e,new}$. Second, $v_t^{e,new} \geq v_t^n$. Third, $v_t^n \geq \bar{v}_t$, where $\bar{v}_t$ denotes the outside option of individuals from reneging on the household planner's decision and leaving the household. Jointly, these constraints guarantee that individuals will accept the household planner's proposed solution and pool their resources within the household.

The household's *budget constraint* is

$$(1+\tau_t^c)\,C_t + (b_t - b_{t-1}) \leq \left(1-\tau_t^l\right) w_t (h_t^{old} e_t^{old} + h_t^{new} e_t^{new}) \\ + UB \cdot s_t + V_t + \left(1-\tau_t^k\right) r_{t-1} b_{t-1} + T_t. \tag{3}$$

Above, τ_t^c is the consumption tax, b_t denotes period-t bonds, τ_t^l is the labor tax, w_t is the real wage, UB denotes unemployment benefits, which are paid to every individual who searches in a period and is unsuccessful in finding a job, V_t denotes net-of-(capital)-tax dividends paid by the firm to the household (recall that the household owns the firm), τ_t^k is the capital tax, r_t is the period-t real interest rate, and T_t denotes government transfers. The household takes all taxes, prices, the unemployment benefit, dividends, and transfers as given.

The household planner's choice variables are the following. C_t, $\kappa_t^{e,old}$, $\kappa_t^{e,new}$, κ_t^n, h_t^{old}, h_t^{new}, e_t, s_t, χ_t, and b_t. Of course, given that $e_t^{old} = (1-\rho)\,e_{t-1}$, then knowing s_t and e_t is sufficient to know the distribution of the entire population across employment states.

In what follows, for brevity, we focus on first order conditions relevant for the labor market, only. In addition, we present the household's optimality conditions for the *baseline version of our DLM model, which is purged from certain elements of labor search theory* (optimality conditions from the full-fledged search model are in the Appendix). In particular, our purging assumes: $p_t = 1$ in all periods t, $\rho = 1$, and $UB = 0$. *These assumptions are broadly in line with those used in Arseneau and Chugh (2012) when the authors show how to collapse their general equilibrium labor search model to a standard real business cycle (RBC) model.* Given these assumptions equation (1) collapses to $e_t = F(\chi_t)$.

As shown in the Appendix, in equilibrium $h_t^{new} = h_t^{old} = h_t$, which is intuitive.

As also shown in the Appendix, as a result of the incentive compatibility constraints, the planner's optimal choice of $\kappa_t^{e,old}$ and $\kappa_t^{e,new}$ implies that in equilibrium in each period t the instantaneous utility of individuals in each employment state is equalized. Therefore, in equilibrium individuals are indifferent between being employed or nonemployed, *so there is no involuntary unemployment*. This is the case regardless of the presence of search frictions, and that is why to make this clear we refer to unsuccessful searchers as "*nonemployed*" instead of "*unemployed*."

The remaining relevant optimality conditions are as follows. For aggregate consumption: $u'(\kappa_t^{e,new}C_t)\kappa_t^{e,new} = (1+\tau_t^c)\,\lambda_t$. This is entirely standard in tax-inclusive frameworks save for the presence of $\kappa_t^{e,new}$ that nonetheless does not affect the intuition behind this equation: the time-t effective (tax-inclusive) marginal utility of consumption is equal to the marginal value of real wealth, λ_t. For hours worked per worker

$$G_t' = \lambda_t \left(1 - \tau_t^l\right) w_t e_t, \tag{4}$$

meaning that the marginal cost of hours worked per worker equals its marginal benefit. Also, combining the optimality conditions for χ_t and e_t implies that

$$D_t' = \lambda_t \left(1 - \tau_t^l\right) w_t h_t \cdot F_t'. \tag{5}$$

Given our purging of labor search components, then in our baseline DLM specification choosing χ_t is the same as choosing e_t. As such, equation (5) is the household's effective employment supply equation, which means that the marginal cost of employment (the right-hand side of this equation, which is χ-dependent) is equal to its marginal benefit (the equation's left-hand side, which is also χ-dependent).

4.2 The Firm

Aggregate output Y_t is generated by the production function $Y_t = Y\left(Z_t, K_t, H_t\right)$. Here, Z_t is exogenous total factor productivity and K_t denotes capital. In line with standard CLM literature we assume that Y_t is linear in Z_t and increasing and concave in K_t and H_t. Of course, $H_t \equiv h_t \cdot e_t$.

The firm's objective function, net-of-(capital)-tax dividends, is given by

$$\mathbb{E}_t \sum_{s=t}^{\infty} \Xi_{s|t} \underbrace{\left\{ \overbrace{\left(1-\tau_s^k\right) \begin{bmatrix} Y\left(Z_t, K_t, h_t e_t\right) - w_s h_s e_s - I_s \\ -r_{s-1} d_{s-1} - \Lambda\left(Z_s\right) \cdot \left(\Phi v_s + \Omega(v_s / v_{s-1}, v_s w_s)\right) \end{bmatrix}}^{\equiv \bar{V}_s} \atop + \left(d_s - d_{s-1}\right) \right\}}_{\equiv V_s}. \tag{6}$$

Above, I_s is investment, d denotes debt, Φ is the exogenous flow cost of posting vacancies v_s. Ω is a standard adjustment cost function that is increasing and convex in the ratio v_s/v_{s-1} and also increasing $v_s w_s$. The product $v_s w_s$ captures in a reduced form way the intuition that hiring costs can reflect expenditures on a human resources department, and therefore are a fraction of the wage bill. Ω is equal to zero whenever v_s equals v_{s-1}, which, in particular, is the case in steady state (the broader relevance of adjustment costs for labor markets is emphasized by Cooper and Willis, 2004, Caballero and Engel, 2004, Cooper and Willis, 2008, and Mumtaz and Zanetti, 2014, among others.)[23] Turning to $\Lambda\left(Z_t\right)$, following, for instance, Pissarides (2000), we assume that the firm's costs of posting vacancies are *potentially* a function of aggregate productivity. However, we do not make any assumption on whether, if productivity is indeed related to vacancy posting costs, higher productivity makes it more costly or less costly for firms to post vacancies. Instead, as discussed below, we arrive at a conclusion regarding the potential relationship between productivity and vacancy posting via empirical analysis.

The firm faces two constraints. First, a standard equation of motion for the capital stock, $K_{t+1} = I_t + (1-\delta) K_t$, where δ is the capital depreciation rate. Second, its perceived evolution of employment, $e_t = (1-\rho) e_{t-1} + q_t v_t$, where q_t is the job filling probability, which the firm takes as given. In words, this equation says that the firm's contemporaneous stock of employed individuals is equal to the sum of all of

[23] Of course, the change in the firm's debt position is not taxed, and, intuitively, we assume that $V_t \geq 0\ \forall t$. Moreover, we do not include investment taxes since, per the evidence in Table 1 they do not have an impact on labor market variables and, furthermore, in our DLM model, in line with CLM models, investment taxes do not have a theoretical impact on labor market variables either.

the previous period's workers who did not lose their job, $(1-\rho)\,e_{t-1}$, and all newly formed employment relationships, which are equal to the fraction of all vacancies posted that are filled in a period, $q_t v_t$.

The firm's choice variables are K_{t+1} (i.e., I_t), d_t, h_t, e_t, and v_t. For brevity, *we present the firm's optimality condition for the baseline version of our DLM model, which, as noted earlier, is purged from certain elements of labor search theory* (optimality conditions from the full-fledged search model are in the Appendix). In particular, as relevant for the firm, these purging assumptions are $q_t = 1$ in all periods t, $\rho = 1$, and $\Phi = 0$ (these assumptions are broadly in line with Arseneau and Chugh, 2012, when the authors show how to collapse their general equilibrium labor search model to a standard RBC model). In this environment the firm's equation of motion for employment collapses to $e_t = v_t$, so the firm's choice of vacancies is one and the same with its choice of employment.

We continue to focus on the labor market. The first order condition for h_t implies that

$$Y_{h_t} = w_t e_t, \tag{7}$$

which of course means that the marginal product of hours worked per worker is equal to its marginal cost and, therefore, that the wage is competitive. The first order condition for employment, which, recall, given our purging assumptions is one and the same with the first order condition for vacancies, is

$$-\Lambda\left(Z_t\right)\frac{\partial\Omega_t}{\partial e_t} = \mathbb{E}_t\Xi_{t+1|t}\frac{1-\tau_{t+1}^k}{1-\tau_t^k}\Lambda\left(Z_{t+1}\right)\frac{\partial\Omega_{t+1}}{\partial e_t}. \tag{8}$$

This means that whenever the firm is adjusting employment, employment demand is forward looking, as in standard models of labor demand with adjustment costs (see, for instance, Sargent, 1979).[24] Of note, the derivation of equation (8) uses the fact that from equation (7) $Y_{h,t}h_t = w_t h_t e_t$, which given the fact that $Y_{h_t}h_t$ equals $Y_{e_t}e_t$ implies, *as a result*, that $Y_{e,t}e_t = w_t h_t e_t$.

[24] In periods in which the firm does not adjust employment demand, adjustment costs are zero and equation (8) implies that employment demand is pinned down by the following optimality condition: $Y_{e_t} = w_t h_t$.

Equation (8) means that firms find it optimal to equate the post-tax marginal cost of changing employment today to the post-tax (discounted) marginal cost of changing employment tomorrow. Another way to interpret this equation is that *firms optimally decide on employment adjustment in order to smooth adjustment costs over time (and, more specifically, smooth the consumption value of net-of-(capital)-tax dividends for the household).* As an example, suppose that at time t an expected increase in next period's capital tax rate τ_{t+1}^k lowers the ratio $\frac{1-\tau_{t+1}^k}{1-\tau_t^k}$. To restore equation (8) the firm will raise $\frac{\partial \Omega_t}{\partial e_t}$, which will require raising expected employment.

4.3 Closing the Model

Throughout the remainder of the paper we henceforth focus exclusively on the baseline ("purged") version of our DLM model. In particular, recall that this purging involves assuming the following: ρ, p_t, and q_t are equal to 1 in all periods, and UB and Φ are equal to zero in all periods. To close the model we assume that government consumption is zero, so that $T_t = \tau_t^c C_t + \tau_t^l w_t h_t e_t + \tau_t^k \left(r_{t-1} b_{t-1} + \bar{V}_t\right)$. This implies that the aggregate resource constraint is given by $Y_t = C_t + I_t + \Lambda\left(Z_t\right) \Omega\left(e_t / e_{t-1}, e_t w_t\right)$ whenever e_t is not equal to e_{t-1}, and $Y_t = C_t + I_t$ whenever the firm does not adjust employment. *The model's equilibrium is discussed in the Appendix.*

5 Operationalizing the Theory

Recall once more that as noted earlier throughout the remainder of the paper we focus exclusively on the "purged" version of our DLM model.

Following the literature most related to our paper, we evaluate our DLM model's performance by using the "business cycle accounting" approach.[25] For our purposes, this involves the following. Suppose that a variable X_t is a function of the vector of variables and parameters $\mathbf{\Psi}_t$ such that $X_t = X\left(\mathbf{\Psi}_t\right)$. The model's performance regarding this variable is evaluated by taking the equation $X_t = X\left(\mathbf{\Psi}_t\right)$ and feeding into it empirical data for $\mathbf{\Psi}_t$, which results in a theory-implied prediction for the

[25] Key references are, for example, Prescott (2004) and Chari, Kehoe, and McGrattan (2007) among others.

behavior of X_t. Assessing the model's fit then involves comparing this theory-implied prediction for the behavior of X_t with its empirical behavior.

Of course, our DLM model's equilibrium condition for h_t (equation (9)) is static, so it is straightforward to test this condition using business cycle accounting. That said, because employment demand (equation (8)) is dynamic, then so is equilibrium employment. Therefore, to be conceptually in line with business cycle accounting, we will assess the fit of our DLM model's dynamic equilibrium employment equation from an ex-post vantage point.

5.1 Functional Forms

In line with related literature we assume a standard constant returns to scale production function $Y_t = Z_t K_t^{\alpha} (h_t e_t)^{1-\alpha}$ where $\alpha \in (0, 1)$ and therefore $Y_{h_t} h_t = (1-\alpha) Y_t$ and $Y_{e_t} e_t = (1-\alpha) Y_t$. Turning to employment demand, we assume that $\Lambda(Z_t) = Z_t^{\zeta}$, where, as discussed earlier, ζ will be estimated and its value could, in principle, be less than zero, greater than zero, or equal to zero. We also assume the following cost function: $\Omega_t = \psi \mathbb{I}_t (e_t/e_{t-1})^{\phi} e_t w_t$, where $\psi > 0$, $\phi > 1$, and $\mathbb{I}_t$ equals zero if e_t equals e_{t-1} and $\left(\frac{\beta\phi}{1+\phi}\right)^{t-1}$ otherwise. As such, $\mathbb{I}_t$ guarantees that adjustment costs are zero whenever the firm is not adjusting vacancies (which, in particular, is the case in steady state), the fact that when adjusting employment $\mathbb{I}_t$ equals $\left(\frac{\beta\phi}{1+\phi}\right)^{t-1}$ is a technical assumption that guarantees that the growth rate of employment is zero in steady state.

Turning to the household, following the assumptions in Shimer (2009) as applicable to the present context we assume $G(h_t) = \gamma \frac{\varepsilon}{1+\varepsilon} (h_t)^{\frac{1+\varepsilon}{\varepsilon}}$, where: γ and ε are parameters that are strictly greater than zero. As such, in our DLM model ε is the Frisch elasticity of the supply of hours worked per *worker*. Also following Shimer (2009), let $u(\cdot) = \ln(\cdot)$. For expositional tractability we assume $F(\chi_t) = \varphi \chi_t^{\sigma}$, where $\sigma \in (0,1)$ and $\varphi > 0$ (parameters are assumed to be in line with only infinite search effort being sufficient to approach a value of F_t equal to 1, even though our assumed functional form for F does not asymptote at 1), and also $D_t = \varrho \chi_t^{\theta}$, where $\theta > 1$ and $\varrho > 0$.

5.2 DLM Testable Implications

5.2.1 Hours Worked per Worker

As shown in the Appendix, combining the demand and supply of hours worked per worker implies the following equilibrium condition, which is one of two testable implications that our DLM model yields about the labor market:[26]

$$h_t = \left[(1-\alpha) \cdot \gamma^{-1} \left(1-\tau_t^l\right) \cdot \left(1+\tau_t^c\right)^{-1} C_t/Y_t\right]^{\frac{\varepsilon}{1+\varepsilon}}. \tag{9}$$

Above, ε is the elasticity of hours worked per *worker* with respect to the wage. Intuitively, increases in labor taxes chip away at the value of the extra hour of work, increases in consumption taxes raise the price of consumption, and therefore increase the opportunity cost of consumption in terms of leisure, and a higher consumption-output ratio reduces the marginal value (in terms of consumption) of an additional hour of work.

To generate our DLM model's predictions of hours worked per worker, we proceed as follows. First, we run a panel of the regression corresponding to equation (9) after taking logarithms. Coefficients are constrained as implied by the theory, and we arrive at a single cross-country estimate of $\frac{\varepsilon}{1+\varepsilon}$, so for our purposes the preference parameter ε is the same across countries. Then, for each country in our sample, we feed country-specific empirical time series data on consumption, consumption taxes, output, and labor taxes, into the right-hand side of equation (9) that, given our estimate of $\frac{\varepsilon}{1+\varepsilon}$, yield our DLM model's *country-specific* predictions for hours worked per worker. Since our interest is in long run trends, in line with related literature, such as Shimer (2009), the value of $\frac{1-\alpha}{\gamma}$ is chosen so that the average of predicted hours worked per worker match the average of their empirical counterpart *on a country-by-country basis.*

5.2.2 Employment

Turning to employment, with our assume functional forms and taking logs equation

[26] Given our functional form assumptions first order condition for aggregate consumption is

$$C_t^{-1} = \left(1+\tau_t^c\right)\lambda_t.$$

Therefore, the optimal values of the κ variables are irrelevant for our analysis.

(8) yields the following "forward looking" condition for employment demand:[27]

$$d\ln e_t = \frac{1+\phi}{\phi} d\ln e_{t+1} + \frac{1}{\phi}\left[\begin{array}{c} d\ln w_{t+1} + \zeta d\ln Z_{t+1} \\ -d\ln \lambda_{t+1} + d\ln\left(1-\tau_{t+1}^{k}\right) \end{array}\right] \tag{10}$$

(see the Appendix for details). Therefore, *from the vantage point of the firm's period-t decision making* equation (10) conveys the following optimal firm-side actions. Higher $d\ln w_{t+1}$, higher $d\ln e_{t+1}$, and *lower* $d\ln \lambda_{t+1}$ are associated with higher future output, given which the firm anticipates an expansion in future employment. In order to smooth adjustment costs, the firm frontloads some of this employment expansion, which puts upward pressure on $d\ln e_t$. For concreteness assume that $\zeta < 0$. As such, higher $d\ln Z_{t+1}$ means lower adjustment costs in the future. In smoothing these costs the firm postpones some contemporaneous adjustment, which puts downward pressure on $d\ln e_t$. Finally, higher capital taxes mean that future net-of-capital-tax dividends will be lower, given which the firm wants to adjust the least possible amount today in order to get as much net-of-tax-dividends today and, therefore, before the increase in capital taxes. This puts downward pressure on $d\ln e_t$.

It follows that the right-hand side of equation (10) reflects *causal* factors affecting the firm's contemporaneous demand. However, solving this equation for $d\ln e_{t+1}$ and lagging the equation one period gives us an ex-post perspective that, therefore, reflects *outcomes* (and *not contemporaneous causality*) that should be observed given the firm's decisions in the earlier period:

$$d\ln e_{t+1} = \frac{\phi}{1+\phi} d\ln e_t - \frac{1}{1+\phi}\left[\begin{array}{c} d\ln w_{t+1} + \zeta d\ln Z_{t+1} \\ -d\ln \lambda_{t+1} + d\ln\left(1-\tau_{t+1}^{k}\right) \end{array}\right]. \tag{11}$$

Combining the dynamic equation for employment demand with a dynamic version of employment supply (see the Appendix for details) yields our DLM model's second testable implication, which is the following dynamic equation for equilibrium

[27] As noted earlier, we will focus on from an ex-post perspective later in order to make business cycle accounting feasible, which is why here for simplicity we drop expectation operators.

employment:[28]

$$d\ln e_t = \frac{\phi}{\phi + \left(\frac{\sigma}{\theta}\right)^{-1}} d\ln e_{t-1}$$

$$+\frac{1}{\phi + \left(\frac{\sigma}{\theta}\right)^{-1}} \left[\begin{array}{c} \left(1+\frac{\varepsilon}{1+\varepsilon}\right) d\ln\left(1-\tau_t^l\right) - \frac{\varepsilon}{1+\varepsilon} d\ln\left(1+\tau_t^c\right) \\ -\frac{\varepsilon}{1+\varepsilon} d\ln\left(C_t/Y_t\right) - d\ln\left(1-\tau_t^k\right) - \zeta d\ln Z_t \end{array} \right]. \tag{12}$$

Intuitively, this is an autoregressive moving average process with exogenous variables (ARMAX) for equilibrium employment—clearly, this equilibrium process is nonexplosive in employment. In this equation the variables scaled by coefficients that include ε trace back to the supply of hours worked per worker, of which employment supply is a function of. The terms that involve ε, which are $\left(1+\frac{\varepsilon}{1+\varepsilon}\right) d\ln\left(1-\tau_t^l\right)$, $\frac{\varepsilon}{1+\varepsilon} d\ln\left(1+\tau_t^c\right)$, and $\frac{\varepsilon}{1+\varepsilon} d\ln\left(C_t/Y_t\right)$, also trace back to the supply of hours worked per worker, and their impact on equilibrium employment is akin to their impact on equilibrium h. In addition, the presence of σ/θ traces back to employment supply and reflects the relative degree of diminishing returns to search.[29]

To operationalize equation (12) via business cycle accounting we first estimate its parameters. To be internally consistent, the regressors $\left(1+\frac{\varepsilon}{1+\varepsilon}\right) d\ln\left(1-\tau_t^l\right)$, $\frac{\varepsilon}{1+\varepsilon} d\ln\left(1+\tau_t^c\right)$, and $\frac{\varepsilon}{1+\varepsilon} d\ln\left(C_t/Y_t\right)$ are generated using the estimate of ε obtained from from running the regression corresponding to equation (9). As such, our (constrained, as implied by the theory) regression of equation (12) yields estimates of $\frac{\phi}{\phi+\frac{\theta}{\sigma}}$, $\frac{1}{\phi+\frac{\theta}{\sigma}}$, and $\frac{\zeta}{\phi+\frac{\theta}{\sigma}}$.

Recall that in estimating equation (9) we run a panel with all countries in our sample since with that equation we are ultimately estimating ε, which is a preference parameter and therefore should not be assumed to be different across countries. However, in estimating equation (12) we are guided by the fact that there are well-known

[28]Moreover, the household's stochastic discount factor is

$$\Xi_{s|t} \equiv \beta^{s-t} C_t \cdot C_s^{-1} \left(1+\tau_t^c\right)\left(1+\tau_s^c\right),$$

where $s \geq t$, which means that higher consumption as well as higher consumption taxes (or, taken together, higher consumption expenditures) at time t lower the marginal value of consumption in that period.

[29]It is straightforward to show that in steady state equilibrium employment is tax-wise only a function of labor taxes (decreasing) and consumption taxes (decreasing).

differences between the relative flexibility of European versus U.S. labor markets (see, for instance, Llosa et al., 2014). For example, consider the OECD's indicators of employment protection legislation (indices that go from 0, which implies least employment restrictions, to 6, which implies most employment restrictions)[30]. In our European sample, the average index for: protection of permanent workers against individual and collective dismissal is 2.47; the average protection of permanent workers against individual dismissal is 2.16; specific requirements for collective dismissal is 3.24; and regulation on temporary forms of employment is 1.91. In contrast, in the United States these figures are, respectively: 1.17 (over 50 percent lower than in Europe); 0.49 (nearly 80 percent lower than in Europe); 2.88 (over 10 percent lower than in Europe); and 0.33 (over 80 percent lower than in Europe).

Importantly, note that in equation (12) all parameters to be estimated can be interpreted as reflecting, in a reduced form way, economic factors related to labor market rigidities. Indeed, a relatively higher value of ϕ means that it is more costly for firms to adjust employment, a relatively higher value of θ/σ means that relative returns to search decrease at a faster rate, and, assuming for concreteness that ζ is negative, a lower ζ means that higher productivity lessens employment adjustment costs by a relatively lower amount. In line with the evidence on labor market rigidities, it follows that there is no reason to expect that these parameters would be the same in Europe as in the United States. Thus, in estimating equation (12) we run a panel for Europe and a separate regression for the United States.

Given the estimated parameter values from running the regressions to estimate equation (12), we generate our DLM model-predicted level employment series for *each country* in our sample as follows. Let x_i denote empirical values for country i's variable x, x_i denote predicted values for country i of variable x, and $\hat{\boldsymbol{\beta}}$ denote the applicable vector of parameter estimates from running the regressions to estimate equation (12). First, we generate our DLM model-predicted employment growth rate for country i between the first growth rate that we can predict conditional on our

[30] https://www.oecd.org/employment/emp/oecdindicatorsofemploymentprotection.htm

data's starting point (period $t-1$ for the purposes of what follows immediately below before ending this section) using the following equation:

$$d\ln(e_{i,t}) = \hat{\boldsymbol{\beta}}' \times \begin{bmatrix} d\ln(e_{i,t-1}), d\ln\left(1-\tau_{i,t}^{l}\right), d\ln\left(1+\tau_{i,t}^{c}\right), \\ d\ln(C_{i,t}/Y), d\ln\left(1-\tau_{i,t}^{k}\right), d\ln(Z_{i,t}) \end{bmatrix}.$$

Thereafter, we predict growth rates using for our lagged growth rates the model's predicted growth rates. In other words, the model's prediction of $d\ln(e_{i,t+1})$ uses $d\ln(e_{i,t})$. *Therefore, except for the first lagged growth rate used, all other lagged growth rates used to get our model-generated predictions are fully and entirely endogenous.*

Second, with our model-generated growth rates in hand, we then use the first empirical level of employment in period t along with the model-predicted growth rate between period t and period $t+1$ to arrive at the model's first predicted level value of employment. We generate the remaining level values of employment by using the previous period's *predicted* employment levels. Akin to our DLM model's hours worked per worker predictions, the (level) employment series predicted by our DLM model is rescaled to have the same mean as the empirical employment series on a country-by-country basis.[31]

5.3 CLM Model H

We operationalize a representative version of the CLM model, in particular, the one used in Shimer (2009), in order to compare results from this model regarding H to the results from our DLM model. This version of the CLM model yields tax-inclusive results that are representative of related literature: a successful prediction of hours worked per population in Europe and highly counterfactual results for the United States.

In the CLM model the production function is the same as in our DLM model, and the household's instantaneous utility is $\ln(C_t) - \varepsilon(1+\varepsilon)^{-1}(H_t)^{\frac{\varepsilon}{1+\varepsilon}}$, so in this case ε is the Frisch elasticity of the supply of hours worked per *population* (in contrast to

[31] We obtain our DLM model's predicted equilibrium employment series using its dynamic version since in our data no two adjacent employment figures are the same. In other words, in taking our model to the data the implication is that employment adjustment costs were paid in every period.

the DLM model, where ε is the Frisch elasticity of the supply of hours worked per *worker*). Of course, all taxes we consider in our DLM model remain the same in the CLM model, and in the CLM model the household's budget constraint is the same as in our DLM model.

All told, as shown in the Appendix, the following is the single equilibrium labor market condition that arises in the CLM model:

$$H_t = \left[(1-\alpha) \cdot \gamma^{-1} \left(1-\tau_t^l\right) \cdot \left(1+\tau_t^c\right)^{-1} C_t/Y_t\right]^{\frac{\varepsilon}{1+\varepsilon}} . \tag{13}$$

(recall that the CLM model does not distinguish between the different margins of labor). Importantly, note that the right-hand side of equations (9) and (13) are the same (therefore, the intuition behind equation (13) is entirely analogous to the intuition behind equation (9)). Of note, this means that per our DLM model the CLM model's equation for equilibrium H is, in fact, an equation for equilibrium h.

In abstract terms it is straightforward to show that our DLM model's equilibrium condition for hours worked per worker is

$$h_t = G^{-1} \left(\lambda_t \left(1-\tau_t^l\right) Y_{h,t} h_t\right)$$

and the CLM model's equilibrium condition for hours worked per population is

$$H_t = G^{-1} \left(\lambda_t \left(1-\tau_t^l\right) Y_{H,t} H_t\right) .$$

With perfect substitutability of e and h in production, then $Y_{h,t}h_t = Y_{H,t}H_t$ in the equations above. Therefore, the fact that our DLM model's equation for equilibrium h is the same as that of the CLM model for equilibrium H is not functional form dependent.

To operationalize equation (13) we take logarithms as in the case of the hours per worker equation from our DLM model and run a constrained panel regression to estimate the CLM model's value of ε. Then, we generate the CLM model-generated predicted H_t using the same methodology used to generate DLM-model predicted h as discussed earlier. *Results from this operationalization are those shown in Figure 1 in the paper's introduction.*

6 Results

Recall that H is the only endogenous labor market variable predicted by the CLM model, and that the H predicted by our DLM model is built from the bottom up by first predicting h and e separately. Per the operationalization description in Section 5, our results obtain from predicting the CLM model's $H_{i,t}$ for each country i in our sample, and predicting our DLM model's $h_{i,t}$ and $e_{i,t}$ for each country in our sample and then constructing $H_{i,t}$ by multiplying these two. Model-generated results for Europe are the simple average across the model-predicted $H_{i,t}$ of european countries in our sample.

In what follows, we first show results from the regressions detailed earlier and highlight the implications of parameter estimates (Section 6.1). Then, we summarize model performance from a quantitative perspective across countries and on an individual basis (Section 6.2). In addition, we address model performance from the trend and contour perspective (Section 6.3). Finally, we focus on the implications of our model for the long-run labor wedge (Section 6.4).

6.1 Parameter Estimates

Table 3 shows results from running, in the fashion discussed earlier, constrained panel of the regressions corresponding to equations (9) and (13) in rows 1 and 2, respectively. All parameter estimates are statistically significant and of the correct sign. For our DLM model's h the implied estimate of ε is 1.44 (in this case the Frisch elasticity of the supply of hours worked per *worker*), and for the CLM model's H the implied estimate of ε is 2.84 (in this case the Frisch elasticity of hours worked per population).

Table 3: Estimates of Labor Elasticities[32]

Variable	$\ln(C_t/Y_t)$	$\ln(1+\tau_t^c)$	$\ln(1-\tau_t^l)$	Country fix. eff.	Obs.
$\ln(h_t)$	-0.59***	-0.59***	0.59***	yes	660
	(0.02)	(0.02)	(0.02)		
$\ln(H_t)$	-0.74***	-0.74***	-0.74***	yes	660
	(0.03)	(0.03)	(0.03)		

[32] Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the UN. Construction of model results use tax data from McDaniel (2007), and consumption and output data are from the Penn Word Tables.

Table 4 shows results from running the constrained regression of equation (12) in panel form for Europe (first row) and individually for the United States (second row). All parameter estimates are statistically significant. Moreover, the implied value of $\phi + \theta/\sigma$ is 11.11 in Europe and 4.16 in the United States. Give these values: (1.) the implied value ϕ is 5.56 in Europe and 1.78 in the United States, which means that the elasticity of employment adjustment costs with respect to the relative size of adjustment is over twice as high in Europe compared to the United States; and (2.) the implied value of θ/σ in Europe is 5.55 and 2.38 in the United States, which means that search returns decrease at a rate over twice as high in Europe compared to the United States. Finally, the implied value of ζ is -0.44 in Europe and -0.79 in the United States. Since ζ is negative, this means that when productivity is higher, employment adjustment costs are lower—intuitively, this can capture in a reduced form way that higher productivity can offset expansionary structural changes in the firm that must take place in order to accommodate more workers. Moreover, the fact that the value of ζ in the United States is less than its value in Europe implies that higher productivity decreases employment adjustment costs by less in Europe than the United States.

All told, we speculated that parameters in our DLM model's dynamic expression for equilibrium employment reflect underlying structural factors related to labor market rigidities. Results shown in Table 4 are indeed in line with this. Indeed, the implied rigidities from our results are consistent with these rigidities being substantially greater in Europe compared to the United States, which is in line with empirical evidence that studies these rigidities explicitly. *Taken together, these results lend substantial validity to our DLM model.*

Table 4: Estimates of Employment Equation $d\ln(e_t)$ regressand[33]

	$d\ln$ of variable:							
Region	e_{t-1}	TFP_t	$\frac{C_t}{Y_t}$	$1+\tau_t^c$	$d\ln 1-\tau_t^k$	$d\ln 1+\tau_t^l$	Country fix. eff.	Obs.
Europe	0.50***	0.04**	-0.09**	-0.09**	-0.09**	0.09**	yes	583
	(0.05)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)		
US	0.43**	0.19**	-0.24**	-0.24**	-0.24**	0.24**	—	53
	(0.19)	(0.08)	(0.09)	(0.09)	(0.09)	(0.09)		

[33]Notes: total work hours are from the Conference Board's Total Economy Database, employment

6.2 Cross-Country Quantitative Performance

A key issue related to our research is understanding the extent to which our DLM model does relatively better or worse at predicting hours worked per *population* across countries compared to the CLM model. To get at this assessment, define for each country i in our sample the sum of squared deviations measure

$$SSD_i \equiv \sum_t \left(d\ln H_{i,t}^{DLM} - d\ln H_{i,t}\right)^2 \cdot \left[\sum_t \left(d\ln H_{i,t}^{CLM} - d\ln H_{i,t}\right)^2\right]^{-1}$$

and the sum of absolute deviations measure

$$SAD_i \equiv \sum_t \left|d\ln H_{i,t}^{DLM} - d\ln H_{i,t}\right| \cdot \left[\sum_t \left(d\ln H_{i,t}^{CLM} - d\ln H_{i,t}\right)\right]^{-1},$$

where $d\ln H_{i,t}$ is the growth rate of empirical H and $d\ln H_{i,t}^{j}$ is model-predicted H by model $j \in \{CLM, DLM\}$. Then, for country i consider the numbers $100\cdot(1-SSD_i) \equiv \widetilde{SSD}_i$ and $100\cdot(1-SAD_i) \equiv \widetilde{SAD}_i$. This means that for $z_i \in \{\widetilde{SSD}_i, \widetilde{SAD}_i\}$ numbers $z_i > 0$ denote that our DLM does z_i percent better than the CLM model at predicting the growth rate of H, while numbers $z_i < 0$ denote that our DLM does z_i percent worse than the CLM model at predicting the growth rate of H. Of course, $z_i = 0$ implies that both models do equally well.

Table 5 shows $\widetilde{SSD}_i$ and $\widetilde{SAD}_i$ for all countries in our sample. *On the basis of these metrics, we conclude that, compared to the CLM framework, our DLM model is an important step forward in understanding and predicting the behavior of hours worked per population.* Results imply that on average our DLM model does better than the CLM model by between 12 and 20 percent, with notable improvements of up to 43 percent for the United Kingdom and 31 percent for the United States. The

is from the OECD, and population data are from the UN. Construction of model results use tax data from McDaniel (2007), and output, consumption and productivity data from the Penn Word Tables.

only country for which model performance is about the same is France.

Table 5: Comparison of CLM and DLM model performance[34]

(in %)	Austria	Belgium	Finland	France	Germany	Italy
$\widetilde{SSD}_i$	16.26	32.64	23.64	0.63	25.26	11.91
$\widetilde{SAD}_i$	4.21	26.5	7.89	−2.43	11.50	9.03
(in %)	Netherlands	Spain	Sweden	Switzerland	UK	US
$\widetilde{SSD}_i$	18.24	11.43	10.72	12.64	43.11	31.49
$\widetilde{SAD}_i$	10.62	7.83	8.19	7.69	28.15	22.7

6.3 Trend and Contour Analysis

Table 6 shows notation used for the purposes of presenting results in what follows. For our DLM model, Figure 5 shows results for h. Figure 6 shows results for e. Finally, Figure 7 shows results for H from both our DLM model and the CLM model.

Table 6: Notation for DLM Model Generated Variables

Notation	Meaning
h (e) DLM	Prediction per equation 9 (12)
H DLM	Product of h DLM and e DLM
h (e) DLM C/Y fix	Prediction per equation 9 (12) holding C/Y fixed
h (e) DLM $cons$ tax fix	Prediction per equation 9 (12) holding τ_t^c fixed
h (e) DLM lab tax fix	Prediction per equation 9 (12) holding τ_t^l fixed
e DLM cap tax fix	Prediction per equation 9 holding τ_t^k fixed
e DLM TFP fix	Prediction per equation 9 holding TFP fixed

Figure 5 shows that our DLM model tracks the behavior of h in both Europe and the United States very well. The same is true for e as shown in Figure 6. In each of these figures, counterfactuals ("fix") holding one at a time constant the ingredients that go into predictions of each variable reveal the most important driving forces associated with the behavior of each variable. Per Figure 5, in the United States, increases in C/Y and τ^l (recall Figure 3) have put downward pressure on h. In Europe the most important variable associated with the behavior of h is τ^l, with results implying that absent the substantial secular increase in τ^l (recall Figure 3) h

[34]Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the UN. Construction of model results use tax data from McDaniel (2007), and output, consumption and productivity data from the Penn Word Tables.

would have been flat.

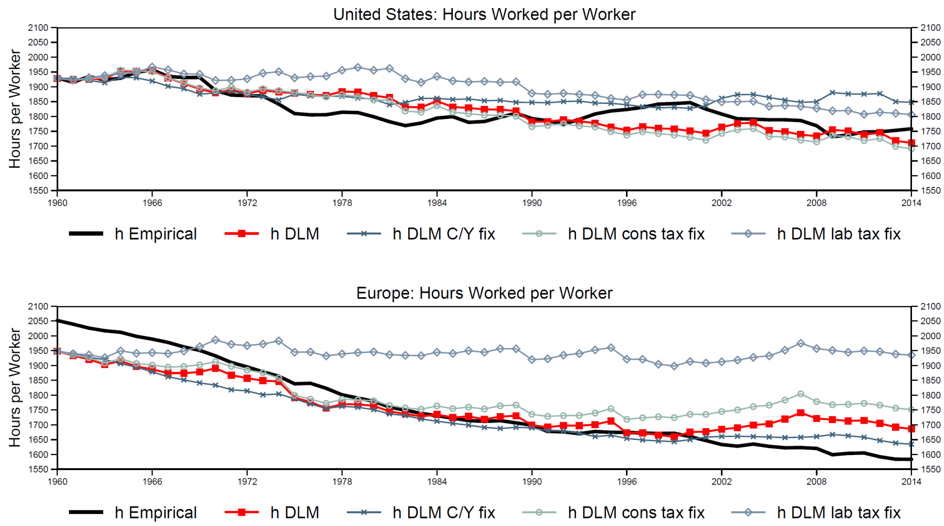

Figure 5: Empirical hours worked per population and DLM model predictions for Europe (bottom panel) and the US (top panel).[35]

Per Figure 6, in the United States, gains in TFP (recall Figure 4) are the most important factor associated with gains in employment, absent which e would have been flat. Taxes and C/Y play a secondary role, and mostly matter for the contour of e. That said, increases in C/Y and τ^l, and decreases in τ^k (recall Figure 3) jointly put downward pressure on e. (Recall that per our DLM model's equation for equilibrium employment, the contemporaneous relationship between capital taxes and employment is not causal, but instead an observed outcome of forward-looking employment demand from earlier periods given which, and in line with intuition, capital taxes put downward pressure on employment demand.) For Europe, the message regarding e from Figure 6 is quite stark: flat e is associated with the secular increase in τ^l offsetting gains in TFP that would have otherwise been associated with gains in e.

[35] Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the UN. Construction of model results use tax data from McDaniel (2007), and output and consumption data from the Penn Word Tables.

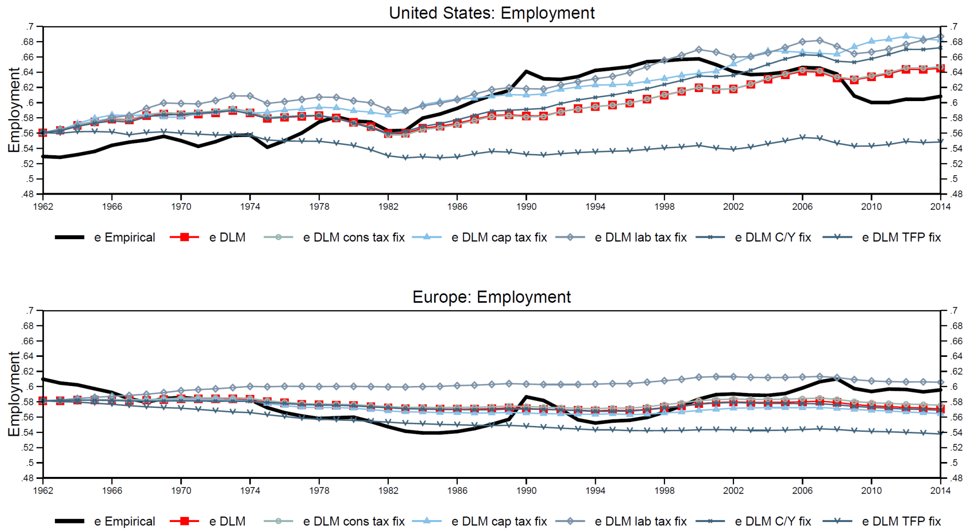

Figure 6: Empirical employment-population ratio and DLM model predictions for Europe (bottom panel) and the US (top panel).[36]

Bringing the two margins of labor together, Figure 7 shows our DLM model's predictions for hours worked per population. Also shown are empirical H and, for reference, the CLM model's predictions as well (already shown in Figure 1). For Europe, both models perform successfully and fairly similarly. For the United States our DLM model matches the shallow V-shape of empirical H, while as discussed

[36] Notes: employment is from the OECD, and population data are from the United Nations. Construction of model results use tax data from McDaniel (2007), and output, consumption and productivity data from the Penn Word Tables.

earlier the CLM model predicts a counterfactual secular decrease in H.

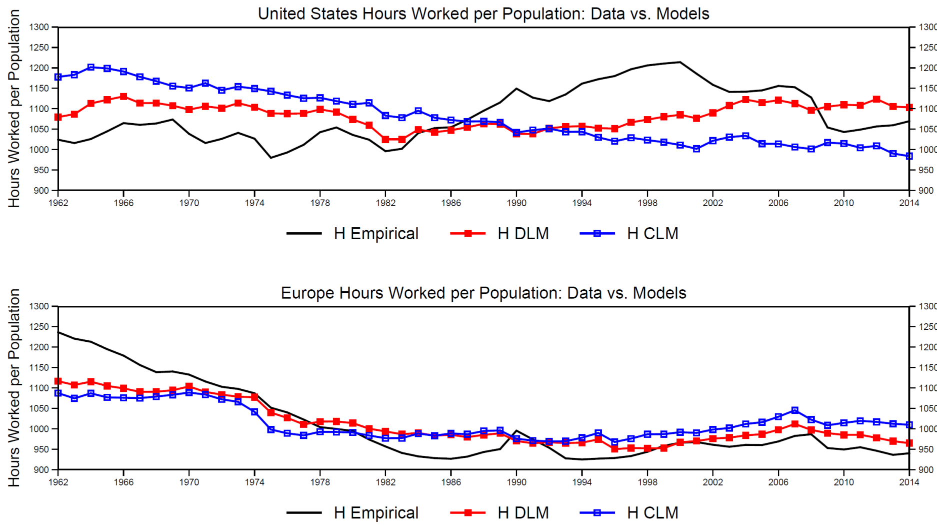

Figure 7 Empirical hours worked per population and DLM and CLM model predictions for Europe (bottom panel) and the US (top panel).[37]

As highlighted earlier in the data section, the labor-tax series from McDaniel (2007), which are *average* taxes, do not reflect, contour wise, the Reagan tax reforms (1981 through 1986), which in contrast the NBER labor-tax series, which are *average marginal* taxes, indeed do reflect. Recall as well that both series have broadly the same trend, and that amid the Reagan tax reforms the McDaniel series imply rising labor taxes—which of course is driven by an increase in the tax base—while the NBER series imply decreasing taxes, as should be the case.

To assess the impact of these differences, Figure 8 shows results for e and H for the United States from operationalizing our DLM model with the NBER taxes, as well as results from the CLM model for H. Regarding e, comparing Figures 6 and 8 shows that our DLM model gets much better at the hump in employment starting in the early 1980s. This makes sense amid decreasing labor taxes as implied by the NBER tax series. Comparing Figures 7 and 8, the same is true for H. *The endpoints of e and H predictions are much tighter as well.* In addition, the CLM model's

[37] Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the United Nations. Construction of model results use tax data from McDaniel (2007), and output, consumption and productivity data from the Penn Word Tables.

predictions continue to yield counterfactual decreasing H.

In the Appendix we elaborate in further detail on the results described immediately above regarding the NBER taxes. We also show that an extension of our DLM model that accounted for differences in trends in employment by gender would for all purposes close the small remaining employment-hump gap between model and data that remains in the 1990s.

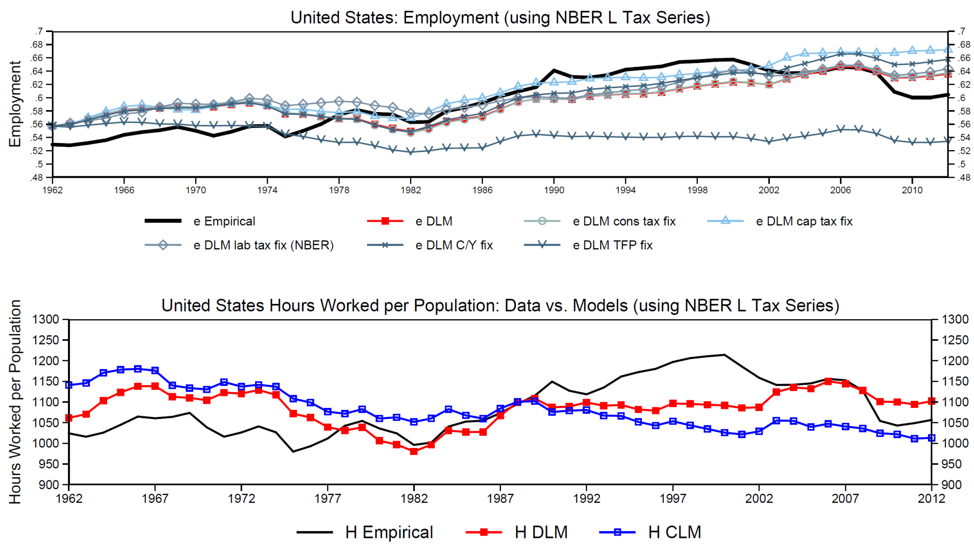

Figure 8: Results for the United States using NBER labor taxes instead of McDaniel (2007) labor taxes.[38]

6.4 Labor Wedge

Our DLM model implies that the CLM model's equation for H is in fact an equation for h. In turn, this implies that per our DLM model, after taxes are accounted for, an important fraction of the remaining labor wedge associated with the CLM model should be employment itself. To test this hypothesis, Figure 9 plots empirical H normalized to 1960, and "Hybrid CLM H" normalized to 1960 as well. These hybrid hours are the product of the tax-inclusive CLM model's predictions of H and *empirical* e. If the CLM model's H predictions are in fact predictions of h, then this

[38]Notes: total work hours are from the Conference Board's Total Economy Database, employment is from the OECD, and population data are from the United Nations. Construction of model results use labor-tax data from the NBER, and output, consumption and productivity data from the Penn Word Tables.

product should track empirical H very well. As shown in Figure 9, this is indeed the case. This result lends further validity to our DLM model and, in particular, the implication that the CLM model's equation for H is in fact an equation for h and that after taxes are accounted for, in the CLM model a large fraction of the remaining labor wedge is employment itself.

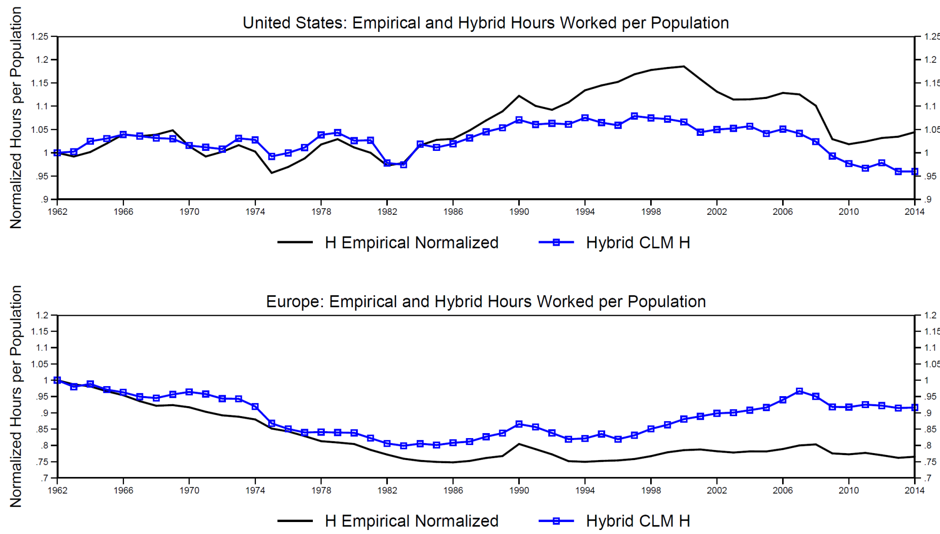

Figure 9: Evidence regarding employment as the labor wedge.[39]

Putting things in broader context, our results regarding the labor wedge imply that when hours worked per population are driven by hours worked per worker, as in the case of Europe (recall Figure 2), the CLM model can give the *impression, and impression only*, of correctly predicting hours worked per population, since the CLM model is in fact predicting hours worked per worker. In contrast, when empirical hours worked per population are driven by employment, as in the case of the United States (recall Figure 2) then the CLM model gives the *impression, and impression only*, of failing.

7 Conclusions

Hours worked per population (H) are fundamentally important for aggregate economic activity. The contemporary canonical macroeconomic model—which only

[39]Notes: employment is from the OECD, and population data are from the United Nations. Construction of model results use tax data from McDaniel (2007), and output and consumption data from the Penn Word Tables.

yields predictions for H—gets at the basic behavior of this variable at business cycle frequency, but fails dramatically at the trend level. Importantly, a common, widely accepted, and tractable benchmark model that can get at the basic forces associated with the trend behavior of H, and, critically, that can explain to a considerable degree the trend behavior of H, remains elusive. Amid this backdrop, identifying the fundamental forces that matter for the response of H to a host of timely and critical trend-level developments is problematic. These developments include, but are not limited to, a slowdown in world output growth, changes in demographics that are currently critical for advanced economies, and policy issues such as labor-market reforms, pension reforms, and tax reforms.

In light of these facts, this paper develops and proposes a framework that can serve as a common reference for modeling the trend behavior of H: the DLM model. Our DLM model, which lies within the representative-agent Walrasian paradigm, is a novel but intuitive and tractable extension of the canonical model. In particular, our DLM model decomposes the trend-level determination of H into the two margins of labor—hours worked per worker (h) and the employment-population ratio (e). Unlike earlier trend-level related literature centered on Walrasian representative agent contexts, our model does so via household-side employment attainment costs and firm-side employment adjustment costs.

Our DLM model identifies trends in the consumption-output ratio and taxes as important forces associated with the behavior of h. Our DLM model also explicitly identifies trends in total factor productivity as critically important for the trend behavior of e, *which is something that by construction earlier related literature cannot get at*, with taxes playing a second-order role for the United States—mattering mostly for the contour of e—but playing a more important role for Europe. Moreover, our DLM model can capture and explain *a new stylized fact that we document*, which is a cross-country relationship between capital taxes and e and H, but not with h. *These relationships have not been highlighted by earlier related literature.* On net, though, regarding taxes our model lends further validity to a literature that proposes taxes as an important factor that can help narrow the long-run labor wedge, even though an endemic feature of this literature is *stark counterfactual results for the United States.*

Our DLM model can track the behavior of h, e, and H very well in *both the United States* and a host of OECD countries. As such, our results suggest that our DLM model could indeed serve its intended purpose of being a framework that can serve as a common reference for modeling the trend behavior of H. This implies a broad and fruitful avenue for future research. In particular, in ongoing research we make use of our DLM model to explore the role of gender and age for the trend behavior of H.

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