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Abstract

In a real economy, decisions on investments in child human capital of children are made by families rather than by atomistic parents as is typically assumed in the literature. This paper incorporates family formation into an otherwise standard dynastic framework with human capital accumulation. The study finds that accounting for differences in taxation and education policies between the U.S. and 10 OECD countries is sufficient to replicate cross-country variations in the degree of assortative matching and its positive correlation with the persistence of intergenerational earnings. Positive assortative matching is crucial to a model's ability to generate realistic levels of intergenerational earnings correlation observed in the data.

JEL Codes: E62, H31, H52, I24, J12, J62.

Keywords: Marital sorting, Intergenerational earnings persistence, Taxation, Education subsidies.

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1 Introduction

Cross-country variations in intergenerational persistence of earnings is a widely documented phenomenon in empirical literature. Among Western economies, Scandinavian countries and Canada have the lowest intergenerational correlation of earnings, while the U.S., U.K. and Southern Europe have the highest earnings persistence (Corak, 2006; Holter, 2015). Understanding the reasons for these differences may shed light on the underlying factors behind intergenerational earnings persistence and optimal policies to promote social mobility. Consequently, a wide range of theoretical and quantitative studies investigating this phenomenon has appeared. The key factors affecting intergenerational persistence of earnings found by the literature include taxation, public education financing, intergenerational correlation of abilities, parental investments in human capital, and borrowing constraints. By employing dynastic life-cycle frameworks incorporating these factors, existing quantitative studies have succeed in explaining at most half of the gap in the intergenerational earnings elasticity between the countries with the highest and the lowest intergenerational persistence of earnings. For instance, Holter (2015) explains from 21 to 54 % of the gap between three Scandinavian countries (Denmark, Norway, Finland) and the U.S. by accounting for cross-country differences in education and taxation policies. Herrington (2015) explains 8.7% of the gap between Norway and the U.S. by accounting for differences in tax policies and regional redistribution of compulsory education subsides. Blankenau & Youderian (2015) explain 8.5% of the gap between the U.S. and Denmark and Norway through accounting for differences in early education subsidies.

In a real economy, decisions on investments in child human capital are made by families rather than by atomistic parents as is typically assumed in existing studies. Moreover, empirical literature demonstrates variations in the degree of assortative matching and its positive connection to the persistence of intergenerational earnings in a number of developed countries (Chadwick and Solon, 2002; Ermisch et al., 2004; Eika et al., 2019). This paper incorporates marital sorting into an otherwise standard dynastic framework with a human capital accumulation process. The study finds that consideration of cross-country differences in taxation and education policies explains positive relationships between the degree of assortative matching and intergenerational persistence of earnings observed in the data. Moreover, positive assortative matching is crucial to a model's ability to replicate realistic levels of intergenerational correlation of earnings in OECD countries. Accounting for differences in taxation and education policies between the U.S. and 10 OECD countries, the benchmark with a marriage market calibrated into the U.S. economy has a superior fit, as opposed to Holter (2015), and the exact counterpart framework that does not consider a marriage market. Therefore, differences in public policies and degrees of marital sorting are not stand alone factors, but are interconnected in explaining cross-country variations in intergenerational earnings persistence.

The remainder of this paper is organised as follows. Section 2 presents an overview of existing literature on cross-country differences in intergenerational persistence of earnings and marital sorting. Section 3 documents a positive correlation between the degree of assortative matching and intergenerational persistence of earnings, and a negative correlation between the degree of assortative matching and tax progressivity. Section 4 studies impacts of taxation and education policies on the degree of assortative matching and parental investments in the human capital of their children in a simplified theoretical setup. Sections 5 and 6 present a quantitative model and its calibration to the U.S. economy. Section 7 concludes with the results.

2 Related Literature

This paper builds on the quantitative literature analysing the role of public policies in explaining cross-country differences in intergenerational earnings elasticity and literature on marital sorting in quantitative macroeconomic models.

The phenomenon of intergenerational persistence of earnings has been studied for several decades, generating a large number of empirical and theoretical studies. Bjorklund & Jantti (1997), Solon (2002), Corak (2006), Jantti at al. (2006), Blanden (2013) and Landerso & Heckman (2017), among others, document substantial cross-country differences in intergenerational persistence of earnings. Moreover, they find that intergenerational earnings elasticity is lower in Nordic countries than in the U.S. and U.K.

Theoretical literature pioneered by Becker and Tomes (1979, 1986) has sought explanations for this phenomenon. Becker and Tomes introduced a model of human capital formation through both imperfect transmission of abilities and investments in human capital made by parents and government. Parents are altruistic towards their children and care about their utilities. Therefore, in this framework, parents invest in the human capital of their children in order to increase their utilities through their future productivity. Relying on this basic assumption, theoretical and quantitative literature has proposed several explanations for the phenomenon of intergenerational persistence of earnings and its variations across countries.

One frequently analysed hypothesis is cross-country differences in taxation and education policies. Existing literature documents a negative correlation between tax progressivity and intergenerational persistence of earnings; see Holter (2015). The study finds that accounting for cross-country differences in tax progressivity explains around 50 % of the variation in intergenerational earnings persistence between the U.S. and 10 OECD countries. Herrington (2015) finds that more progressive taxes in Norway contribute to less intergenerational earnings persistence than in the U.S.

Moreover, the literature finds connections between intergenerational persistence of earnings and public spending on education. Holter (2015) demonstrates that countries with higher social mobility tend to have more generous public education investments at state and federal levels, especially at the tertiary level. This empirical finding is in line with Solon's (2004) analytical result that less generous public investments into education lead to higher intergenerational persistence of earnings. However, in Holter's quantitative model, the estimated impact of education policies on intergenerational persistence of earnings turns out to be moderate. A quantitative study by Blankenau & Youderian (2015) finds that accounting for cross-country differences in public expenditures on early childhood education explains around 10% of the gap in intergenerational persistence of earnings between the U.S. and Denmark and Norway.

Overall, most existing quantitative studies correctly predict the directions of tax and education policies impacts on intergenerational persistence of earnings (see Holter, 2015; Blankenau & Youderian, 2015; Herrington, 2013). However, on average, around 50 % of the gap in intergeneration earnings elasticity between the U.S. and other OECD countries remains unexplained. This study finds that accounting for marital sorting improves the performance of an otherwise standard dynastic life-cycle model of human capital formation in explaining cross-country differences in intergenerational mobility. Following the standard approach of modelling tax and education policies in quantitative studies, this paper finds that the sum of squared errors of model predictions versus data is reduced by around 33 % as opposed to a counterpart model without a marriage market.

This paper is connected to the literature on the marriage market and its role in explanating intergenerational earnings mobility and inequality. Alm & Whittington's (1999) and Wiik et al.'s (2010) empirical papers show the importance of economic factors including taxation for marital decisions. A broad empirical literature represented by Atkinson et al. (1983), Chadwick and Solon (2002) and Ermisch et al (2004), among others, demonstrates positive connection between assortative matching and intergenerational earnings persistence in the U.K., U.S. and Germany, respectively. Greenwood et.al. (2014) and Eika et al. (2019) show that positive assortative matching has a non-negligibly positive impact on income inequality in the U.S. and in several European countries, respectively. Relying on a search model of marital decisions pioneered by Mortensen (1988), Fernandez et al. (2005) explain a positive correlation between wage inequality and the degree of assortative matching via multiple equilibria phenomenon. The empirical part of their paper demonstrates substantial cross-country differences in the degree of assortative matching and a positive correlation between the degree of assortative matching and wage inequality.

This paper demonstrates that variations in tax and education policies provides an alternative explanation for cross-country differences in marital sorting and its connection to intergenerational earning persistence and income inequality. This relates the current paper to quantitative literature on marriage markets. Early studies include Aiyagary et al. (2000), Regalia & Rios-Rull (2001), Fernandez & Rogerson (2001), Greenwood et al. (2003) and others. Those papers develop quantitative models with marital sorting to analyse factors affecting intergenerational mobility, increases in single motherhood, income inequality and welfare consequences of child support policies, respectively. The models are calibrated to the U.S. economy. Similarly, this paper develops a dynastic life-cycle model in which altruistic agents decide on their marital status and investments in the human capital of their children. Assumptions including family decision making through Nash bargaining, fertility choices and divorces are excluded from the model. This simplification allows for the introduction of larger numbers of search rounds for realistic modelling of the assortative matching.

In more recent literature, Guner & Knowles (2007), Greenwood & Guner (2008), and Greenwood at. al. (2016) develop dynamic search models of marriage and divorce. These studies mainly focus on the role of household sector progress, increases in skill premiums, declines in marriage rates, growing degrees of marital sorting, and income inequality observed in the U.S. over recent decades. Similarly to those studies, this paper develops a dynamic search model of marriage. I introduce multiple periods of matching rounds and parental human capital investments to analyse the role of public policies in explaining cross-country differences in the degree of marital sorting and its connection to intergenerational earnings persistence.

3 Stylised Facts

This section presents empirical evidence on the relationships between intergenerational persistence of earnings, degrees of assortative matching, income inequality and tax policy parameters. Following the literature, intergenerational persistence of earnings or intergenerational earnings elasticity (IEE) is measured in a standard way using a coefficient β in the regression of the logarithm of sons' earnings $\ln(y_{son})$ versus the logarithm of fathers' earnings $\ln(y_{father})$: $\ln(y_{son}) = \alpha + \beta \ln(y_{father}) + \epsilon$. The estimates of intergenerational persistence of earnings are based on Corak (2006), who provides an overview of the most recent cross-country results. The estimates for Italy and Spain are from Holter (2015), who relies on empirical studies for those countries. The numbers illustrate a well-known pattern: high persistence of earnings in the U.S and U.K. and low persistence in Scandinavian countries and Canada; see Appendix A, table 5, column "IEE".

The degree of assortative matching is measured as the correlation between the partners' years of schooling based on LIS household level survey data covering 1995, and 2000.[1] The sample for estimation includes couples between 25 and 65 years of age[2] for whom information on years of education is available for both partners. Cohabiting couples are treated as married. This approach is in line with the one employed by Fernandez at al. (2005) for estimation of the degree of assortative matching in the empirical part of their paper. The estimates are presented in the Appendix A, table 5, column "Assortative matching".

Income inequality is measured as the logarithm of 90th to 10th gross earnings percentiles ratio, P90/P10, from OECD Statistics, https://stats.oecd.org/. The estimates are presented in the column "Log P90/P10".

The tax progressivity wedge is defined in a standard way as $1 - \frac{1-T'(y_2)}{1-T'(y_1)}$ where $T'(y_2)$ and $T'(y_1)$ are marginal taxes at income levels y_1 and y_2; see Guvenen et al. (2014). Following

[1]These dates are similar to the timespan employed in the literature for intergenerational correlation of earnings and public policies parameters estimation.

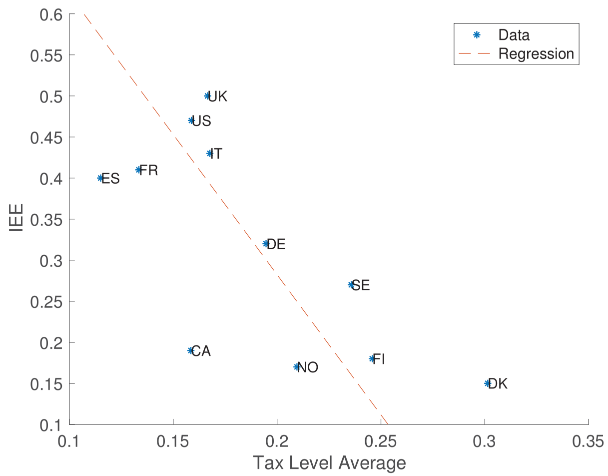
[2]Corresponds to the age of the adult population in the model.

Benabou (2002), I employ a standard assumption of $T'(y) = 1 - \theta_0 y^{-\theta_1}$. Given this functional form specification, the tax progressivity wedge becomes $1 - (\frac{y_2}{y_1})^{-\theta_1}$. The estimates of θ_1 are provided by Holter et. al. (2019), while $y_2 = 2AW$ and $y_1 = 0.5AW$, as in Holter (2015), where AW is an average wage. The tax level is captured by the tax rate corresponding to average earnings based on OECD tax and benefit calculator data.[3] The estimates of tax policy parameters appear in the columns "Tax Progressivity Wedge" and "Average Tax".

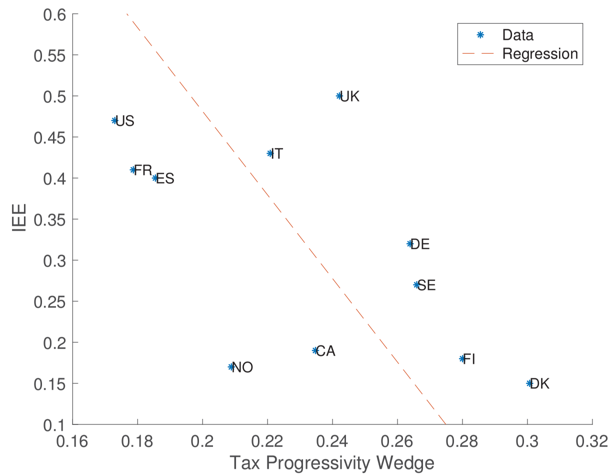
The results for 11 OECD countries analysed in this paper demonstrate that countries with more progressive taxes have lower intergenerational persistence of earnings and income inequality. This is in line with Holter's (2015) findings. Similarly to Fernandez at al. (2005), who demonstrate a positive correlation between assortative matching and skill premiums, the degree of assortative matching is positively correlated with income inequality measured by the logarithm of P90/P10 ratio; see table 6, Appendix A. This paper uncovers new relationships which are beyond the scope of Holter's paper. The countries with more progressive taxation and higher average levels of taxes have higher degrees of assortative matching. Moreover, the degree of assortative matching is positively correlated with intergenerational persistence of earnings and income inequality. The scatter plots and corresponding regression lines for selected variables are depicted in figure 1 below.

[3] https://www.oecd.org/els/soc/benefitsandwagestax-benefitcalculator.htm. The tax was estimated as an average tax rate of a 40 year old head of household with average earnings, 2 children and a partner who makes 39% (OECD average) of his income.

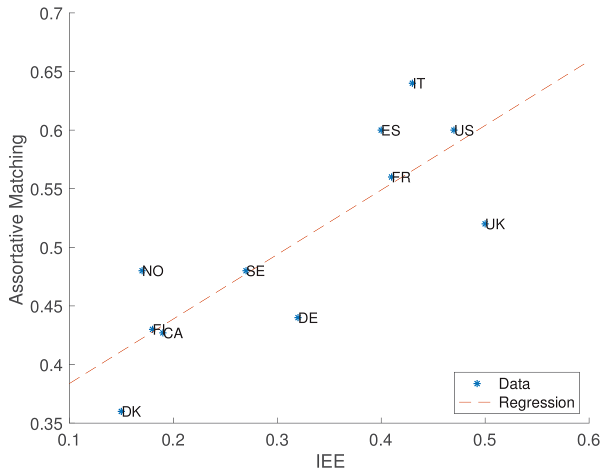
Figure 1: Differences in assortative matching, earnings persistence and tax policies across OECD countries



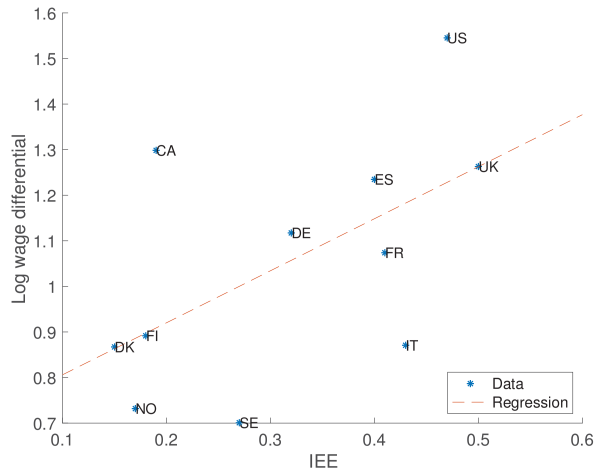
A: Tax level average vs. IEE



B: Tax progressivity wedge vs. IEE



C: Assortative matching vs. IEE



D: Log wage differential vs. IEE

4 A Simple Theoretical Example

To illustrate the qualitative connections between assortative matching, public policies, and investments in the human capital of children, I construct a simple, analytically solvable model based on Solon (2004) and Fernandez et.al (2005).

I analyse a 2 period economy populated by male and female agents.[4] The distribution of productivities is exogenous. For the sake of tractability, assume that one half of the population of each gender has low productivity y_l, while the other agents of both genders have productivities y_h, $y_h > y_l$.[5] There is no gender gap in pre- and after tax incomes between individuals of an identical productivity type. Following Fernandez et al. (2005), I assume that there are two rounds of matching in the marriage market. In the first period of their lives agents meet each other randomly and decide whether to marry or not depending on the observed productivity of the potential partner and match-specific quality shock $b_1 \geq 0$, where b_1 is a random variable with CDF F_b. For simplicity, there is no divorce in the economy. If they are married in the first period, a couple decides how much to consume and how much to invest in the human capital of their children. In the second period, agents who did not form a household in the first period are randomly matched with potential partners and draw a random realisation of matching shock $b_2 \geq 0$, where b_2 is a random variable with CDF F_b. In the first period, agents pay net taxes t_h and t_l depending on productivity types. Taxes finance education subsidies for children.

A couple married in the first period shares a common utility function, which is defined as follows:

$$u^{HM_1}(i, j, c_1, c_2, b_1) = log(c_1) + \alpha log(h_c) + b_1 + \beta log(c_2)$$

[4]In a dynastic multi-period setup, the utility of parents would depend on the utilities of their children, which in turn would depend on their consumption and marital decisions. This property makes an analytical solution of the dynamic model non-feasible and motivates the 2 period simplification.

[5]Arbitrary distribution of productivity types makes implications of taxation and education policies for marriage patterns and intergenerational income mobility substantially less tractable.

where i and j are the productivity types of agent i and his or her partner j respectively (due to gender symmetry, there is no need for male and female subscripts), c_t is the consumption of a couple in the periods $t = 1, 2$, h_c is the human capital of each child, b_1 is a match quality shock drawn in period 1 when a couple meets, α is an altruism factor, β is a time discount coefficient. I do not explicitly model the connection between chid human capital and productivity type, but assume that they are positively related, so that parental utility is increasing with human capital of each child. The human capital of each child is determined by parental investments in education e according to the following technology:

$$h_c = A(e + g)^{\psi}$$

where $A > 0$, $\psi \in (0, 1)$, $g > 0$ is a government education subsidy.

If married in the second period, agents do not have children and make only consumption decisions. Therefore, the utility of a couple married in the second period depends on consumption and matching quality only:

$$u^{HM_2}(i, j, c_2, b_2) = log(c_2) + b_2,$$

$$c_2 \leq y_i + y_j.$$

The assumption of $b_2 \geq 0$ guarantees that all single agents marry in the second period.

4.1 Matching assumptions

To make obtaining analytically-tractable results feasible, I make the following assumptions.

Assumption 1. Both high and low productive individuals always accept the same productivity partners in the first period, while a highly productive individual may reject or accept a low productive candidate in the first period depending on the realisation of matching quality shock b_1. This assumption holds under the following restrictions on utilities:

$$u^{*HM_1}(h, h, b_1 = 0) > log(y_h - t_h) + \beta\big(V(h) + E(b_2)\big)$$

$$u^{*HM_1}(l,l,b_1=0) \geq log(y_l - t_l) + \beta\big(V(l) + E(b_2)\big)$$

$$u^{*HM_1}(h,l,b_1=0) < log(y_h - t_h) + \beta\big(V(h) + E(b_2)\big)$$

where $V(i)$ is expected utility depending on the household consumption in the second period for a single agent of type $i \in \{h,l\}$, u^{*HM_1} is an optimal utility value defined below.

Denote $b = b_1 - \beta E(b_2)$. Under the conditions above, there is a threshold level b^*, so that for all $b \geq b^*$ high productive individual marries a low productive partner in the first period. By assumption 1, high and low productive individuals who meet partners with the same productivity in the first period match assortatively. Therefore, the degree of assortative matching in the first period is determined by b^* only.[6] The levels of expected second period utilities that sustain this type of equilibrium correspond to:

$$V(i) = \frac{1}{2}u^{HM_2}(i,h,E(b_2)) + \frac{1}{2}u^{HM_2}(i,l,E(b_2))$$

since there are equal shares of high and low productive individuals who remain single at the beginning of the second period, $i \in \{h,l\}$.

4.2 A household problem formed in a first period

A couple married in the first period solves the following problem:

$$u^{HM_1}(i,j,c_1,c_2,b_1) = log(c_1) + \alpha log(h_c) + b_1 + \beta log(c_2)$$

$$c_1 + en \leq y_i - t_i + y_j - t_j,$$

$$c_2 \leq y_i + y_j,$$

where $i,j \in \{h,l\}$.

After solving the married couple problem, the optimal level of investments in education e^* and utility u^{*HM_1} become

$$e^* = \frac{\alpha\psi(y_i - t_i + y_j - t_j) - gn}{n(1+\alpha\psi)},$$

[6]Fernandez et. al. consider a similar case, but to support this type of equilibrium, they assume that in the second period, single agents are exogenously matched with partners of the same productivity.

$$u^{*HM_1}(i,j,b_1) = log\left(\frac{y_i - t_i + y_j - t_j + gn}{1+\alpha\psi}\right) + \alpha log\left(A\left(\frac{\alpha\psi(y_i - t_i + y_j - t_j + gn)}{n(1+\alpha\psi)}\right)^{\psi}\right)$$

$$+b_1 + \beta log\left(y_i + y_j\right).$$

4.3 The problem of an individual who stays single in the first period

If an agent with productivity type i decides to remain single in the first period, in a second period he or she is matched randomly with a potential partner, draws a match quality shock realisation b_2, does not have children and decides on his or her consumption maximising the following utility function:

$$u^{HS_1}(i, c_1, c_2, E(b_2)) = log(c_1) + \beta\big(V(i) + E(b_2)\big)$$

given budget constraint

$$c_1 \leq y_i - t_i$$

and expected utility $V(i)$ depending on the agent's productivity type, $i \in \{h, l\}$. After solving the single agent problem, optimal utility corresponds to

$$u^{*HS_1}(i, E(b_2)) = log(y_i - t_i) + \beta\big(V(i) + E(b_2)\big).$$

4.4 Propositions

The condition under which a high productive individual would marry a low productive individual is defined by the following inequality:

$$u^{*HM_1}(h,l,b_1) \geq u^{*HS_1}\big(h, E(b_2)\big) \ (*)$$

Since for all $b \geq b^*$ a high productive individual would marry a low productive agent, the proportion of married couples formed by different productivity types in first period would constitute $\frac{1}{2}\big(1 - F(b^*)\big)$. Therefore, the lower the b^*, the higher $1 - F(b^*)$, or proportion of "mixed" households, resulting in a lesser degree of assortative matching.

The government budget constraint in the first period corresponds to:

$$\big(1 - \frac{1}{2}F(b^*)\big)gn \leq t_l + t_h$$

Consider two different reforms similar to the quantitative model analysis in the next section. First, assume that education subsidy g is fixed, while tax progressivity is increasing due to higher net transfer $-t_l$ for low productive individuals.

Proposition 1. The degree of assortative matching is decreasing with net transfers to low productive individuals $(-t_l)$. For proof, see Appendix B.

Optimal parental investments in education e^* is an increasing linear function of net parental income. Since declines in the net tax of low productive individuals is exactly offset by increases in the net tax of his or her high productive partner, the income of mixed couples remains unchanged. In contrast, the net income of couples consisting of matched high/low productive agents and, consequently, their investments in the education of their children decline/increase, respectively. Therefore, intergenerational earnings persistence declines.

Now assume that tax progressivity is fixed, while education subsidy g increases. Denote $t_h = at$, $t_l = t$, $a > 1$, $t > 0$. The fixed tax progressivity assumption is captured by constant parameter a. Education subsidy g can be adjusted through parameter t corresponding to the average taxation level.

Proposition 2. The degree of assortative matching is decreasing with public spendings on education g. The same property applies if a more generous education subsidy is financed by an increase in the tax for high productive individuals instead of an increase in the average taxation level. For proof, see Appendix B.

Optimal parental investments in education e^* is a decreasing function of g. Therefore, higher public expenditures lead to lower parental or private investments in the education of children and, consequently, lower intergenerational correlation of earnings.[7]

[7] This result is analogous to Holter's (2015) finding based on a simplified theoretical example and driven

The results demonstrate that in the current simplified framework, more generous education subsidies and higher net transfers for low productive individuals would always lead to a lower degree of assortative matching and lower intergenerational persistence of earnings.

In a rich life-cycle dynastic framework, connections between public policies, marital sorting and intergenerational persistence of earnings are more complicated, because parents consider the expected future utilities of their children when making decisions. Those utilities in turn depend on the children's marriage market prospects. In the remainder of this paper, I demonstrate that a rich quantitative model correctly replicates the positive correlation between the degree of assortative matching and intergenerational persistence of earnings, when cross-country differences in public policies are accounted for. Moreover, the sum of squared errors in intergenerational earnings elasticity predictions reduces by around one third as opposed to those produced by an analogous model without marital decisions.

5 Model

5.1 Setup

The economy is populated by an equal number of males m and females f. A period in the model corresponds to 5 years. An agent's life duration is deterministic and corresponds to 13 periods or 65 years. The first 5 periods are equivalent to the 0-24 years individuals spend in the parental household and do not make economic decisions. By the age of 25, agents start their independent life. There are 8 periods of adult life, starting at 25 - 29 years of age. Each individual receives labor income determined by her or his productivity. Single agents decide whether to get married or wait till next matching round. Marriage occurs only when both individuals agree. If individuals get married before the age of 45 (the 10th lifetime period) they give birth to an exogenously defined number of children and incur time and education

by an assumption of substitutability between consumption and child human capital in the utility function of married couples.

costs of raising them. Time costs are exogenous, while expenditures on education are chosen by parents, who are altruistic towards their children. There are no divorces in the economy. Additionally, there are no births outside of wedlock.

These simplifications dramatically reduce the computational burden of the model. Moreover, according to the U.S. Census Bureau, Survey of Income and Program Participation (SIPP), 2008 Panel, the average proportion of individuals who have ever been divorced among the adult population is 22.4 for females and 20.5 % for males. The share of currently divorced individuals is also relatively low and equals 11.3 and 9.1 % respectively.[8]

The proportion of single parents is relatively low. Using PSID data, Regalia and Rios-Rull (2001) finds that, the share of single mothers is 13.7 % in 2001. According to the OECD Family Database 2011 data, the proportion of single-parent households is around 11 % in the U.S. An average estimate for OECD countries is around 8 %.[9]

For simplicity, retirement age is not modelled in the current framework, because marital decisions as well as investments in human capital of the children are typically made before retirement age. Only same age individuals can get married. Given that the duration of each period is 5 years, this is a realistic assumption.

5.2 Married Households

At each period, single individuals meet each other on the marriage market. Marriage can start at any period $i = 1, .., 8$ of adult life. Once met, a couple draws a match-specific bliss shock $b(i) \in N\left(\bar{b}(i), \sigma_b^2\right)$ where $\bar{b}(i)$ is a mean, and σ_b is a standard deviation of the

[8]According to the 1996 and 2000 waves of LIS data used for model calibration, the share of divorced individuals is about 13 % of the 25-65 years old population. The estimate is calculated as the proportion divorced or separated individuals in the sample. Other possible statuses include "married", "never married/not in union", where "married" or "union" refers not only to de jure but also de facto situations, and "widowed" (about 1.5 %).

[9]http://www.oecd.org/els/family/database.htmstructure, only couple and single parent or single adult households are considered; "other" household types are excluded from the calculations.

corresponding bliss shock distribution. The mean $\bar{b}(i)$ depends on life period i when potential marriage may start.

$$\bar{b}(i) = \begin{cases} b_y, & \text{if } 1 \leq i \leq 4, \\ b_o, & \text{if } 5 \leq i \leq 8. \end{cases}$$

An assumption $b_y \geq 0$ guarantees that getting married young and having children may be desirable given the negative sign of the expected utility of children due to $\sigma = 2$ determining intertemporal elasticity of substitution in the CRRA utility function.[10] The bliss shock is constant during the marriage. Parameter b_o is normalised to 0. As demonstrated in the calibration section, once the proportion of individuals who got married young (under 45) is matched by calibrating b_y along with other parameters and setting $b_o = 0$, the overall proportion of married agents - potential calibration target for $b_o = 0$ is very close to the U.S. data. The standard deviation of σ_b affects the degree of assortative matching. Higher values of the standard deviation would lead to a lower degree of assortative matching due to higher importance of non-income factors for the marital decision.

Given the realisation of a bliss shock, each partner's characteristics including ability a_g and productivity p_g, $g \in \{f, m\}$, and life period i when individuals meet, a couple solve the following problem if marriage takes place.

5.2.1 Agents who get married in life periods 1-4 (ages 25 - 44)

Agents who get married in periods 1-4, have children. For simplicity, fertility is not modelled in the current framework,[11] and, there is no option to be childless. All married couples give birth to n children during the first period of their marriage. The first 4 periods of married life are devoted to raising and educating children. If agents marry in the life time

[10] This assumption is analogous to Regalia and Rios-Rull's (2001) assumption of direct utility function Ω added to the expected value function of children when agents grow older.

[11] Introduction of endogenous fertility would substantially increase the computational burden of the model. Moreover, there is a lack of data on fertility-income profiles for OECD countries (except for the U.S.) needed for evaluation of the model is performance.

period i, then the duration of married life corresponds to $9 - i$ periods or 25 - 40 years.

First period of marriage

Agents incur time costs of raising 0-4 year old children. No investments in education are made in this period. Utility V^{HM} of a household consisting of a married couple and their children is defined as follows:

$$V^{HM}(i,j,p_m,a_m,p_f,a_f,b(i)) = \max_{c} \quad \left\{u(c,b(i)) + \beta E_{a_c}\left[V^{HM}(i,j',a_c,p_m,p_f,b(i)|a_m,a_f)\right]\right\}$$

$$\text{s.t.} \quad c = \xi(i,j)\left[wgp_f(1-\tau_f)(1-\omega) + wp_m(1-\tau_m) + 2tr\right]$$

where $i = 1,..,4$ is an adult life period when marriage starts, $j = 1$ is a period of marriage, $j' = j+1$, p_m, a_m, p_f, a_f are male and female productivity and ability shocks realisations respectively, c is consumption of the household, g is the gender wage gap, ω is the time costs of raising n children, τ_f and τ_m are taxes depending on male and female productivities respectively, tr is a transfer, a_c is the ability of children, the utility of the household formed by a married couple is defined as:

$$u(c,b(i)) = \frac{c^{1-\sigma}}{1-\sigma} + b(i)$$

where $\sigma > 0$, $b(i)$ is a matching bliss shock specified above, $\xi(i,j)$ is an adult equivalence scale parameter which depends on the life period when marriage takes place (determined by both i and j). This parameter captures economies of scale in household consumption and takes the following functional form, as in Greenwood et al. (2003):

$$\xi(i,j) = \begin{cases} \left(\frac{1}{2+qn}\right)^{\chi}, & \text{if } 1 \leq i \leq 4 \text{ and } j \leq 5, \\ \left(\frac{1}{2}\right)^{\chi}, & \text{if } 5 \leq i \leq 8 \text{ or } j > 5. \end{cases}$$

In the case of standard parameters values $q = 0.3$, $\chi = 0.5$ and number of children per family $n > 0$, equivalence scale parameter $\xi > 0.5$ provides the economic motive for marriage.

Second - fourth periods of marriage

Agents make decisions on investments in primary and secondary education of their children.

$$V^{HM}(i,j,a_c,p_m,p_f,b(i)) = \max_{c,e_{j-1}} \quad \{u(c,b(i)) + \beta V^{HM}(i,j'=j+1,a_c,p_m,p_f,b(i),h_{c,j-1})\}$$

$$\text{s.t.} \quad c = \xi(i,j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr - ne_1\big]$$

$$h_{c,j-1} = h_{c,j-2} + a_c\big[h_{c,j-2}(e_{j-1} + \tilde{g}(j))\big]^{\psi_0}$$

where $i = 1,..,4,\ j = 2,3,4,\ e_1$ are investments in primary education, $\{e_{j-1}\}_{j=3}^{4}$ are investments in the first and second periods of secondary education, n is the number of children, $h_{c,0}$ is a minimum level of human capital, $0 < \psi_0 < 1$ is a parameter determining the curvature of the human capital production function in the period of primary and secondary education, $\tilde{g}(j=2) = g_1$, is government subsidies for primary education, $\tilde{g}(j=2,3) = g_{2,3}$, is public spendings on secondary education.

Fifth period of marriage

Parents make decisions on whether to send their children to college and, if yes, how much to spend on their eduction.

$$\begin{aligned} V^{HM}(i,j,a_c,p_m,p_f,b(i),h_{c,j-2}) = \max_{c,e_{j-1}} \quad & u(c,b(i)) + \gamma\big[(1-\delta(a_c,h_{c,3}))\{0.5\sum_{k\in m,f} E_{z_c}V_k(p_c^0,a_c)\} \\ & + \delta(a_c,h_{c,3})\{0.5\sum_{k\in m,f} E_{z_c}V_k(p_c^1,a_c)\}\big] \\ & + I(i<4)\beta V^{HM}(i,j'=j+1,p_m,p_f) \\ \text{s.t.} \quad & c = \xi(i,j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr - ne_4\big] \\ & p_c^1 = z_c h_{c,4}^1,\ p_c^0 = z_c h_{c,4}^0 \\ & h_{c,4}^1 = h_{c,3} + a_c\big[h_{c,3}(e_4 + g_4)\big]^{\psi_1}, h_{c,4}^0 = h_{c,3} \\ & \delta(a_c,h_{c,3}) = 1 - exp(\theta a_c h_{c,3}) \end{aligned}$$

where $i = 1,..,4,\ j = 5,\ I(i<4) = 1$ if $i < 4$ and 0 otherwise, so that for agents who got married in life period 4, the 5th period of marriage is the last life period, and also the last period of marriage, $\gamma > 0$ is parental altruism, $\delta(a_c,h_{c,3})$ is the probability of college completion which increases with a child's abilities a_c and human capital accumulated by the time of high school completion $h_{c,3}$, $\theta < 0$, V_k, $k \in \{m, f\}$, are value functions of male m and female f individuals at the time they enter adult life, defined below. For simplicity it is assumed that parents are not aware of their children's gender and have equal proportions of male and female children. Therefore, the probability of a child being female or male equals $\frac{1}{2}$.[12] By the time of leaving the parental household, children draw labor market luck shock z which determines their productivity p in their adult lives along with human capital $h_{c,4}$.

Periods six to eight of marriage

The duration of marriage for agents who got married in the period $i = 1, 2, 3$ of their adult lives corresponds to 8,7, and 6 periods respectively. After the 5th period, children leave the household so their parents do not make any economic decisions and their utility depends only on consumption as defined below:

$$\begin{aligned} V^{HM}(i, j, p_m, p_f, b(i)) = \quad & u(c, b(i)) + \beta V^{HM}(i, j' = j+1, p_m, p_f) \\ \text{s.t.} \quad & c = \xi(i, j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr\big] \\ & 5 < j < J(i) \end{aligned}$$

$$\begin{aligned} V^{HM}(i, j, p_m, p_f, b(i)) = \quad & u(c, b(i)) \\ \text{s.t.} \quad & c = \xi(i, j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr\big] \\ & j = J(i) \end{aligned}$$

where $i = 1, 2, 3$, $J(i) = 9 - i$ is the last period of marriage.

5.2.2 Agents who get married in life periods 5-8 (ages 45 - 64)

Agents who get married in life periods 5-8, corresponding to ages 45 - 64, do not have children. This assumption is realistic since typically women complete their fertility decisions

[12]This simplifying assumption is analogous to one from Regalia & Rios-Rull's (2001) paper. Due to the presence of a gender wage gap, returns on investments in education are different for male and female children. Consequently, the dimensionality of the problem would grow substantially if parents were aware of their children's gender and deciding on investments in education of female and male children separately.

by the age of 45. Consequently, no economic decisions are made and for each marriage period utility is defined as follows.

$$\begin{aligned} V^{HM}(i,j,p_m,p_f,b(i)) = \quad & u(c,b(i)) + \beta V^{HM}(i,j'=j+1,p_m,p_f) \\ \text{s.t.} \quad & c = \xi(i,j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr\big] \\ & j < J(i) \end{aligned}$$

$$\begin{aligned} V^{HM}(i,j,p_m,p_f,b(i)) = \quad & u(c,b(i)) \\ \text{s.t.} \quad & c = \xi(i,j)\big[wgp_f(1-\tau_f) + wp_m(1-\tau_m) + 2tr\big] \\ & j = J(i) \end{aligned}$$

where $i = 5,..,8,\ J(i) = 9 - i$ is the last period of marriage.

5.3 Single adult households

Every period a single adult household meets another single male $k = m$ or female $k = f$ individual characterised by productivity p' and abilities a' with probability $\frac{\Omega_k(i+1,p',a')}{\int_{x'} d\Omega_k(i+1,p',a')}$, $x' = \{p', a'\},\ k \in \{f, m\}$ where $\Omega_k(i+1,p',a')$ is a non-normalised distribution of single individuals across productivity and ability types in the period $i+1$.

For a male individual with productivity p and ability a the utility of being single in period i is defined as follows:

$$\begin{aligned} V_m^{HS}(i,p,a) = \quad & u^{HS}(c) + \beta \int_{b'}\int_{x'} \big[i_m(i+1,p,a,p',a')V^{HM}(i+1,1,p,a,p',a',b') + \\ & + [1 - i_m(i+1,p,a,p',a',b')]V_m^{HS}(i+1,p,a)\big] \frac{d\Omega_f(i+1,p',a')}{\int_{x'} d\Omega_f(i+1,p',a')} dF_i(b') \\ \text{s.t.} \quad & c = wp(1-\tau_m) + tr \end{aligned}$$

For a female individual with productivity p and ability a the utility of being single in period

i is defined as follows:

$$\begin{aligned} V_f^{HS}(i,p,a) = \quad & u^{HS}(c) + \beta \int_{b'} \int_{x'} \big[i_m(i+1,p',a',p,a,b')V^{HM}(i+1,1,p',a',p,a,b')+ \\ & + [1-i_m(i+1,p',a',p,a,b')]V_f^{HS}(i+1,p,a)\big] \frac{d\Omega_m(i+1,p',a')}{\int_{x'} d\Omega_k(i+1,p',a')} dF_i(b') \\ \text{s.t.} \quad & c = wgp(1-\tau_f) + tr \end{aligned}$$

where $i_m(i+1,p,a,p',a',b)$ indicates a positive marital decision between a male with productivity p and abilities a and a female with productivity p' and abilities a' in life period $i+1$, b' is a realisation of matching bliss shock, $F_i(b')$ is corresponding CDF that depends on the period i when a potential marriage may start, $i = 1,..,8$.

$$i_m(i+1,p,a,p',a',b') = \begin{cases} 1, & \text{if a male with } p,a \text{ marries a female with } p',a' \text{ given } b', \\ 0, & \text{otherwise.} \end{cases}$$

The one-period utility function $u^{HS}(c)$ of single households is defined as:

$$u^{HS}(c) = \frac{c^{1-\sigma}}{1-\sigma},$$

where $\sigma < 1$.

In the last life period for both genders, utility is specified as follows.

$$\begin{aligned} V_k^{HS}(i,p_k,a_k) = \quad & u^{HS}(c) \\ \text{s.t.} \quad & c = \begin{cases} wp_m(1-\tau_m) + tr, & \text{if } k = m, \\ wgp_f(1-\tau_f) + tr, & \text{if } k = f. \end{cases} \\ & i = 8 \end{aligned}$$

5.4 Value functions of agents at the beginning of the first adult life period

Since agents are altruistic towards their children, the utility of a household consisting of a married couple depends on the expected value functions of their children at the moment when they enter adult life. The value function of a young individual of gender $k \in \{m, f\}$ with productivity p and ability a at the beginning of the first period of adult life is defined as:

$$
\begin{aligned}
V_m(p,a) = \quad & \int_b \int_x [i_m(1,p,a,p',a',b) V^{HM}(1,1,p,a,p',a',b) + \\
& [1 - i_m(1,p,a,p',a',b)] V_m^{HS}(1,p,a)] \\
& \frac{d\Omega_f(1,p',a')}{\int_{x'} d\Omega_f(1,p',a') = 1} dF_1(b) \\
V_f(p,a) = \quad & \int_b \int_x [i_m(1,p',a',p,a,b) V^{HM}(1,1,p',a',p,a,b) + \\
& [1 - i_m(1,p',a',p,a,b)] V_f^{HS}(1,p,a)] \\
& \frac{d\Omega_m(1,p',a')}{\int_{x'} d\Omega_m(1,p',a') = 1} dF_1(b)
\end{aligned}
$$

5.5 Marital decisions

Given the realisation of a matching bliss shock b, a male with productivity p and ability a marries a female with productivity p' and ability a' if the utility of being single is less than or equal to the utility of being married for both individuals:

$$
\begin{aligned}
V_m^{HS}(i,p,a) &\leq V^m(i, j=1, p, a, p', a', b) \\
V_f^{HS}(i,p',a') &\leq V^m(i, j=1, p, a, p', a', b)
\end{aligned}
\tag{*}
$$

$$
i_m(i,p,a,p',a',b) = \begin{cases} 1, & \text{if (*) is satisfied,} \\ 0, & \text{otherwise.} \end{cases}
$$

5.6 Stationary distributions

The non-normalised distribution of single male and female individuals across productivity and ability types in the period $i = 1$ is determined by the stationary distribution of young agents across human capital $h_{c,4}$ levels acquired by the moment of entering adult life and realisation of market luck z and abilities a shocks. The productivity is defined as $p = zh_{c,4}$.

Denote $X = A \times P$, where A and P are sets of possible values of abilities and productivities respectively, $x = \{a, p\} \in X$, $x' = \{a', p'\} \in X'$, $X' = X$. The non-normalised distribution of single male and female individuals across productivity and ability types in the periods $2 \leq i \leq 8$ is given by $\Omega_m(i, p, a)$ and $\Omega_f(i, p, a)$ respectively.

$$\Omega_m(i, x) = \int_b \int_X^x \int_{X'} [1 - i_m(i-1, x, x', b)] \frac{d\Omega_f(i-1, x')}{\int_X d\Omega_f(i-1, x')} d\Omega_m(i-1, x) dP(b)$$

$$\Omega_f(i, x) = \int_b \int_X^x \int_{X'} [1 - i_m(i-1, x', x, b)] \frac{d\Omega_m(i-1, x')}{\int_X d\Omega_m(i-1, x')} d\Omega_f(i-1, x) dP(b)$$

Similarly, non-normalised distribution of couples of males of type $\bar{x} = \{\bar{p}, \bar{a}\}$ and females of type $\bar{x}' = \{\bar{p}', \bar{a}'\}$ who draw realisation b of matching bliss shock and who got married in the period i is given by $G(i+1, \bar{x}, \bar{x}', b)$.

$$G(i+1, \bar{x}, \bar{x}', b) = \int_b \int_X^{\bar{x}'} \int_X^{\bar{x}} i_m(i, x, x', b) d\Omega_m(i, x) d\Omega_f(i, x') dP(b).$$

Normalise the size of female and male cohorts who enter adult lives in each period of the model economy to 1.[13] Since there is no random mortality in the economy, the size of the cohort remains stable till the end of the life-time period, and the sum of female or male individuals who got married and those who remained single in each life period $i = 1, .., 8$ is equal to 1:

$$\int_b \int_X \int_X G(i, x, x', b) dx dx' db + \int_X \Omega_k(i, x) dx = 1; k \in \{f, m\}$$

5.7 Government

The government collects income taxes to finance uniform transfers tr, lump-sum education subsidies $g_i, i = 1; \{2, 3\}; 4$ and exogenous government expenditures G. Taxes are defined according to the following formula from Guvenen et. al. (2011). For an individual with labor income equal to productivity pr, the tax rate τ is specified by the following equation:

$$\tau = \tau_1 \left(\frac{pr}{\bar{pr}}\right)^{0.2} + \tau_2 \left(\frac{pr}{\bar{pr}}\right)^{0.4} + \tau_3 \left(\frac{pr}{\bar{pr}}\right)^{0.6} + \tau_4 \left(\frac{pr}{\bar{pr}}\right)^{0.8}$$

[13]Population growth determined by fertility rates is taken into considerations for calculations of aggregate values.

The estimates of parameters τ_1,.., τ_4 for 11 OECD countries and different family types are from Holter (2015); see table 7 in Appendix C.

Following Holter (2015), I assume lump-sum educational subsidies. Subsidies for primary education are denoted as g_1, for the first and second periods of secondary education, subsidies are assumed to be identical and are denoted as $g_{2,3}$, for tertiary education, subsidies are denoted as g_3. This functional form choice facilitates comparability of the results in this paper with those obtained by Holter. As in Restuccia & Urratia (2004) and Holder (2015), this paper treats locally funded education subsidies as private spendings on education. Central and regional components contribute to "pure" public expenditures on education. The education subsides are estimated based on UNESCO data[14] on government expenditures per student as % of GDP per capita, and OECD "Education at a Glance"[15] data on the sources of public educational funds; see results in table 8, Appendix C.[16]

Exogenous government expenditures G are set equal to 16.1 % of GDP. This estimate is obtained by subtracting total government spendings on education (2.9%[17] of GDP) from 19% corresponding to the estimate of total government spending (including expenditures on education) provided by Krusell & Rios-Rull (1999).

5.8 Stationary equilibrium

A stationary equilibrium consists of t_0 population size N_0, cohort growth rate γ, average productivity $\bar{pr}$, government policies including parameters determining income taxes τ_k, $k \in \{m, f\}$, education subsidies $g_i, i = 1; \{2, 3\}; 4$ and transfer tr defined in subsection 5.7, equilibrium wage $w = 1$, a set of value functions $V^{HM}(i, j = 1, p_m, a_m, p_f, a_f, b(i))$,

[14]http://data.uis.unesco.org/

[15]https://www.oecd.org/education/education-at-a-glance/

[16]Holter (2015) evaluates education subsidies based on UNESCO and OECD data from 2000-2005. However, there are no estimates provided for Canada, Sweden and Germany due to unavailability of the data. In this paper, I update the estimates and fill in the gaps for Canada and Germany based on the latest data from 2006 - 2010.

[17]Education at a Glance, 2005.

$V^{HM}(i, j = 2, ..5, a_c, h_{c,j-2}, p_m, p_f, b(i))$, $V^{HM}(i, j = 6, ..J(i), p_m, p_f, b(i))$ for couples who get married in periods $i = 1, ..4$; $V^{HM}(i, j = 1, ..J(i), p_m, p_f, b(i))$ for agents who get married in periods $i = 5, ..8$, $J(i) = 9 - i$; $V_k^{HS}(i, p, a)$ for single individuals; $V_k(p, a)$ for young individuals entering adult lives, $k \in \{f, m\}$; marital decision rules $i_m(i, p_m, a_m, p_f, a_f, b(i))$; parental decision rules regarding investments in the human capital of their children; non-normalised stationary distributions of married and single individuals $G(i, p_m, a_m, p_f, a_f, b(i))$ and $\Omega_k(i, p, a)$, $k \in \{f, m\}$ for $i = 1, .., 8$ such that:

a) value functions V^{HM} and parental decision rules regarding investments in the human capital of their children solve the problem of a household consisting of married couples specified in the subsection 5.2 given the value functions of young individuals entering their adult lives V_k, $k \in \{f, m\}$, education subsidies $g_i, i = 1; \{2, 3\}; 4$, taxes τ_k, $k \in \{m, f\}$ and transfer tr;

b) value functions V_k^{HS}, $k \in \{f, m\}$ solve the problem of households consisting of single individuals specified in subsection 5.3 given marital decision rules i_m, value functions V^{HM} of the households consisting of married couples and non-normalised stationary distributions of single individuals Ω_k, $k \in \{f, m\}$, taxes τ_k, $k \in \{m, f\}$ and transfer tr;

c) value functions of young individuals entering their adult lives V_k, $k \in \{f, m\}$ is defined as specified in subsection 5.4 taken V^{HM}, V_k^{HS}, $k \in \{f, m\}$, marital decision rules i_m and non-normalised stationary distributions of single individuals Ω_k, $k \in \{f, m\}$ as given;

d) marital decision rules i_m are defined as in subsection 5.5 given V^{HM}, V_k^{HS}, $k \in \{f, m\}$;

e) non-normalised stationary distributions of single individuals Ω_k, $k \in \{f, m\}$, and married couples G follow recursive rules defined in subsections 5.6 and 5.7, given marital decision rules i_m and the distribution of young individuals across productivity and ability types;

f) stationary distribution of young individuals entering their adult lives across productivity and ability types is determined by parental decision rules on investing in the human capital of their children and the stochastic process of intergenerational transmission of abilities a and stationary distribution of labor market luck shock z;

g) the government budget is balanced.

6 Calibration

The parameters of the model can be divided into two groups. The first group includes parameters that are set exogenously, taking standard values or values estimated by the results of empirical studies. The second group consists of parameters that are calibrated jointly, so that the model matches key moments in the U.S. economy. The parameters are summarised in table 1 below.

Table 1: Exogenously set parameters from external sources

Parameter	Value	Description	Source
g_1 (primary)	0.101	Public expenditures on education	UNESCO & OECD
$g_{2,3}$ (secondary)	0.114		2000-2005
g_4 (tertiary)	0.209		
ω	1	Time cost of children	De la Croix & Doepke (2003)
g	0.21	Gender earnings gap	OECD, https://data.oecd.org
n	2.87	Number of children per married couple	Greenwood et. al. (2003)
χ	0.5	Consumption equivalence parameter	Greenwood et. al. (2003)
q	0.3		Greenwood et. al. (2003)
t_c^1	0.8	Time costs, college	Restuccia & Urratia (2004)
t_c^0	0.4	Time costs, college, dropouts	Restuccia & Urratia (2004)

Public expenditures on education are evaluated based on government expenditures per student expressed as a percentage of GDP per capita provided by the World Bank, World Development Indicators, 2000 - 2005. The information on initial sources of public educational funds and final purchasers of educational resources by level of government for primary, secondary and tertiary (tables B4.3a and b, Education at a Glance, 2004) is utilised to evaluate central and regional expenditures treated as public spending on education and local expenditures treated as private spending, as in Restuccia & Urratia (2004).

The number of children per family is from Greenwood et. al. (2003), who estimate fertility rates for married women based on PSID data. The data covers 1983-1990 and provides information on the number of children born. The estimation period is similar to that used to evaluate intergenerational persistence of earnings by Solon (2004). Since a non-negligible proportion of females in the sample were still of fertile age, the regression was used to predict the number of children borne by women by age 44. The estimated number of children ever borne by married women is utilised as an estimate of the number of children per family, since no out-of-wedlock births are allowed in the model.[18]

Parameters χ and q translate household income into consumption per adult family member, taking scale effects into consideration. Following Greenwood et.al. (2003), this study assumes intermediate values of those estimates reported by the literature.

De la Croix & Doepke (2003) employ the estimate of time costs of raising children as equal to 2.25 years per child. Given that the number of children born is set to 2.87 for each family as in Greenwood et. al. (2003), this would imply total costs equal to 6.46 years in the model economy. Assigning non-zero time costs of children to the second period of marriage (years 5-9) would non-negligibly increase the computational burden of the model because, instead of applying the overall income of a couple as a state variable in the household problem for the second period of marriage, one would need to keep track of male and female productivities separately. Therefore, for the sake of simplicity the fraction of time spent on children is set equal to 1 in the first period of marriage, which corresponds to 5 years.

[18]Given the estimated share of married individuals at 69.5% and assuming no out-of-wedlock births, the average number of ever-born children per woman in the model is equal to 2.87*0.695 + 0*0.305 = 1.995. According to the World Bank data, available at https://data.worldbank.org/, the total number of births per woman fluctuates between 1.97 and 2.08, with an average of 2.02. Therefore, the current framework does not inflate the average fertility rate.

Following Greenwood et. al. (2015), I assume that females earn a fraction of the salary of a male with equivalent productivity. This fraction corresponds to 1 minus the gender wage gap g. The OECD provides an estimate of the gender wage gap, defined as the difference between median earnings of women relative to the median earnings of men (see https://data.oecd.org/earnwage/gender-wage-gap.htm). The data refers to full-time employees.

Time costs of attending college t_c are set equal to 0.8, which implies 4 years corresponding to the standard duration of tertiary education for students who complete college. For students who drop out, time costs of college correspond to 0.4, which is equivalent to 2 years. This assumption is in line with the estimate employed by Restuccia & Urratia (2004).

The remaining set of parameters presented in table 2 below is calibrated jointly so that the model replicates key characteristics of the U.S. economy. I minimise the sum of squared deviations of the statistics (corresponding to the targets in the table below) predicted by the model from corresponding data moments. I denote the parameter vector as $\Psi = (h_{min}, \phi_0, \phi_1, \gamma, b_y, \sigma_b, \theta, \sigma_a, \rho_a, \sigma_z)$, x_i as statistics simulated in the model, $\bar{x_i}$ as its empirical analog, $i = 1, .., 10$, the calibration procedure can be formulated as follows:

$$\Psi^* = \arg\min_\Psi \sum_{i=1}^{10} \left(\frac{x_i(\Psi) - \bar{x_i}}{\bar{x_i}} \right)^2 .$$

Standard errors for the parameters obtained are not provided due to unavailability of estimates for variances of empirical moments.

The benchmark model fit for endogenously calibrated parameters is presented in 2 above[19]. The results demonstrate that the model captures the U.S. economy quite accurately. Moreover, the marriage market parameters including the degree of assortative matching and the share of married individuals below the age of 45 is matched relatively precisely. Neverthe-

[19]Table 9 in Appendix C presents the datasources for estimation of U.S. statistics. A slight imprecision in the matching of certain calibration targets may be explained by the discrete nature of the model. Productivity, human capital, labor market luck shock and ability grids sizes are set at the levels that allow for avoidance of grid-dependence of the model solution, and at the same time guarantee reasonable computational time.

Table 2: Endogenously calibrated parameters and benchmark model fit

Name	Value	Description	Target	Data	Model
h_{min}	1.700	Minimum level of human capital	University attendance ratio	0.530	0.535
ϕ_0	0.585	Human capital, before university	Private spending, prior-university	0.493	0.485
ϕ_1	0.495	Human capital, in university	University premium	1.75	1.771
γ	0.365	Parental altruism	Private spending, university	0.631	0.600
b_y	0.057	Additional value of marriage, young	Share of young married agents	0.695	0.698
σ_b	0.005	Std. deviation of match quality	Degree of assortative matching	0.605	0.602
θ	-0.155	Parameter affecting university failure	University drop out rate	0.321	0.319
σ_a	0.388	Std. of ability shock	Share of h.c. in earnings variance	0.615	0.621
ρ_a	0.125	Autocorrelation, ability shock	IEE	0.470	0.484
σ_z	0.360	Std. deviation, labor market shock	Log 90 to 10 ratio	1.545	1.535

less, even though parameter b_o (determining the mean of the marriage bliss shock for older individuals) is normalised to 0, the model captures the overall share of married individuals adequately: 0.801 in the model versus 0.772 in the data.

7 Results

Employing the framework of marital sorting and human capital formation presented above, I evaluate whether accounting for marital sorting and public policies may improve the performance of the otherwise standard life-cycle model in explaining cross-country differences in the intergenerational persistence of earnings. I find that accounting for differences in taxation and education policies between the U.S. and 10 OECD countries is sufficient to replicate a positive relationship between the degree of assortative matching and intergenerational persistence of earnings. Moreover, the model provides more accurate predictions of intergeneration earnings correlation in 11 OECD countries. The sum of squared errors reduces by about one third compared to Holter's model, which does not account for the marriage market. The results of the decomposition analysis in sections 7.1 and 7.2 show that improvement in the model performance may be partially driven by a simplifying assumption of an absence of inter vivo transfers and savings in the economy. Nevertheless, a positive degree of assortative matching is crucial for the model's ability to produce realistic levels of intergenerational correlation of earnings observed in OECD countries.

7.1 Explaining cross-country differences in assortative matching and intergenerational earnings persistence

I evaluate the model's performance in explaining cross-country differences in the degree of assortative matching and intergenerational persistence of earnings if differences in national public policies are accounted for. As in Holter (2015), 10 OECD countries are analysed. I start by introducing taxation and education policies of the 10 countries into the model, while keeping the rest of the parameters as in the benchmark (U.S.) economy: see policies parameters in table 7 and 8, Appendix C. Then I discuss the model's performance in replicating key stylised facts discussed in the section 3. To disentangle the effects of different policies, I repeat a similar exercise by replacing only taxes or education subsidies with corresponding country specific policies.

Taxation and education subsidies

The model correctly replicates the relationships between intergenerational persistence of earnings, income inequality, tax progressivity and average tax levels. The model predicts a strong negative correlation between intergenerational persistence of earnings and average tax levels (-0.68 in the model vs. -0.7 in the data); intergenerational persistence of earnings and the tax progressivity wedge (-0.64 in the model vs. -0.6 in the data): see figure 2 below, subfigures A and B, and table 10 with correlations in Appendix C. As in Holter's model, higher tax levels and progressivity discourage parents from investing in the human capital of their children. Consequently, the share of private contributions to overall investments in human capital decreases and weakens the correlation between parental and child earnings, leading to lower intergenerational persistence of earnings. Moreover, since distribution of private spending on the education of children is compressing, income inequality also decreases. The model correctly predicts a strong negative correlation between income inequality and average tax levels (-0.49 in the model vs. -0.62 in the data) and inequality and the tax progressivity wedge (-0.502 in the model vs. -0.498 in the data). However, the model overestimates the levels of inequality for the countries with the lowest earnings persistence (see figure 2, subfigure D).

A key novel assumption introduced in this paper is the presence of a marriage market. The model correctly replicates a positive link between intergenerational persistence of earnings and the degree of assortative matching in the data (the correlation in the model is 0.81 vs. 0.82 in the data: see figure 2, subfigure C).

On the one hand, higher average tax levels, tax progressivity and education subsidisation have negative impacts on the degree of assortative matching. A more generous taxation system typically implies higher levels of transfers, lower after-tax income of more productive individuals and higher after-tax income of less productive agents. Higher after-tax income of low productive individuals may increase the relative benefits of marriage with a low income partner. More generous transfers and education subsidisation[20] may discourage parents from spending on the education of their children and, consequently, reduce the costs or increase the benefits of marriage. Therefore, for a given realisation of matching quality shock, a high productive agent is more likely to marry a low productive individual than in an economy

[20]The degree of education subsidisation is difficult to capture with a single measure such as, for instance, tax progressivity, since public spending on primary, secondary and tertiary education may vary within a given country. For instance, in Scandinavian countries, public expenditures (coming from federal and regional sources) on primary and secondary education are quite moderate, while public expenditures on university education are the highest of the 11 OECD countries. In contrast, in Italy and Spain, the order of these two types of education spending is the opposite. Nevertheless, employing the same data on education subsidies as in this paper, Holter (2015) demonstrates that countries with higher average tax levels and tax progressivity tend to have more generous public expenditures on tertiary education.

with a less generous tax system and less education subsidisation. Consequently, the degree of assortative matching declines. This directly contributes to lower intergenerational correlation of earnings, through weakening of the income correlation within a couple, and indirectly, through reducing marriage market returns on investments in the human capital of children. This intuition is similar to propositions 1 and 2 for the simple model example in section 4.

On the other hand, higher average tax levels, tax progressivity, and education subsidisation may have positive impacts on the degree of assortative matching. As demonstrated in section 4, even in a very simple framework, the impact of taxes and education subsidies on the degree of assortative matching can be ambigious. Lower net taxes may increase the relative benefits of single life. More generous education subsidisation and redistribution compress the distribution of agents across productivity levels, implying lower pre- and after-tax incomes for the most productive individuals. Lower after-tax income of highly productive agents may increase the marginal benefits of marrying an individual with relatively high productivity. Those factors positively affect the degree of assortative matching.

Nevertheless, the results obtained in this model of marital sorting and human capital formation demonstrate that the resulting impacts of higher average tax levels, tax progressivity and more generous education subsidies on the degree of assortative matching is negative.

Moreover, the model correctly captures the positive correlation between the degree of assortative matching and inequality measured by log P90/P10. This finding is similar to Ferdandez et. al. (2005), who demonstrate a positive connection between the degree of marital sorting (measured as the correlation of partners' years of schooling, as in this paper) and the skill premium equivalent to the inequality measure in their model. In contrast to Fernandez at. al. (2005), who explain this pattern though multiple equilibria in a theoretical model, this paper demonstrates that accounting for cross-country differences in taxes and education subsidies is sufficient to generate a positive link between the degree of marital sorting and inequality.

Only taxation

I assume that tax functions are country-specific, while education subsidies expressed as percentage of GDP per capita are fixed at the U.S. level. The model that accounts only for differences in taxation policies, replicates key stylised facts nearly as precisely as the model that accounts for variation in both taxation and education policies (benchmark); see figure 4 in Appendix C. Moreover, the model provides a somewhat more accurate prediction of cross-country differences in intergenerational persistence of earnings than the benchmark model. This happens due to the fact that countries with high persistence of earnings such as Italy, Spain, and France have relatively high proportion of federal and state financing of primary and secondary education, which has negative impacts on the persistence of earnings in the model. If education subsidies are fixed at the U.S. level, the model predicts more precise higher values of intergenerational earnings correlation for those countries.

Only education subsidisation

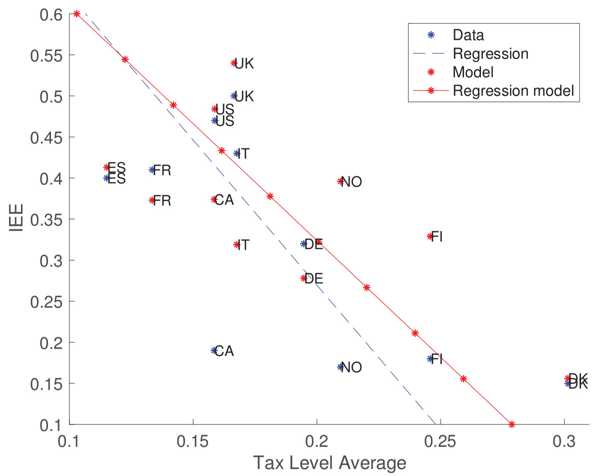
Now assume that education subsidies expressed as percentage of GDP per capita take country-specific values, while the tax function corresponds to the benchmark U.S. economy. The model in which only differences in education policies are considered has substantially inferior performance compared to the frameworks that account for country-specific taxes. The model overestimates intergenerational persistence of earnings and Log P90/P10 ratios for most countries, confirming the dominant role of cross-country differences in taxation systems in explaining intergenerational correlation of earnings and income inequality patterns. Additionally, the model underestimates the degree of assortative matching across countries, demonstrating the resulting negative impact of more generous education subsidisation on the degree of marital sorting; see figure 5 in Appendix C. In most countries, except the U.K., either primary and secondary or tertiary education subsidisation levels are higher than in the U.S., leading to lower degrees of marital sorting than in the benchmark model.

The results demonstrate that consideration of cross-country differences in taxation is more important for explanation of the key stylised facts than education policies. In subsequent subsections I analyse the importance of marriage markets and positive assortative matching assumptions for model performance.

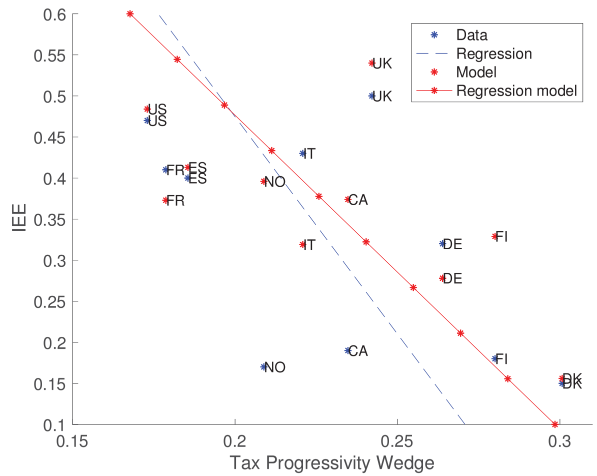
7.2 The role of the marriage market assumption

In this model, labor is the only production factor and investments in human capital of children is the only form of intergenerational transfers. Agents are not able to accumulate savings in the form of capital or make in-vivo transfers to their children. Consequently, comparison of the model's results with Holter's (2015) framework, which accounts for both human capital investments and one-time in-vivo transfers from parents to children might be misleading. To overcome this limitation and provide an objective assessment of the role of the marriage market in explaining cross-country differences in the intergenerational persistence of earnings, I construct an exact counterpart of the benchmark model, but without marital sorting. The counterpart model assumes an analogous human capital accumulation process and abstracts from the presence of savings in the economy. A household consists of a single agent who enters adult life at the age of 25 and retires at 65. An exogenous number of children arrive in the first period of adult life. The number of children per household is estimated as $\bar{n}/2 = 1$, where $\bar{n}$ is the average number of children per women in a benchmark model. Investments in the human capital of children are made in the 2nd-5th periods of the agent's life.

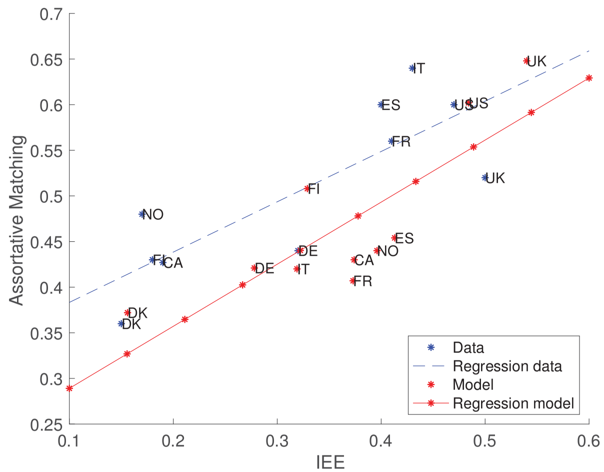
Figure 2: Model performance in explaining stylized facts. Taxes and education subsidies



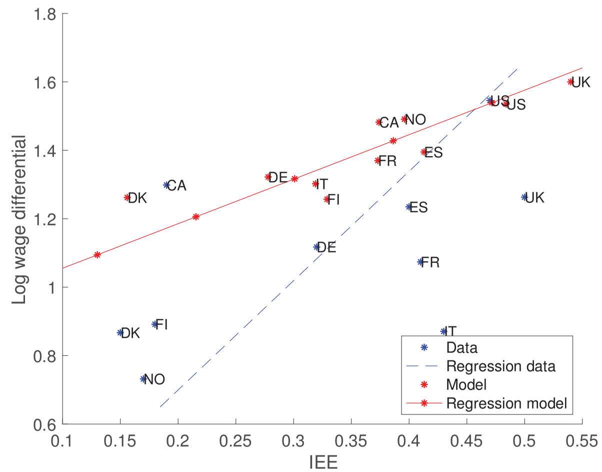
A: Tax level average vs. IEE



B: Tax progressivity wedge vs. IEE



C: Assortative matching vs. IEE



D: Log wage differential vs. IEE

The parameters including h_{min}, ϕ_0, ϕ_1, γ, b_y, σ_b, θ, σ_a, ρ_a are jointly calibrated so the model replicates key statistics of the U.S. economy. The calibrated parameters and model fit are presented in Appendix C, tables 11 and 12.

Given a calibrated model, I repeat same exercise as in the previous subsection by considering differences of taxes and education subsidies, as well as only taxes or education subsidies. The results and comparison with the benchmark model are presented in table 3. The sum

Table 3: Cross-country differences in public policies and IEE. Role of marriage market

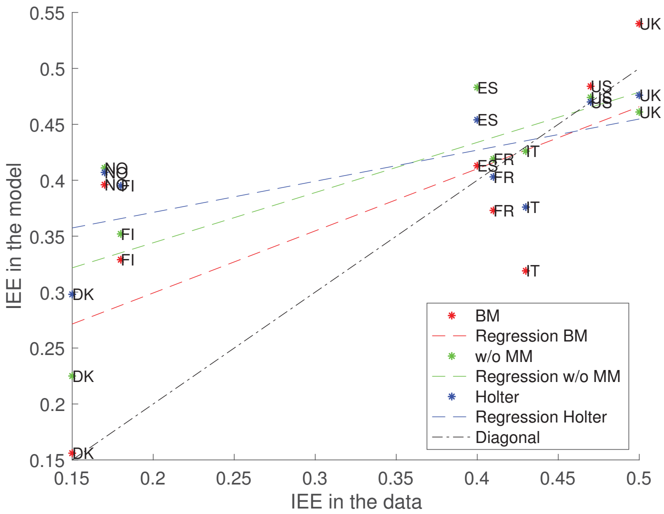
Country	**Data**	**Taxes & Education**			**Taxes**			**Education**		
		BM	**w/o MM**	**H**	**BM**	**w/o MM**	**H**	**BM**	**w/o MM**	**H**
Denmark	0.15	0.156	0.225	0.298	0.139	0.186	0.299	0.356	0.423	0.439
Norway	0.17	0.396	0.411	0.407	0.352	0.392	0.404	0.373	0.474	0.458
Finland	0.18	0.329	0.352	0.395	0.297	0.324	0.375	0.458	0.487	0.468
Canada	0.19	0.374	0.485	-	0.479	0.472	0.463	0.416	0.499	-
Sweden	0.27	-	-	-	0.31	0.382	0.382	-	-	-
Germany	0.32	0.278	0.372	-	0.297	0.384	0.384	0.391	0.461	-
Spain	0.4	0.413	0.483	0.454	0.472	0.481	0.481	0.408	0.478	0.439
France	0.41	0.373	0.419	0.403	0.449	0.443	0.443	0.379	0.475	0.432
Italy	0.43	0.319	0.426	0.376	0.419	0.438	0.438	0.335	0.486	0.425
U.S.	0.47	0.484	0.474	0.47	0.484	0.47	0.47	0.484	0.474	0.47
U.K.	0.5	0.54	0.461	0.476	0.469	0.467	0.467	0.543	0.491	0.477
SSE all	-	0.125	0.192	-	0.141	0.172	0.215	0.229	0.39	-
SSE H	-	0.089	0.102	0.131	0.141	0.172	0.215	0.173	0.275	0.252

of squared errors "SSE all" is calculated for all countries for which both taxation and education parameters are estimated in this paper, while "SSE H" are calculated for countries with both types of parameters estimated by Holter (2015). The benchmark model ("BM") demonstrates a superior fit versus the counterpart model without a marriage market ("w/o MM"). The sum of squared errors of model IEE predictions for all countries decreases by

35/18/41 %, if cross-country differences in both taxation and education policies, taxes only or education subsidies only are accounted for; see columns "BM" versus "w/o MM", line "SSE all". If only differences in education subsidies are considered, the model fit depreciates in the case of both frameworks.

Additionally, the benchmark model demonstrates superior performance compared to both the counterpart model without a marriage market and Holter's framework ("H") for the identical set of countries as in Holter (2015). However, the difference in the models' performance is minor. The sum of squared deviations of fitted versus actual values of IEE decreases by about 12.7/32.1 % if both policies are factored in, 18/34.4 % if taxes only, 37.1/31.3 % if education subsidies only are accounted for; line "SSE H", see also figure 3 with actual vs. fitted IEE values for different models. Consequently, consideration of a marriage market may amplify the impact of taxation and education policies on intergenerational earnings persistence and improve performance of an otherwise standard life-cycle dynastic model of human capital formation. On the one hand, the degree of assortative matching may have a direct impact on intergenerational persistence of earnings through weakening or strengthening correlations between fathers' and sons' earnings. On the other hand, when deciding on their children's education, parents consider not only labor market but also marriage market returns on human capital investments. More generous taxation and education subsidies decrease the income gap between the most and least productive individuals. Therefore, the benefits of marrying a relatively high productive partner decline and discourage parents from investing in their child's human capital and, consequently, contribute to further decreases in intergenerational earnings persistence.

Figure 3: Actual vs. model IEE. Taxes and education subsidies, countries as in Holter (2015)



7.3 Role of positive assortative matching

To evaluate the importance of positive assortative matching for explaining cross-country differences in intergenerational persistence of earnings, I compare the results in the benchmark model versus the counterpart model with random matching of agents ("RM"). This assumption is equivalent to the marital decision matrix i_m having all elements equal to 1, so that agents accept an offer from any candidate they meet. As table 4 demonstrates, the intergenerational earnings persistence predicted by the model drops dramatically for all countries. Countries with the highest intergenerational persistence of earnings, the U.S. and U.K., become similar to Denmark and Norway in a real economy, while for model Scandinavian countries, intergenerational earnings correlations fall below 10 %. These results demonstrate the high importance of positive assortative matching for explaining the observed levels of intergenerational earnings mobility in OECD countries.

Table 4: Impact of random matching on IEE

Country	**Data**	**Taxes & Education**	
		BM	**RM**
Denmark	0.15	0.156	0.039
Norway	0.17	0.396	0.094
Finland	0.18	0.329	0.067
Canada	0.19	0.374	0.192
Sweden	0.27	-	-
Germany	0.32	0.278	0.047
Spain	0.4	0.413	0.205
France	0.41	0.373	0.118
Italy	0.43	0.319	0.077
U.S.	0.47	0.484	0.168
U.K.	0.5	0.54	0.185

8 Conclusion

I develop a life-cycle dynastic model of marital sorting and human capital formation to study whether consideration of a marriage market together with public policies may improve model performance in explaining cross-country differences in intergenerational earnings persistence. I find that accounting for differences in taxation and education policies between the U.S. and 10 OECD countries replicates a positive relationship between the degree of assortative matching and intergenerational persistence of earnings. This demonstrates that cross-country differences in public policies and the degree of marital sorting are interconnected rather than separate factors in determining variations in intergenerational earnings elasticity. The model with marital sorting reduces the sum of squared errors of intergenerational earnings persistence predictions by nearly one third, as opposed to Holter's (2015) model, which does not consider a marriage market. This improvement may be partially driven by the simplifying assumption of an absence of inter vivo transfers and savings in the model. Nevertheless, the study shows that positive assortative matching is crucial to the model's ability to replicate reasonable levels of intergenerational correlation of earnings in OECD countries.

Future research may consider introduction of savings and the possibility of divorces and single parenthood into the economy for more realistic modelling of intergenerational transfers and family formation. Availability of country data on regional distribution of public education expenditures as in the case of Norway, analysed by Herrington (2015), could make approximation of education subsidies more precise. Additionally, this study assumes that cross-country differences in public policies are exogenous. Endogenizing taxes and education subsidies as an outcome of political processes or a social planner problem might be an interesting extension.

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Abstrakt

V reálných rozhodnutích o investování do lidského kapitálu dětí je rozhodnutí častěji činěno rodinami nežli jedním rodičem, jak se obvykle předpokládá v literatuře. Tento článek zahrnuje formování rodiny do jinak standardního dynastického modelu s akumulací lidského kapitálu. Studie zjišťuje, že započtení rozdílů ve zdanění a politikách vzdělávání mezi USA a 10 zeměmi OECD je postačující k replikování variability asortativního párování a jeho pozitivní korelace s persistencí mezigeneračních výdělků napříč zeměmi. Pozitivní asortativní párování je klíčové pro schopnost modelu generovat realistické úrovně korelace příjmů napříč generacemi, které jsou pozorovány v datech.

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