# Demographics, Labor, and the Great Recession

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**Abstract**

Since the Great Recession, output and labor diverted from their pre-crisis long term trends. We show that demographics is able to explain a significant portion of the gap between the long-term trend and the data, for both output and labor. An important reason why demographics play an important role during the crisis's recovery period is that the Great Recession coincides with the "baby boomers" entering the age cohorts associated with lower levels of labor force participation. Accounting for these demographic changes, we document that labor is converging to a different employment trend. Furthermore, we modify the standard growth model and calibrate it to capture the demographic features of the data for the period 1990 - 2015. Our results show that by 2015 the output and labor gap have been reduced by just 2.5% and 1.2% respectively.

## 1 Introduction

Recent literature has reached the consensus that after the Great Recession, output and labor in the United States diverted from their pre-crisis long term trends. Although many theories are trying to explain the sources of these patterns, one plausible candidate is demographics. The start of the crisis coincided with the "baby boomers" entering age cohorts associated with lower levels of labor force participation and retirement. Hence, this shift in the demographic composition has the potential of explaining the observed economic activity during the recovery.

The objective of this paper is to quantify the effects demographic changes had on the evolution of output and labor in the recovery period after the Great Recession. For this, we first carry out an in depth analysis of employment trends for the time period 1990 - 2015. We document that a significant portion of the literature is incorrect when comparing the evolution of labor after the crisis with its pre-crisis trend. More specifically, we construct a counterfactual trend in which we account for demographic effects on the intensive margin, number of hours worked, and the extensive margin, labor force participation. We find that our counter factual trend of employment, which accounts for demographics, reduced the gap in between the pre-crisis employment trend and the data by 83.7%.

Given this evidence of the potential effects of demographics on labor supply, we develop a growth model that incorporates demographics. More specifically, demographics affect the dynamics of the model through the growth rate of population and through changes in the age distribution of the population across time. We calibrate this model to match moments of the US pre-crisis economy.

Using this model, we first analyze how much demographics would have accounted for changes on output and labor in absence of the Great Recession. We document that 35% of the output gap between the pre-crisis trend and the data is explained by demographics. The channel through which demographics affect output is through a reduction in the hours worked by agents in the model. We then expand our analysis to also include fluctuations in total factor productivity. We find that this specification is able to reduce the gap in between output in the model and output in the data to 2.5%. Furthermore the gap in between labor in the model and in the data reduces to 1.2%.

This paper is organized as follows. Section 2 reviews literature related to demographics and the Great Recession. In Section 3, we carry out an in depth analysis of trends in employment, taking into account the effects that demographics has on labor supply. In Section

4 we develop a framework that modifies the standard Growth model to include demographic changes. In Section 5, we use this model to explain the patterns of macroeconomic variables that we perceive in the data. Section 6 concludes.

## 2 Literature Review

This paper is related to two main branches of the literature: the Great Recession and Demographics. Since 2008, many hypotheses have tried to understand the reasons behind the slow recovery in aggregate output and employment for the United States. Robert Hall (2014) quantifies the contribution of different factors to explain their role in the slow recovery of aggregate variables. He documents that through 2013, output was 13 percentage points below its 1990 - 2007 trend, where the main contributors to this gap were the fall in business capital, productivity, and labor force participation.

From a more theoretical standpoint, the causes and mechanisms behind the Great Recession have been broad. For example, Schaal and Taschereu-Dumouchel (2015) set up standard neoclassical growth model with monopolistic competition and coordination failures to explain long recessions. They find that a big transitory shock, like the one in 2007, can force the economy into a steady state characterized by lower output and employment. On the other hand, Shimer (2012) sets up a search model with real wage rigidities to explain jobless recoveries. He documents that the interaction of rigid wages with search frictions are important for a persistent slow recovery in economic activity. Heathcote and Perri (2016), Mian and Sufi (2011 and 2014), Mian, Rao and Sufi (2013) and Midrigan and Philippon (2016) study mechanisms by which a fall in housing prices, housing net worth, and tightening of credit standards caused declines in household debt, consumption and employment. Our paper is similar to these in the sense that it tries to understand the reduction in output and employment that occurred after the crisis of 2007. It differs from these as it tries to quantify the role of demographics in explaining the fall in output and labor.

The discussion on demographics and its effects on growth and employment has been increasing in the past few years in the literature. First, Hayashi and Prescott (2003) and Chen et. al. (2005 and 2006), modify the standard growth model to account for dynamics in exogenous variables such as the growth in population. Among the caveats of only considering population growth in the standard neoclassical growth model is that demographics only affect the household by increasing its size across time. In other words, population growth does not take into account possible effects of changes in the population distribution across age groups as well as differences in agents' decision making at different age groups.

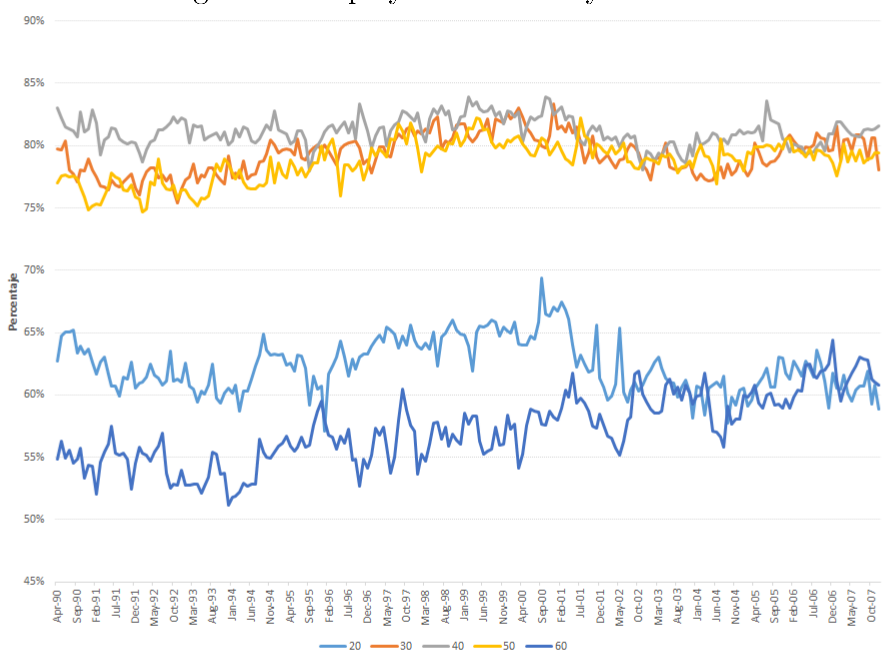
Using an empirical approach, Maestas et. al. (2016) find that the effects of the population's age structure has an important impact on output per capita growth for the US. They document that a 10% increase in the population above 60 years causes a decrease in 5.5% in the growth rate of GDP per capita. Given these aspects, we consider a modification of the standard growth model, which accounts for differences in the population composition of age groups across time.

Since the Great Recession, there has been a bigger discussion on the relationship in between demographics and labor supply. In his quantitative approach, Hall (2014) estimates that of the 13 percentage point drop in output, 1.1 was explained by the effect of the aging of baby-boomers on labor force participation. Maestas et. al. (2016) find that of the 5.5% reduction in the output growth rate caused by demographics, two-thirds is a result of slower growth in labor productivity of workers across the age distribution, while the rest is a result of slower growth in the labor force. To our knowledge, the closest work analyzing the effects of demographics on labor supply is by Henriksen and Cooley (2016). They set up a life-cycle model to examine how demographic induced changes in the intensive (hours worked) and extensive (employment) margins of labor supply affect the slowdown in output growth. Our paper differs to the aforementioned, as we analyze the specific effects that demographics have on macroeconomic aggregates through the lens of a modified growth model.

# 3 Employment Trends

We use monthly micro data from the Current Population Survey (CPS) obtained from the Integrated Public Use Microdata Series, IPUMS. To understand the effects of demographics on labor supply and output after the great recession, we start our analysis by documenting stable labor patterns before the crisis, for the period 1990 - 2007. We focus on this time period for the following reasons. We exclude the period before 1990 because women employment rate was raising as a consequence of the increase of their participation in the labor force. Additionally, after 2007, the Great Recession had a negative impact on labor.

Figure 1: Employment Ratio by Cohorts

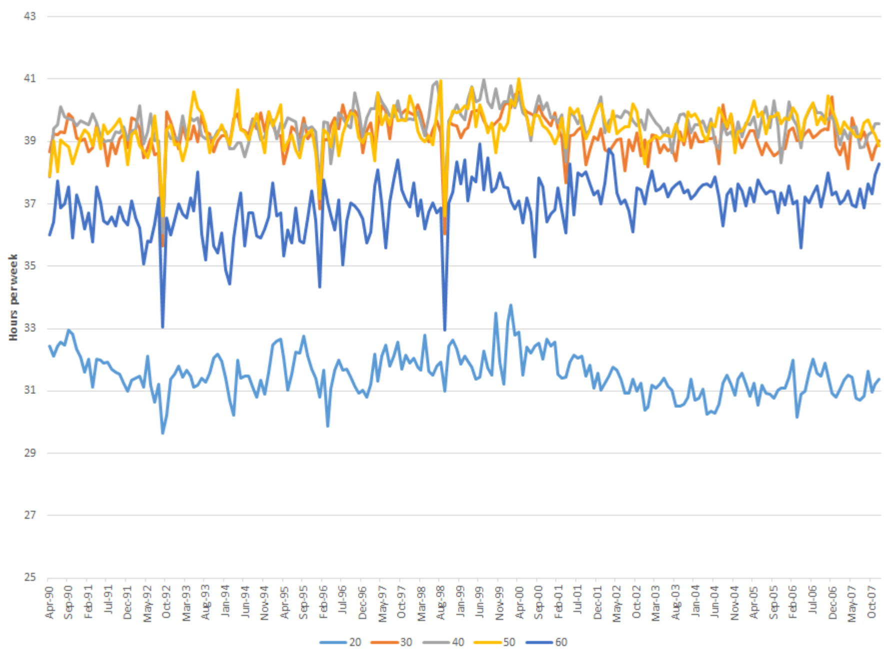



Source: Current Population Survey

We analyze employment and hours worked by age cohort in between 1900 and 2007. For each cohort, we observe the number of workers, and the total amount of hours worked. As Figure 1 shows, there is a stable evolution of the employment ratio ($E_t^a$), measured as the ratio of employment to population. For example, the monthly employment ratio for workers with age 40 fluctuated in between 78% and 83%; similar patterns are found across age cohorts. We estimate the average hours worked by those employed in each cohort ($h_t^a$), as the ratio of total hours to the total number of employed in each age group. Figure 2, shows that this statistic is also stable over time.

To statistically test for the stability in the employment ratio and hours worked, we fit a line through the time series of these statistics (linear regression). We find that the slope of the linear regression is statistically zero for most years between 25 and 50 years old. The slope is statistically negative for younger cohorts, and positive for older cohorts. However, in both cases the slope is relatively small[1].

Figure 2: Average Hours Worked by




Source: Current Population Survey

Using these statistics of the employment ratio and average hours worked, we construct a counterfactual of the total hours worked in the absence of the Great Recession. The

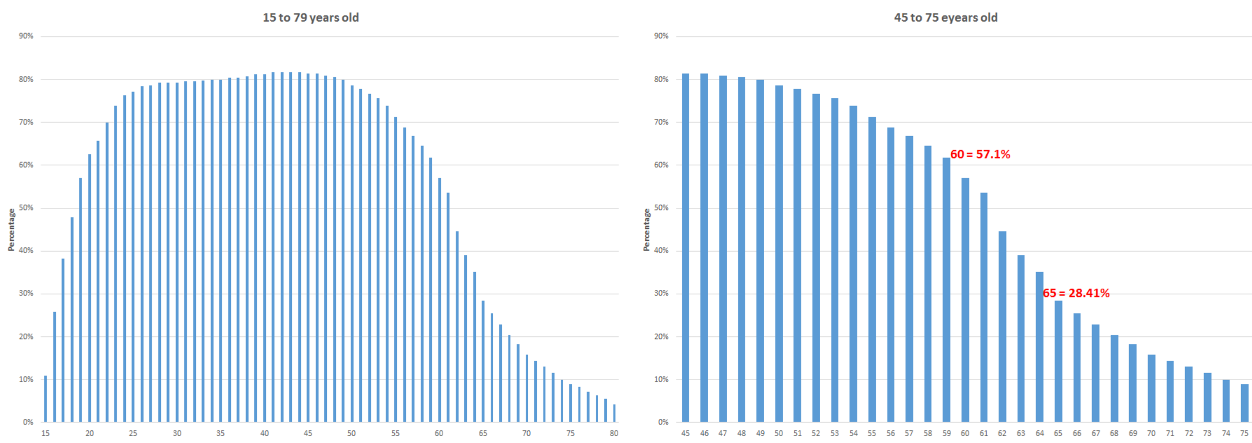
[1]The slope coefficient is statistically significant for ages 15 to 20 (negative) and above 55 (positive). On average the slope for younger cohorts implies a 2.7% decrease of employment ratio over 10 years, and for older cohorts implies an increase of 3.4% over 10 years.

motivation for this is to have an aggregate labor measure that allows us to compare the actual data to what would have happened without the crisis. We calculate the counterfactual in the following manner. Given the stability of the employment ratio and average hours worked for every cohort, we calculate the average of these measures across time as in equations (1) and (2):

$$\overline{E}^a = \frac{1}{T} \sum_{t=1990:2}^{2007:4} E_t^a, \tag{1}$$

$$\overline{h}^a = \frac{1}{T} \sum_{t=1990:2}^{2007:4} h_t^a. \tag{2}$$

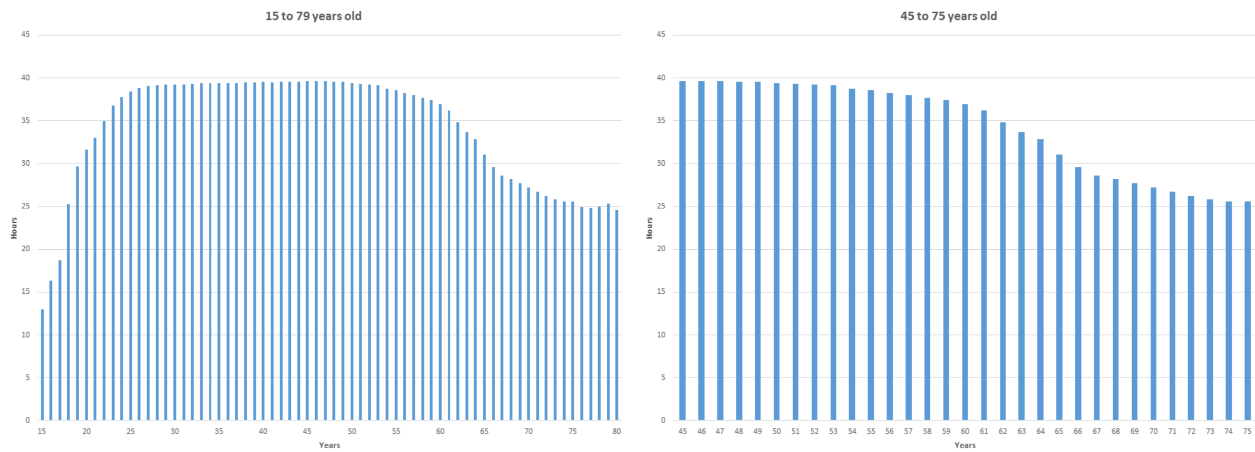
Figure 3: Average Employment Ratio by Cohorts




Source: Authors' calculation with data from CPS.

Figures 3 and 4 plot these statistics for every age group. The patterns portrayed in Figures 3 and 4 are similar. For young cohorts, the employment ratio is lower as most individuals in these cohorts are most likely with schooling responsibilities. For the case of average hours worked, young individuals also work a smaller number of hours, a result that is most likely due to their time being allocated to schooling. For age cohorts above 60, we can see that there is a fall in both employment ratio and average hours worked. As expected, older individuals begin to retire at around the age of 60, which causes the employment ratio to fall. More specifically, in between the ages of 60 and 65 , the average employment ratio falls in about 30 percentage points. Also, the average hours worked falls for older individuals; in between the ages of 60 and 65, the average hours worked falls in more than 5 hours. Hence, older cohorts would affect aggregate labor supply through the extensive margin, by choosing to not supply labor, and the intensive margin, by choosing to work less hours.

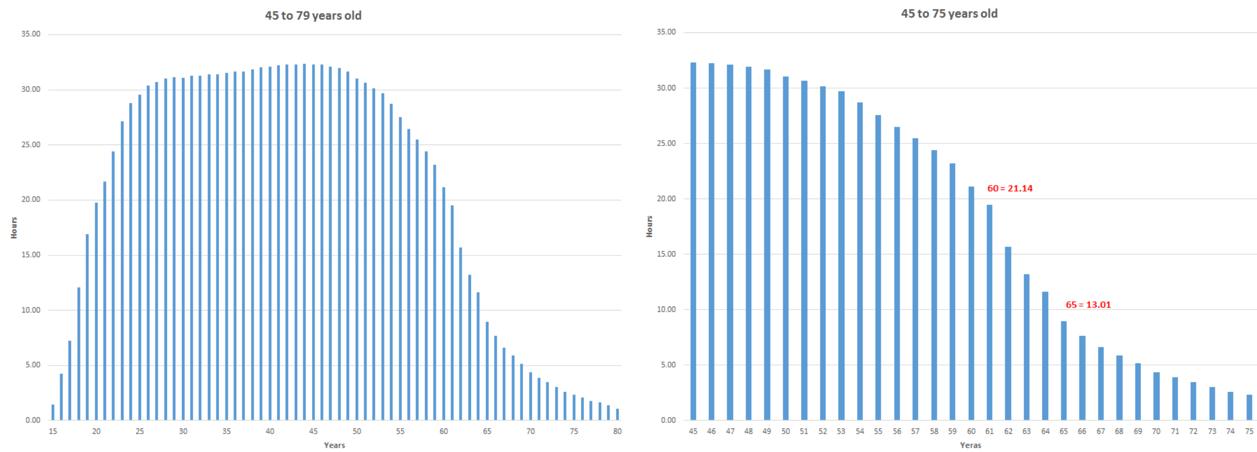
Figure 4: Average Hours Worked by Cohorts




Source: Authors' calculation with data from CPS.

The product in between $\bar{E}^a$ and $\bar{h}^a$ yields the number of hours worked per person in age cohort. Figure 5, shows this product. For older cohorts, there is a stronger decline in the number of hours worker per person in contrast to the average hours worked, as a consequence of labor supply falling through the extensive and intensive margins. Comparing the age cohort of 60 to that of 65, there is a decrease in the number of hours worked per person of more than 12 hours (58% drop).

Figure 5: Number of Hours Worked per Person by Cohorts




Source: Authors' calculation with data from CPS.

Focusing our analysis on the drop of labor supply of older cohorts is important, as it is a potential explanation of the apparent slow recovery of hours after the Great Recession. The years of the crisis coincide with the start of the baby boomer generation entering older cohorts and leaving the labor force. As a result, demographics played an important role during the years of the Great Recession, as they did in the 1980s and 1990s, when the baby boomers were at their most productive stage of their lives.

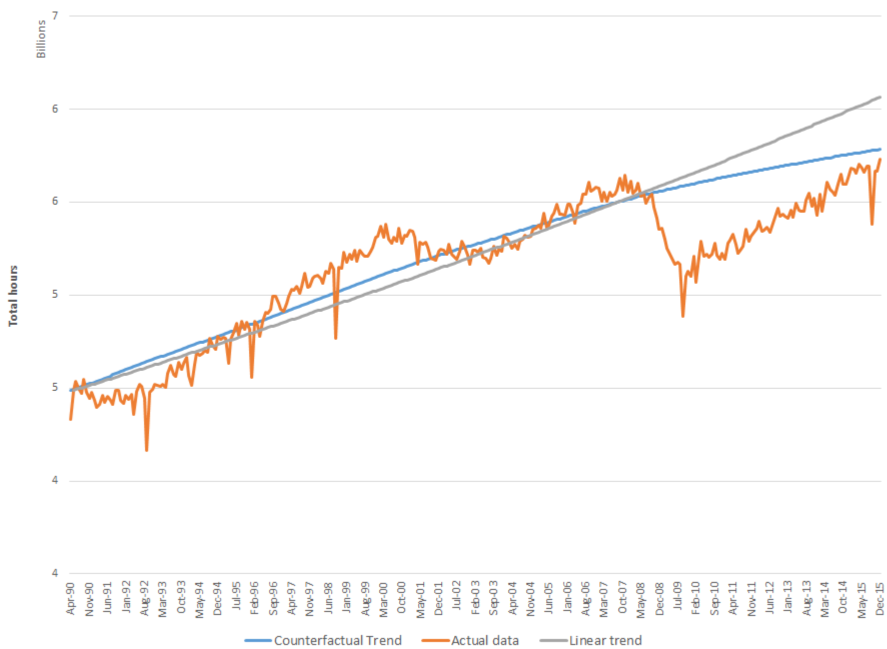
Next, we construct the total hours worked for the time period analyzed above 1990 - 2007, as well as the time period afterwards, 2008 - 2015. For each year $t$, we multiply the product in between $\bar{E}^a$ and $\bar{h}^a$, times the population in its corresponding cohort, $(P_t^a)$. Then we sum across age cohorts:

$$H_t = \sum_{a=15}^{79} \overline{E}^a * \overline{h}^a * P_t^a.$$

This total hours worked after 2007 is our counterfactual measure of hours in absence of the Great Recession. Assuming that the employment ratio and average hours worked had not changed, which is a reasonable assumption given the stability of $E_t^a$ and $h_t^a$, $H_t$ is the level of hours we would have expected in the economy given only demographic changes, through

$P_t^a$. Figure 6 plots three pieces of data: the linear trend of employment without taking into account demographics[2] (gray line), our employment counterfactual, $H_t$ (blue line), and the actual data (orange line). It is evident from Figure 6 that the linear trend of total hours and the data move parallel to each other; in 2015 the gap in between these was -5.8% of the actual hours. On the other hand, the data and our counterfactual measure of employment are converging as the gap in between these is just -0.9% of the actual hours..

Figure 6: Total hours worked




Source: Authors' calculation with data from CPS and Census

We are conscious that the Great Recession constituted an important crisis, generating a big deviation of employment from its pre-crisis trend. However, it is also important to note that demographics play an important role in explaining the reason why employment did not recover to its trend before the crisis. The aging of the working age population implies a fall in the total hours worked, which is captured by our counterfactual employment trend.

[2]This is estimated as the fitted line for the data in between 1990 and 2007, and then using this fitted line to forecast the years after 2008.

Comparing the data to this counterfactual employment trend shows that demographics is important in explaining the "slow" recovery in labor. Furthermore, it provides evidence that ignoring demographic changes from economic analysis can be detrimental not only for labor supply but for economic activity as a whole.

# 4 Growth Model and Demographics

In this section, we describe a variation of the growth model, in which the representative household is comprised of individuals with different ages. We will use this model to generate our quantitative results, similar to the approach by Hayashi and Prescott (2002) and Chen et. al. (2006). Below, aggregate variables are defined by capitalized letters, while per-capita variables are lower-cased.

## 4.1 Households

We assume there is a representative household with $N_t$ members at time $t$. Population grows at rate $\gamma_{Nt} = \frac{N_t}{N_{t-1}}$. For each $t$, there is a number of $P_t^a$ members of age $a$, so that $N_t = \sum_{a=s}^{S} P_t^s$, where $s$ and $S$ are the youngest and oldest ages in the household, respectively. Also, the household owns capital and rents it to firms. Further, the household solves the following problem:

$$
\begin{aligned}
\max_{\left\{\{c_t^a, h_t^a\}_{a=s}^{S}, K_{t+1}, X_t\right\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \sum_{a=s}^{S} P_t^a \left(\log\left(c_t^a\right) + \alpha^a \log\left(T - h_t^a\right)\right) \\
s.t. \\
\sum_{a=s}^{S} P_t^a c_t^a + X_t \leq & w_t \sum_{a=s}^{S} P_t^a h_t^a + r_t K_t - \tau_t \left(r_t - \delta\right) K_t - \pi_t \quad for\ t = 0,\ 1, ... \\
K_{t+1} = & X_t + \left(1 - \delta\right) K_t \quad for\ t = 0,\ 1, ... \\
given\ K_0,
\end{aligned}
$$

where aggregate consumption is $C_t = \sum_{a=s}^{S} P_t^a c_t^a$ and aggregate hours are $H_t = \sum_{a=s}^{S} P_t^a h_t^a$, $T$ is the total time endowment per member, $\beta$ is the discount factor, $\alpha^a$ is the share of leisure in the utility function for individuals with age $a$, $w_t$ is the wage rate, $r_t$ is the rental rate of capital, $\delta$ is the depreciation rate, $\tau_t$ is the tax rate con capital income, $\pi_t$ is a lump-sum tax.

## 4.2 Firms

There is a representative firm, with the standard Cobb-Douglass Production Function, $Y_t = A_t K_t^{\theta} H_t^{1-\theta}$, where $Y_t$ is aggregate output, $A_t$ is total factor productivity, $K_t$ is the capital stock rented by the firm, and $H_t$ is the labor input of the firm measured in aggregate hours. We define $\theta$ as the share of capital in output. We assume that $A_t$ grows at rate $\gamma_{At} = \left(\frac{A_t}{A_{t-1}}\right)^{\frac{1}{1-\theta}}$.

## 4.3 Government

The government taxes household's income on capital and lump-sum tax $\pi_t$, and uses these resources to finance government spending $G_t$ so that the government budget balances every period:

$$G_t = \tau_t \left(r_t - \delta\right) K_t + \pi_t.$$

## 4.4 Competitive Equilibrium

The resource constraint of the economy is given by:

$$C_t + X_t + G_t = Y_t,$$

where $C_t$ is aggregate consumption, $X_t$ is aggregate investment and $G_t$ is government purchases.

Given a government policy $\{G_t,\ \pi_t,\ \tau_t\}_{t=0}^{\infty}$, a competitive equilibrium for this economy is an allocation $\left\{\{c_t^a, h_t^a\}_{a=s}^{S},\ X_t,\ K_t,\ Y_t\right\}_{t=0}^{\infty}$ and a sequence of prices $\{w_t,\ r_t\}_{t=0}^{\infty}$, such that:

1. given the government policy and prices, the allocation solves the household's problem,

2. given the government policy and prices, the allocation maximizes firm's profits such that factor prices equal their marginal products, $w_t = (1-\theta) A_t \left(\frac{K_t}{H_t}\right)^{\theta}$ and $r_t = \theta A_t \left(\frac{K_t}{H_t}\right)^{\theta-1}$.

3. the government budget is satisfied,

4. and the market clearing condition holds: $\sum_{a=s}^{S} P_t^a c_t^a + K_{t+1} - (1-\delta) K_t + G_t = A_t K_t^{\theta} \left(\sum_{a=s}^{S} P_t^a h_t^a\right)^{1-\theta}$.

## 4.5 Numerical Solution

We solve the model in a similar manner to Hayashi and Prescott (2002) and Chen et. al. (2006). First, we compute the steady state of the U.S. economy in the sufficient distant future, using the calibrated parameters and exogenous variables. The steady state is obtained from the equilibrium conditions of the model. With this steady state, we apply a shooting algorithm toward this steady state from the given initial conditions, corresponding to the first trimester of 1990. The solution to this algorithm is an equilibrium transition path from the initial conditions to the final steady state.

The equilibrium conditions are characterized by the standard intratemporal condition, Euler equation, and resource constraint obtained from the household's and firm's optimality conditions:

$$\frac{\alpha^a c_t^a}{T-h_t^a} = (1-\theta)\, A_t \left(\frac{K_t}{\sum_{a=s}^{S} P_t^a h_t^a}\right)^{\theta} \quad \forall a,\ \forall t, \tag{3}$$

$$\frac{c_{t+1}^a}{c_t^a} = \beta \left[1 + (1-\tau_{t+1}) \left(\theta A_{t+1} \left(\frac{K_{t+1}}{\sum_{a=s}^{S} P_{t+1}^a h_{t+1}^a}\right)^{\theta-1} - \delta\right)\right] \quad \forall a,\ \forall t, \tag{4}$$

$$K_{t+1} = (1-\delta)\, K_t + A_t K_t^{\theta} \left(\sum_{a=s}^{S} P_t^a h_t^a\right)^{1-\theta} - \sum_{a=s}^{S} P_t^a c_t^a - G_t \quad \forall t. \tag{5}$$

To obtain the steady state, first we detrend all variables so that $\hat{x}_t = \frac{x_t}{A^{\frac{1}{1-\theta}}}$ for per capita variables and $\hat{x}_t = \frac{X_t}{A^{\frac{1}{1-\theta}} N_t}$ for aggregate variables. Equations (3) through (5) become:

$$\frac{\alpha^a \hat{c}_t^a}{T-h_t^a} = (1-\theta) \left(\frac{\hat{k}_t}{\sum_{a=s}^{S} \eta_t^a h_t^a}\right)^{\theta} \quad \forall a,\ \forall t, \tag{6}$$

$$\frac{\hat{c}_{t+1}^a}{\hat{c}_t^a} = \frac{\beta}{\gamma_{At+1}} \left[1 + (1-\tau_{t+1}) \left(\theta \left(\frac{\hat{k}_{t+1}}{\sum_{a=s}^{S} \eta_{t+1}^a h_{t+1}^a}\right)^{\theta-1} - \delta\right)\right] \quad \forall a,\ \forall t, \tag{7}$$

$$\gamma_{At+1}\gamma_{Nt+1}\hat{k}_{t+1} = \hat{k}_t \left[\left(\frac{\hat{k}_{t+1}}{\sum_{a=s}^{S} \eta_{t+1}^a h_{t+1}^a}\right)^{\theta-1} (1-\psi_t) + (1-\delta)\right] - \sum_{a=s}^{S} \eta_t^a \hat{c}_t^a \quad \forall t, \tag{8}$$

where $\psi_t$ is the ratio of government purchases to output, $\frac{G_t}{Y_t}$, and $\eta_t^a$ is the ratio of the population of individuals of age $a$ at time $t$ to the total population at time $t$, $\frac{P_t^a}{N_t}$.

In steady state, detrended variables do not grow and the ratio of individuals of any age $a$ with respect to total population remains constant. Hence the steady state equilibrium conditions are given by:

$$\frac{\alpha^a \hat{c}^a}{T - h^a} = (1-\theta)\left(\frac{\hat{k}}{\sum_{a=s}^{S} \eta^a h^a}\right)^{\theta} \quad \forall a, \tag{9}$$

$$1 = \frac{\beta}{\gamma_A}\left[1 + (1-\tau)\left(\theta\left(\frac{\hat{k}}{\sum_{a=s}^{S} \eta^a h^a}\right)^{\theta-1} - \delta\right)\right] \quad , \tag{10}$$

$$\gamma_A \gamma_N \hat{k} = \hat{k}\left[\left(\frac{\hat{k}}{\sum_{a=s}^{S} \eta^a h^a}\right)^{\theta-1}(1-\psi) + (1-\delta)\right] - \sum_{a=s}^{S} \eta^a \hat{c}^a. \tag{11}$$

# 5 Demographics and Macroeconomic Aggregates

## 5.1 Calibration

We calibrate the growth model described above to determine the effects of demographic changes on economic activity in the United States. The time period we use for calibration corresponds to 1990 - 2007. The model has four parameters that are the same for all the household: $\theta$ (capital share in production), $\delta$ (depreciation rate), $\beta$ (discount factor), and $T$ (total discretionary hours in a week). Also, there is an age specific parameter ($\alpha^a$). For our analysis, we shut down the government, so that its revenue and expenditure is equal to zero. The values for the four common parameters are shown in Table 1. These are calculated in the standard way, as detailed in the Appendix.

**Table 1: Parameters**

| | |
|---|---|
| $\theta$ | 0.33 |
| $\delta$ | 0.058 |
| $\beta$ | 0.948 |
| $T$ | 100 |

The disutility of labor, $\alpha^a$, is an age specific parameter that is chosen such that the average of hours worked in the model is the same as the hours worked in the data, for each age. Using the intratemporal condition of our model, (3), we obtain:

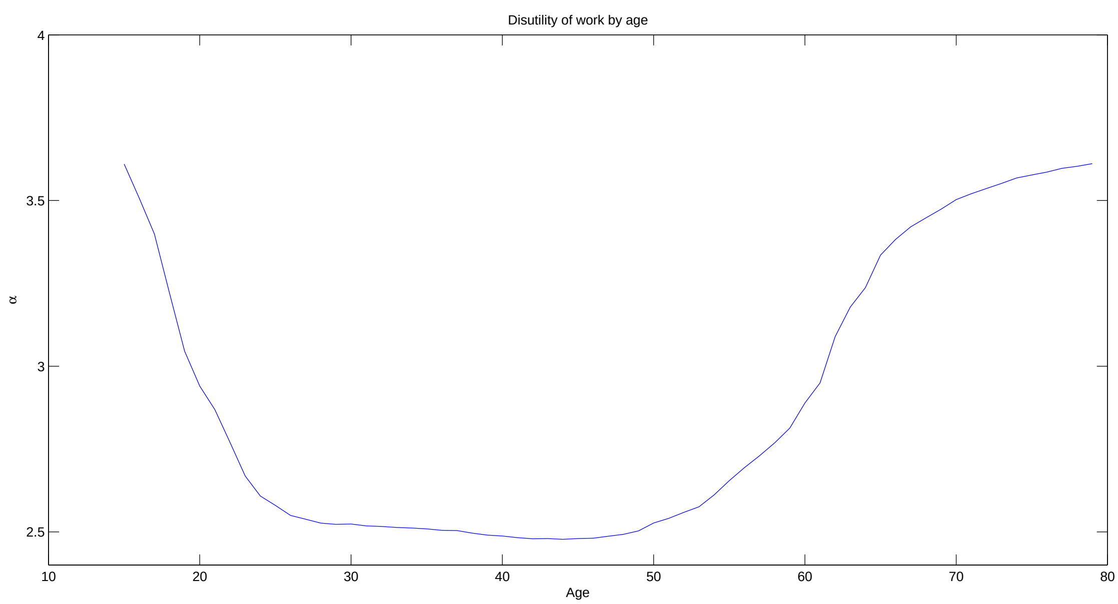
$$\frac{\alpha^i \hat{c}^i}{T - h^i} = \frac{\alpha^j \hat{c}^j}{T - h^j} \;\; \forall\, a = i, j.$$

The Euler condition, (4), implies that consumption level is the same for all ages. As a result, the above equation simplifies to:

$$\alpha^i = \frac{T - h^i}{T - h^j} \alpha^j \;\; \forall\, a = i, j.$$

Using our data counterparts, $\overline{h}^a$, calculated in equation (2), we calibrate $\alpha^a$ for all $a$. Figure 7 portrays the values of the disutility of labor by age. Our parameters vary between 2.45 and 3.56. These are higher than what is documented in the literature. The reason for this is that we consider hours per person by age as in figure 5, and not the average hours worked (as in figure 4).

Figure 7: $\alpha^a$



As mentioned before, we are interested in quantifying the effects of demographics on output and labor. We will carry out two experiments. The first only considers the effect of demographics on our model economy and sets up a counterfactual of how macroeconomic aggregates would have evolved in absence of the Great Recession. Demographics affect economic activity through the population growth rate, $\gamma_{Nt}$, and through the ratio of the population of individuals of age $a$ at time $t$ to the total population at time, $\eta_t^a$. Both $\gamma_{Nt}$ and $\eta_t^a$ are measured using data from the census. Using the solution method described in Section 4.5, we use these time series and a constant TFP growth rate $\bar{\gamma}_A = \frac{1}{T}\sum_{t=1990}^{2007} \gamma_{At}$ to obtain the equilibrium path for macroeconomic aggregates[3]. We compare the evolution of the aggregates in our model to those of the data to quantify the importance of demographics in explaining trends in economic activity. Our second experiment builds on the first one by considering demographic effects ($\gamma_{Nt}$ and $\eta_t^a$) along with time-varying TFP growth rates, $\gamma_{At}$[4].

## 5.2 Results

The period 1990 - 2015 is a time frame which constitutes a transition from a fast growing population composed of middle-aged individuals to a slow growing population with older individuals. Incorporating this feature into our model, we analyze the transitional dynamics of several macroeconomic aggregates for the pre-crisis period (1990 - 2007) and the years after the crisis (2008 - 2015). As mentioned in Section 5.1, at first we only consider these demographic effects, and exclude any other exogenous time varying variables, such as TFP. This allows us to understand how the economy would have behaved in absence of the Great Recession.

[3]For the first experiment's final steady state, we set the population growth to 0.4%, which is consistent with the census's estimation of the growth rate for the period 2050 - 2060. Also, we set the growth rate of TFP in steady state equal to the average growth rate between 1990 and 2007.

[4]For the second experiment's final steady state, we set the population growth rate equal to 0.4% and the TFP growth rate equal to the average TFP growth for the period 2008 - 2015.

The first aggregate we evaluate is the capital to output ratio. There are two effects at work in the demographic transition of this economy. First, the decrease in the population growth rate generates an increase in the consumption per capita over time. Second, the aging of population reduces the amount of labor offered to the market, while keeping constant the number of people consuming. This second effect reduces the consumption per capita over time. These two effects offset each other, as can be inferred from (7). As a consequence of this, our model predicts an almost time invariant trend for the capital to output ratio as can be observed in Figure 8.

Figure 8: Capital/Output ratio with only Demographic Changes

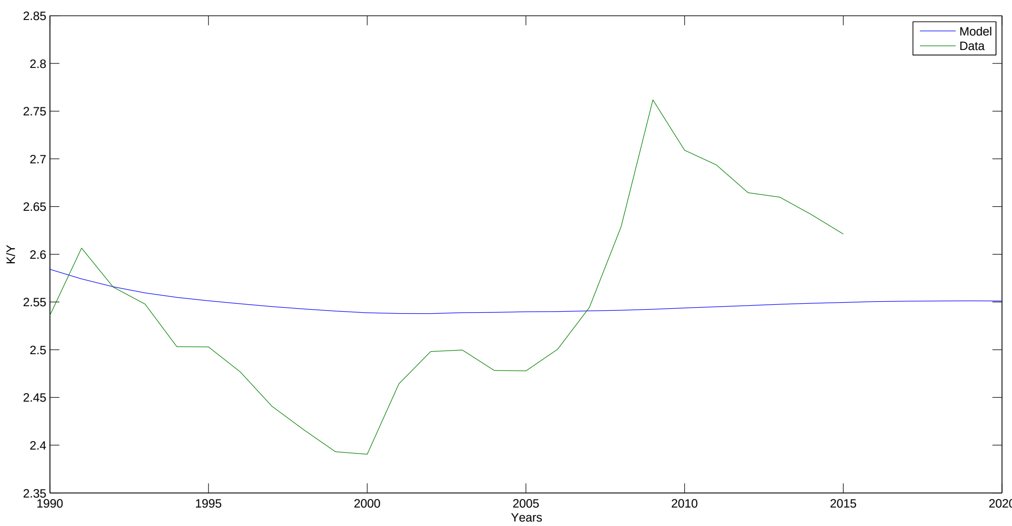


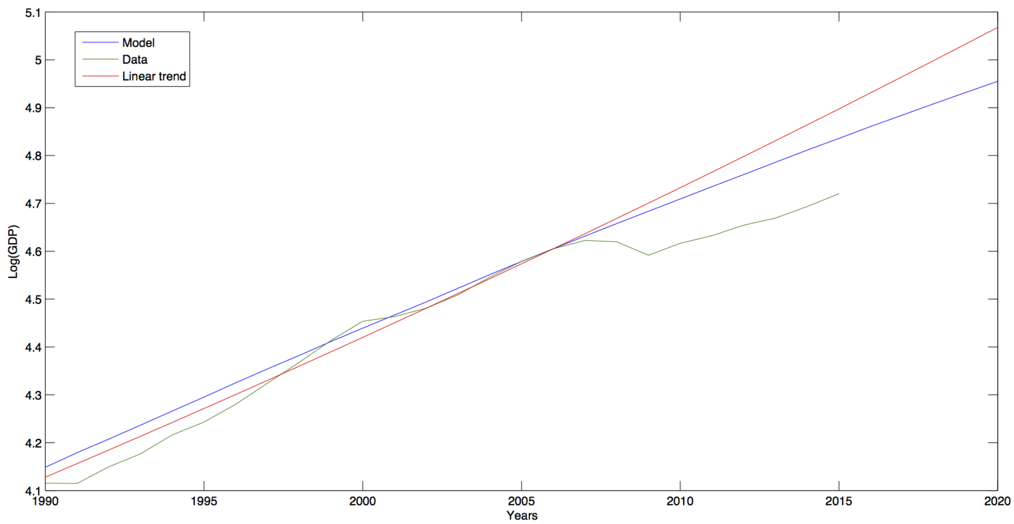

Figure 9 presents the evolution of output in the data since 1990 (green line). It is clear that after the Great Recession, output deviated from its previous trend (red line) and did not converge back to it[5]. A model which excludes the demographic changes we account for in our model would yield an output trend similar to the linear trend of Figure 9[6]. By

[5]The linear trend is calculated as the trend of the data from 1990 to 2007.

[6]We solve our model with constant population growth rate and time invariant population composition, and obtain a output series similar to that of the linear trend.

considering demographic changes, through changes in the population growth rate and the population composition, our model is able explain at least part of the deviation of GDP from its trend previous trend.

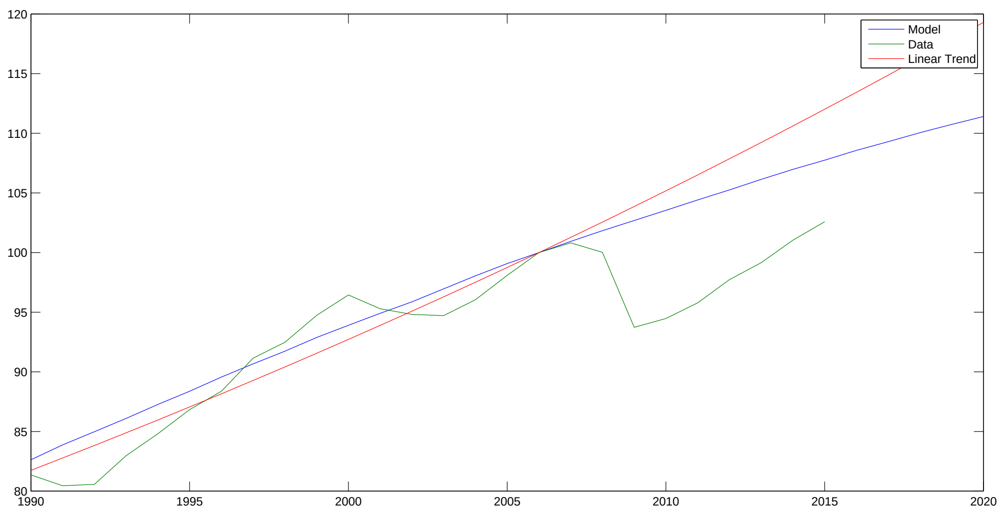
Figure 9: GDP with only Demographic Changes




The model with only demographic changes is not able to account of all of the drop in GDP, as the main contributor of the drop was the Great Recession, which is not modeled in our first experiment. Our exclusion of the negative TFP shock generated by the Great Recession is necessary for us to quantify the only effects of demographics in explaining the deviation of the data from its pre-crisis linear trend. We document that demographics accounts for 35% of the gap in between the pre-crisis linear trend and the data.

The channel through which changes in the population growth rate and the population composition affects output is by the reduction of labor supply. As the population ages, labor supply falls due to reduction in the hours supplied by the older cohorts. Figure 10 is the model counter part of Figure 6. When we compare the model's total hours to the counter factual employment trend of Figure 6, we can see that the fall of the latter is more pronounced. In the model, demographics only affects labor supply through the intensive margin, i.e. the number of hours supplied by each cohort. The counterfactual employment trend also takes into account the effects of demographics on the extensive margin. That is, older cohorts participate less in the labor force.

Figure 10: Labor with only Demographic Changes




Our second experiment builds on the previous one by incorporating TFP changes also into the analysis. Hence, this model will also account for TFP movements for the time period 1990 - 2015, where the most important was the negative TFP shock of the Great Recession. Figure 11 shows the evolution of the capital to output ratio. We can see that the model does a much better job of capturing the movements in the data. Comparing Figure 11 to Figure 8, we conclude that demographic changes which only affect the economy through labor supply are not able to account for the dynamics in the capital to output ratio. Also, the model predicts a higher level of capital-output due to the decrease in the TFP growth rate[7].

[7] The final steady state was calculated using the average TFP growth rate of the period 2008 - 2015, which is smaller to the growth rate of the period 1990 - 2007.

Figure 11: Capital-output ratio with Demographic and TFP Changes

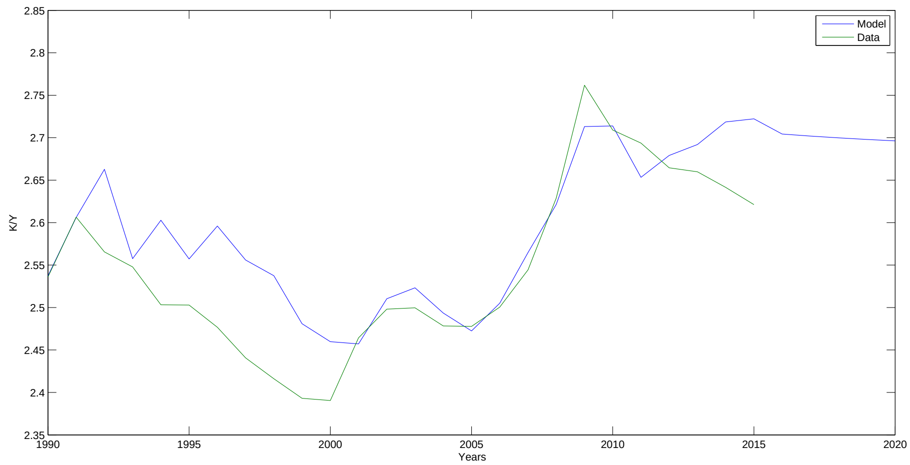
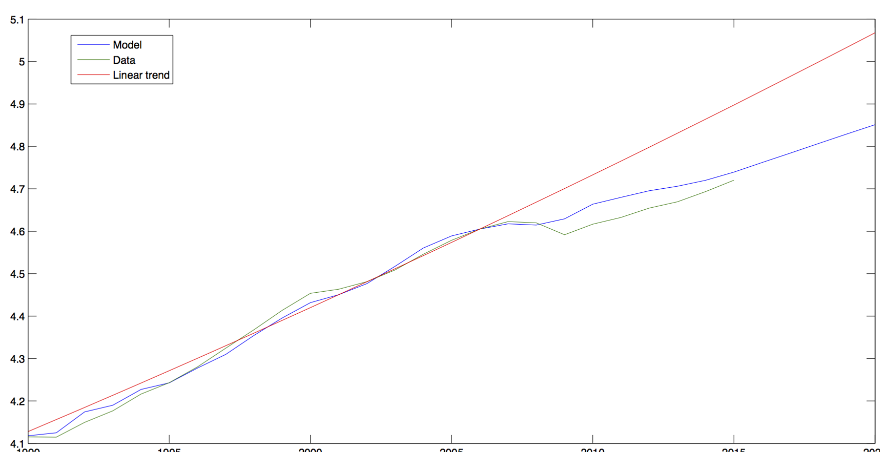


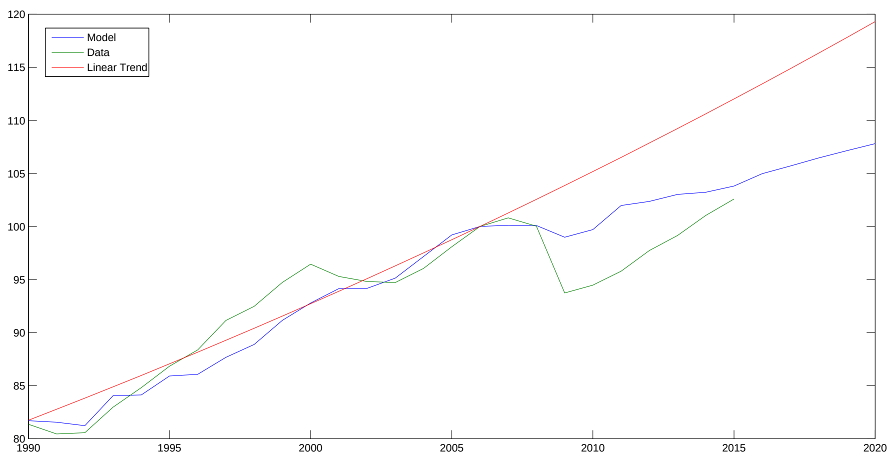

Figure 12 presents the evolution of GDP when we account for both demographic and TPF changes in our model. We can see that the model explains most of the drop in the GDP. Furthermore, by 2015 the gap between out model prediction and the data is only 2.5%. Thus the interaction of TFP and demographic changes do fairly well in capturing the evolution of output for the US economy.

Figure 12: GDP with Demographic and TFP Changes



Demographic and aggregate productivity changes generate a model employment counterpart that has similar movements to total employment hours seen in the data. For example, by adding TFP changes to the analysis, employment in the model falls in the year of the crisis, 2008. This feature was not captured in the previous exercise by construction. By 2015, the gap in between the model and data employment series was of about 1.2%. If our model was able to capture effects through the extensive margin, we suspect that this gap would be even smaller.

Figure 13: Labor with Demographic and TFP Changes




# 6 Conclusions

The effects of demographics may not be big or fast, but they have the potential of being important. The Great Recession coincides with a unique demographic period. At the start of the crisis, the generation of baby boomers started to enter retirement. Even though demographics is not what caused the Great Recession, it has the potential of explaining certain patterns for the slow recovery after the recession. For example, demographics play an important role in total hours worked and GDP not returning to their pre-crisis trend levels. In this paper, we quantify the effects demographics had on explaining the evolution of output and labor.

We develop a modified version of the standard growth model. This model incorporates demographics into the neoclassical framework through population growth rates and changes in population composition across time. We calibrate this model to test the implications of these demographic changes. First, we abolish the effects of the Great Recession on economic activity, so that we can evaluate how demographics affected output and labor for the time period 1990 - 2015. We find that the model explains 35% of the between output's pre-crisis trend and the data. We find that labor also drops but not substantially. This is a consequence of demographics only affecting labor through the intensive margin, amount of hours worked. If we considered a framework in which agents decided whether to participate in the labor force or not, the we expect that hours would drop further in the model. When we account for TFP changes for the time period analyzed, we find that the model does a better job of capturing movements in the data, for different macroeconomic aggregates.

It is important to note that our model only considers the effects of demographics on labor supply, which limits the effects of demographics on other variables. We are not considering potential interesting effects of savings decisions by different cohorts that can be important. Also, we are not considering effects that demographics can have on productivity, as suggested by Kuznets (1960). The first, can be carried out in a life cycle framework, while the second implies creating a theory of how productivity can be affected by aging and decreasing population growth rates. We consider both of these important in order to quantify the effects of demographics on economic activity. Our future research agenda will build upon the work of this paper and will seek to incorporate these two mechanisms into our analysis.

# 7 Bibliography

Chen, Kaiji, Ayşe İmrohoroğlu and Selahattin İmrohoroğlu. 2006. "The Japanese Saving Rate." American Economic Review, 96(5): 1850-1858.

Chen, Kaiji, Ayse Imrohoroglu & Selahattin Imrohoroglu, 2006. "Secular Movements in U.S. Saving and Consumption," 2006 Meeting Papers 154, Society for Economic Dynamics.

Flood, Sarah, Miriam King, Steven Ruggles, and J. Robert Warren. Integrated Public Use Microdata Series, Current Population Survey: Version 4.0. [Machine-readable database]. Minneapolis: University of Minnesota, 2015.

Hall, Robert. E, 2014. "Quantifying the Lasting Harm to the U.S. Economy from the Financial Crisis," NBER Macroeconomics Annual 2014, Volume 29, pages 71-128 National Bureau of Economic Research, Inc.

Hayashi, Fumio, & Edward C. Prescott, 2002. "The 1990s in Japan: A Lost Decade," Review of Economic Dynamics, Elsevier for the Society for Economic Dynamics, vol. 5(1), pages 206-235, January.

Heathcote, Jonathan and Fabrizio Perri (2016). “Wealth and Volatility”. Working Paper. Federal Reserve Bank of Minneapolis and CEPR.

Henriksen, Espen & Cooley, Thomas (2016). “The Demographic Deficit”. Working paper.

Kuznets, Simon (1960). “Population Change and Aggregate Output”. Chapter in “Demographic and Economic Change in Developed Countries”. Columbia University Press. Pages 324 - 351.

Maestas, Nicole & Mullen, Kathleen J. & Powell, David, 2016. "The Effect of Population Aging on Economic Growth, the Labor Force and Productivity," Working Papers 1063-1, RAND Corporation.

Mathieu Taschereau-Dumouchel & Edouard Schaal, 2015. "Coordinating Business Cycles," 2015 Meeting Papers 178, Society for Economic Dynamics.

Mian, Atif & Amir Sufi, 2012. "What explains high unemployment? The aggregate demand channel," Chicago Booth Working Paper.

Mian A., Rao, K. and Sufi,A. (2013), “Household Balance Sheets, Consumption, and the Economic Slump”,Quarterly Journal of Economics, 128, 1687–1726.

Midrigan, Virgiliu & Philippon, Thomas, 2016. "Household Leverage and the Recession," CEPR Discussion Papers 11407, C.E.P.R. Discussion Papers.

Shimer, Robert, 2012. "Wage rigidities and jobless recoveries," Journal of Monetary Economics, Elsevier, vol. 59(S), pages S65-S77.

# 8 Appendix

To calibrate the model, we use standard methods of Growth Accounting. Parameters $\delta$ and $K_0$, the depreciation rate and the initial capital are calculated together, so that two conditions are satisfied. We use 1964 as the first data of capital, so any miscalculation of the initial capital is reduced by depreciation over time. First, the initial capital output ratio of the data is equal to the average of the capital output ratio for the first ten years,

$$\frac{K_{1964}}{Y_{1964}} = \frac{1}{10}\sum_{1964}^{1974}\frac{K_t}{Y_t}.$$

Second, the depreciation rate times the average of the capital-output ratio of the model is equal to the average of the ratio of depreciation over GDP in the data.

$$\frac{1}{44}\sum_{1964}^{2007}\frac{\delta K_t}{Y_t} = \frac{1}{44}\frac{depreciation}{Y_t}$$

$\theta$ is calculated as the sample average over 1990 to 2007 of the compensation of capital. $\alpha^a$ is calculated for every age with the formula:

$$\alpha^a = \frac{T - h^a}{T - h^b}\alpha^b,$$

such that the hours decided by each cohort matches the sample average of the data. $\beta$ is calculated using the intertemporal equation 7. $T$ is the total discretionary hours in a week.