

# On the Origin and Causes of Long-Run Growth

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# Motivation

- What can explain the long period of stagnation followed by rapid growth?
- Both Neoclassical and Endogenous growth (AK models) theories were developed to better understand the long run growth process
- Numerous research ideas attempting to understand long-run growth
  - Physical capital by itself leads to diminishing returns (rather quickly)
  - Clearly human capital plays an important role
  - Models of innovation also developed to understand the growth process



Figure 1: GDP per capita in a select few countries: 1500-2000

- Vast literature emphasizes the 'proximate' and 'fundamental' causes
  - Physical Capital: Solow (1956), Cass (1965), Koopmans (1965)
  - Human Capital: Lucas (1988), Becker et. al. (1990), Mankiw et. al. (2002)
  - Innovation: Romer (1986), Grossman and Helpman (1991), Aghion and Howitt (1992)
  - Institutions: North (1990), Hall and Jones (1999), Acemoglu et. al. (2001)
  - Finance: King and Levine (1993)
  - Initial Conditions: Engerman and Sokoloff (1997)
  - Human Capital: Glaeser et. al. (2004), Galor (2005)
  - Geography: Sachs (2001)

- Need a framework to assess quantitatively the ability of a model to generate long run growth
  - Very few quantitative approaches in general (Hansen and Prescott, 2002 is an exception)
  - These quantitative approaches rely on exogenous TFP changes
- In this paper, we will examine the ability of a model of human capital appropriately modified (and physical capital) to understand growth over the long run.

## The Need for a Modified Approach

- Not easy to empirically implement/assess these models/mechanisms. For instance, in the seminal work by Lucas (1988)
  - Assumption of linearity has been questioned
    - \* "The conclusion has to be that [the constant returns] version of the endogenous-growth model is very un-robust. It cannot survive without exactly constant returns to capital. But you would have to believe in the tooth fairy to expect that kind of luck." Solow (1994)
  - Difficult to identify aggregate spillover; measures typically small - Acemoglu and Angrist (2000)
  - No empirical counterparts to measure human capital
  - Cannot generate protracted transitions (indeed converges instantly to the balanced growth path)

- Becker, Murphy and Tamura (1990)
  - Assume returns to human capital increases as stock of human capital rises
  - Multiple steady states
    - \* Rely on luck to generate the transition from 'bad' SS to 'good' SS
  - Transitions rather quick

# Our Approach

- Three modifications to the standard Lucas (1988) model
  - Finite lifetimes
  - Diminishing returns to human capital accumulation
  - Parental spillover (human capital of the parent is an input in the production of human capital for the child)
- These features help take the model to the data
  - We use observations on schooling, earning profile and other moments to pin down the deep parameters



# Roadmap

- Present a very simple model - income maximization
  - Illustrates key forces at work - parental spillover
  - Exogenous forces can help rationalize the data - changes in real interest rates and lifespan
- Move to a more realistic model - endogenous fertility
  - Generates long transitions
- Argue that micro evidence lends support to macro calibration

## Ben-Porath (1967)

Maximize Lifetime Income

$$\max \int_6^R e^{-r(a-6)} [wh(a)(1 - n(a)) - x(a)] da$$

subject to

$$\dot{h}(a) = z_h [n(a)h(a)]^{\gamma_1} x(a)^{\gamma_2} - \delta_h h(a), \quad a \in [6, R),$$

and

$$h(6) = h_0$$

- Can rationalize schooling and earnings profile
- But cannot generation long transition paths

## Simple Model with Parental Spillover

“The most valuable of all capital is that invested in human beings; and of that capital the most precious part is the result of the care and influence of the mother” Alfred Marshall, Principles of Economics, Vol. 1, p. 592

- Parent’s human capital affects two things
  - Initial stock of human capital (parental investments in early childhood)
  - Effective ability
- For now, treat parental spillover as an externality
- Goal is to simulate the transition path from an initial condition

## Adding a Parental Spillover

$$\max \int_6^R e^{-r(a-6)} [wh(a)(1 - n(a)) - x(a)] da$$

subject to

$$\dot{h}(a) = z_h [n(a)h(a)]^{\gamma_1} x(a)^{\gamma_2} \underbrace{h_P^{\gamma_3}} - \delta_h h(a), \quad a \in [6, R),$$

and

$$h(6) = \underbrace{h_P^{\gamma_4}}$$

- Define schooling  $s$  as the time period for which  $n = 1$

- Optimal  $s$  satisfies  $F(s) = \frac{h_P^{\gamma_4(1-\gamma_1-\gamma_2)}}{z_h h_P^{\gamma_3}}, F'(s) < 0,$

- The human capital level at the end of the schooling  $h(s + 6) \propto h_P^{\frac{\gamma_3}{1-\gamma_1-\gamma_2}}$

- Endogenous growth obtains when  $\gamma_4 = 1$  and  $\gamma_1 + \gamma_2 + \gamma_3 = 1$
- Lucas uses a framework such to justify his celebrated equation (13) - the AK formulation

”It is a digression I will not pursue, but it would take some work to go from a human capital technology of the form (13), applied to each finite-lived individual (as in Rosen’s theory), to this same technology applied to an entire infinitely-lived typical household or family. To obtain (13) for a family, one needs to assume both that each individual’s capital follows this equation and that the initial level each new member begins with is proportional to (not equal to!) the level already attained by older members of the family.”

Lucas (1988)

## Aggregation

Let  $\bar{h}$  be the average (per person) level of human capital. Then

$$\bar{h} = \int_{6+s}^R h(a)(1 - n(a))\phi_t(a)da.$$

- Calibration

- $F(k, h) = zk^\theta h^{1-\theta}$
- $\theta = 0.33$
- $\delta_k = 0.075$
- circa 2000:  $R = 64$  and  $T = 78.8$

Step 1 involves calibrating 3 parameters,  $z_h$ ,  $\gamma_1$ , and  $\gamma_2$ . The moments (circa 2000) used to pin down these parameters are:

1. Wage rate at age 55/wage rate at age 25 of 1.94
2. Years of schooling of 12.45
3. Schooling expenditures as a fraction of GDP of 4.2

Parameter	$z_h$	$\gamma_1$	$\gamma_2$
Value	0.19	0.61	0.29

Left with 2 (important) parameters  $\gamma_3$  and  $\gamma_4$

1. GDP per capita in 2000/GDP per capita in 1500 = 26
2. Years of schooling in 1500 = 0.2

Assume that  $r = 10\%$  and  $T = 40$  circa 1500

Parameter	$\gamma_3$	$\gamma_4$
Value	0.06	0.77

- Need to calculate the transitional dynamics from initial stock of human capital as it converges to SS
  - Life expectancy changing from 40 to 80 years
    - \* Data from Maddison
  - Real interest rates falling from 10% to 5%
    - \* Homer and Sylla (2005)
    - \* Clark (2005)
    - \* Maddison's data indicates a large increase in  $K/Y$



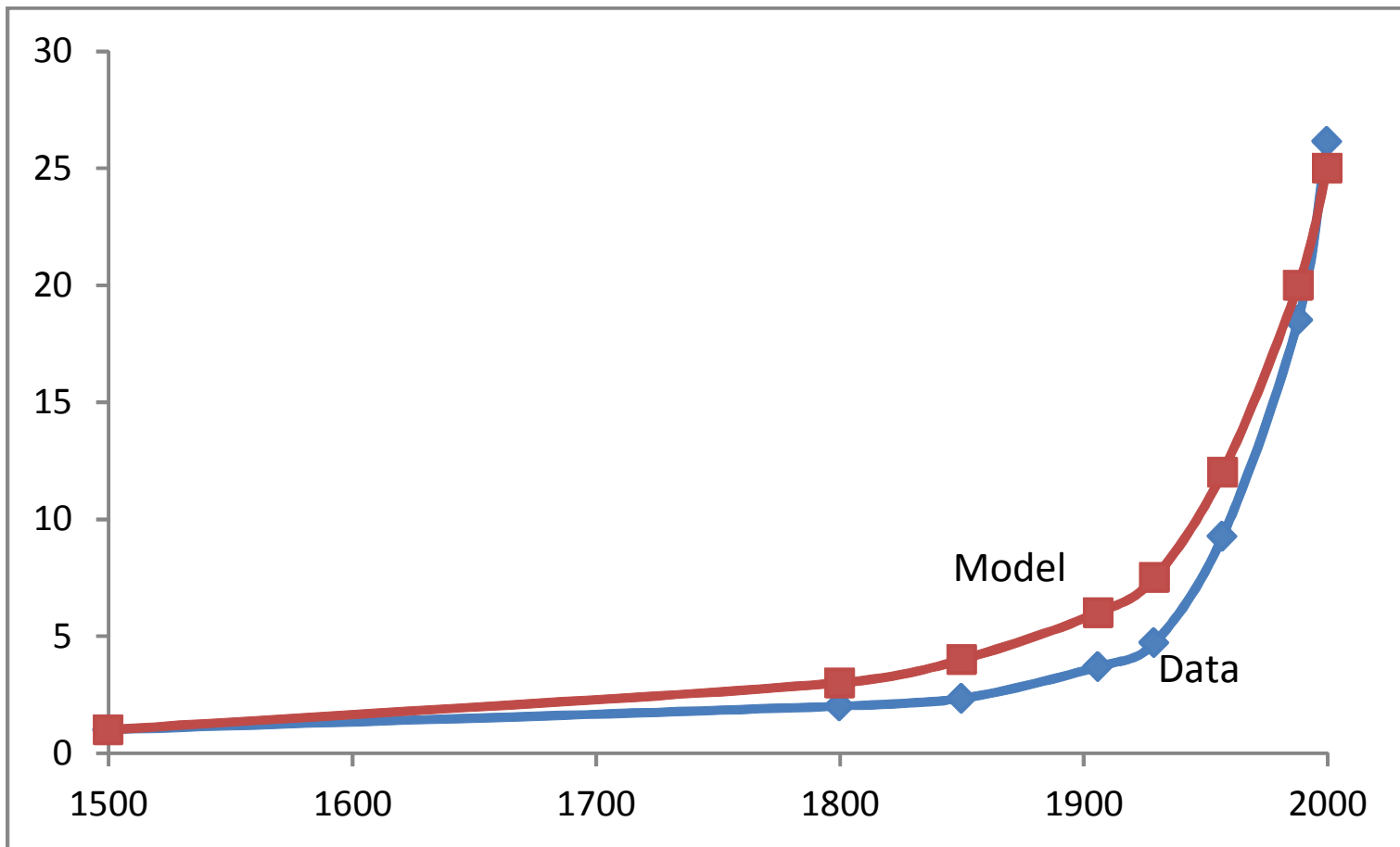


Figure 2: GDP per capita between 1500 and 2000

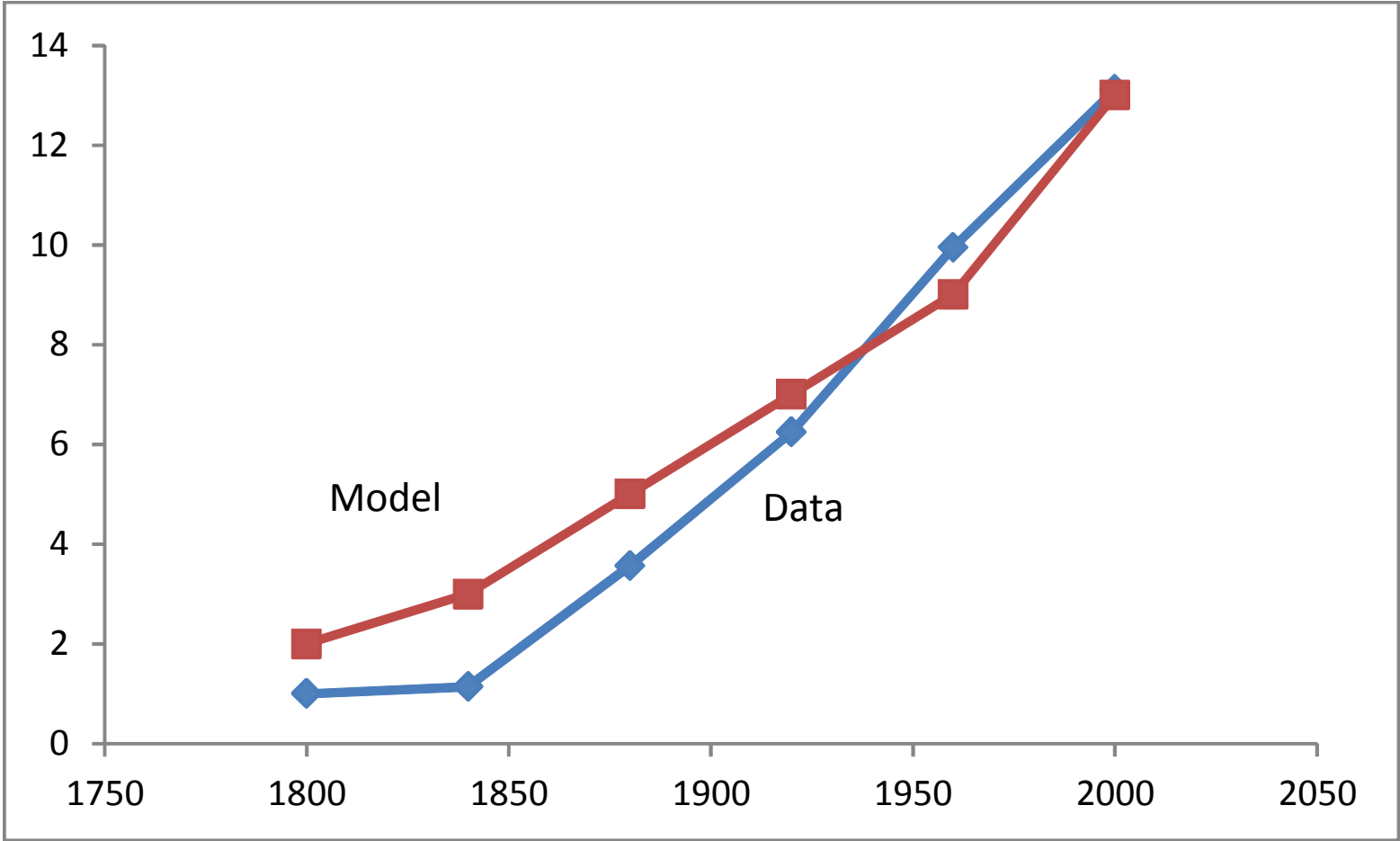


Figure 3: Years of Schooling

## Understanding the Transitional Dynamics

- Fall in real interest rates (from 1500 to 1800) important in generating take off from stagnation.
  - Slow fall in  $r$  implies slow rise in GDP
- Increase in life expectancy important after 1800
- Model can generate the pattern of long run growth
- More complete theory calls for a framework that can generate fall in real interest rates

# Dynastic Model

- Two Goals: Internalize parental externality & rationalize fall in  $r$
- The demographic transition and industrial revolution have long been thought to be closely related
- Models of endogenous fertility can accomplish this
  - Fertility rates (affect effective discount factors) and interest rates are related
  - Issue: Fertility rates did not fall until 1750 but years of schooling started to rise from 1500
    - \* Need to be consistent with this

## Economic Environment

- A representative household formed at age  $I$  (age = age of parent)
- At age  $B$ ,  $f$  children are born
- Household retires at age  $R$ , Dies at  $T$
- Parents imperfectly altruistic (Barro-Becker type preferences)
  - Place weight  $\alpha_0 f^{\alpha_1}$  on children's utility
  - Invest in their human capital and leave bequests
- Lifespan  $T$  exogenous

Household chooses  $\{c_i\}_{i=I}^T, b^k, f, \{n_i, x_i\}_{i=I}^R, \{c_i^k, n_i^k, x_i^k\}_{i=B}^{B+I}$  to solve

$$V(h_I, b, h^p) = \max \left\{ \sum_{i=I}^T \beta^{i-I} u(c_i) + b(f) \sum_{i=B}^{B+I} \beta^{i-I} u(c_i^k) + b(f) \beta^B V(h_I^k, b^k, h_{B+I}) \right\}$$

subject to

$$\begin{aligned} & \sum_{i=I}^T \frac{c_i}{(1+r)^{i-1}} + f \sum_{i=B}^{B+I} \frac{c_i^k}{(1+r)^{i-1}} + f \frac{b^k}{(1+r)^B} \\ = & \underbrace{\sum_{i=I}^R w \frac{h_i(1-n_i) - x_i}{(1+r)^{i-1}}}_{\text{Lifetime Earnings}} + \underbrace{f \sum_{i=B}^{B+I} w \frac{h_i^k(1-n_i^k) - x_i^k}{(1+r)^{i-1}}}_{\text{Child Labor Earnings}} + b(1+r) \end{aligned}$$

and  $b^k \geq 0$ . If bequests are in the interior, Euler equation for bequests is given by

$$\frac{f^{1-\alpha_1}}{\alpha_0} = [\beta(1+r)]^B \left( \frac{c_I^k}{c_I^P} \right)^\sigma .$$

- If bequests are positive, investments in human capital are efficient.
- In a SS, the real interest rates and fertility rates are related one for one.
  - Fertility rates effectively appear in the discount factor
- Start off at an initial human capital level and hope that
  1. Model generates a fall in  $f$  starting around 1800
  2. GDP begins to take off around that time
  3. Schooling rises

## Calibration of Dynastic Model

- Set  $\sigma = 3$ ,  $\beta = 0.96$
- Use same 5 moments as earlier to calibrate  $z_h, \gamma_1, \gamma_2, \gamma_3, \gamma_4$
- Need also to calibrate  $\alpha_0, \alpha_1, h_0$ 
  1. Intergenerational transfers/GDP in 2000 = 4%
  2. Fertility rate in 2000 = 2
  3. Fertility rate in 1500 = 7

Exact Match



Parameter	$z_h$	$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\alpha_0$	$\alpha_1$	$h_0$
Value	0.1724	0.61	0.29	0.06	0.82	0.72	0.65	1.2

- We are now in a position to simulate the model's transition path from 1500 to 2000.
- The only exogenous change is the change in life expectancy from 40 to 80
- Initial human capital needs to be low in order to match a very low GDP per capita in 1500

- In 1500, bequests are zero. Parents are poor enough that they would like to borrow against their childrens' income
  - They underinvest in childrens' human capital
- Over the course of time, human capital stocks rise and the marginal return to investing in human capital falls
- At some point, dynasties get rich enough that they bequeath a positive amount
- Human capital stocks and GDP rise rather rapidly from this point
- Able to generate long protracted transitions as well as take-off.

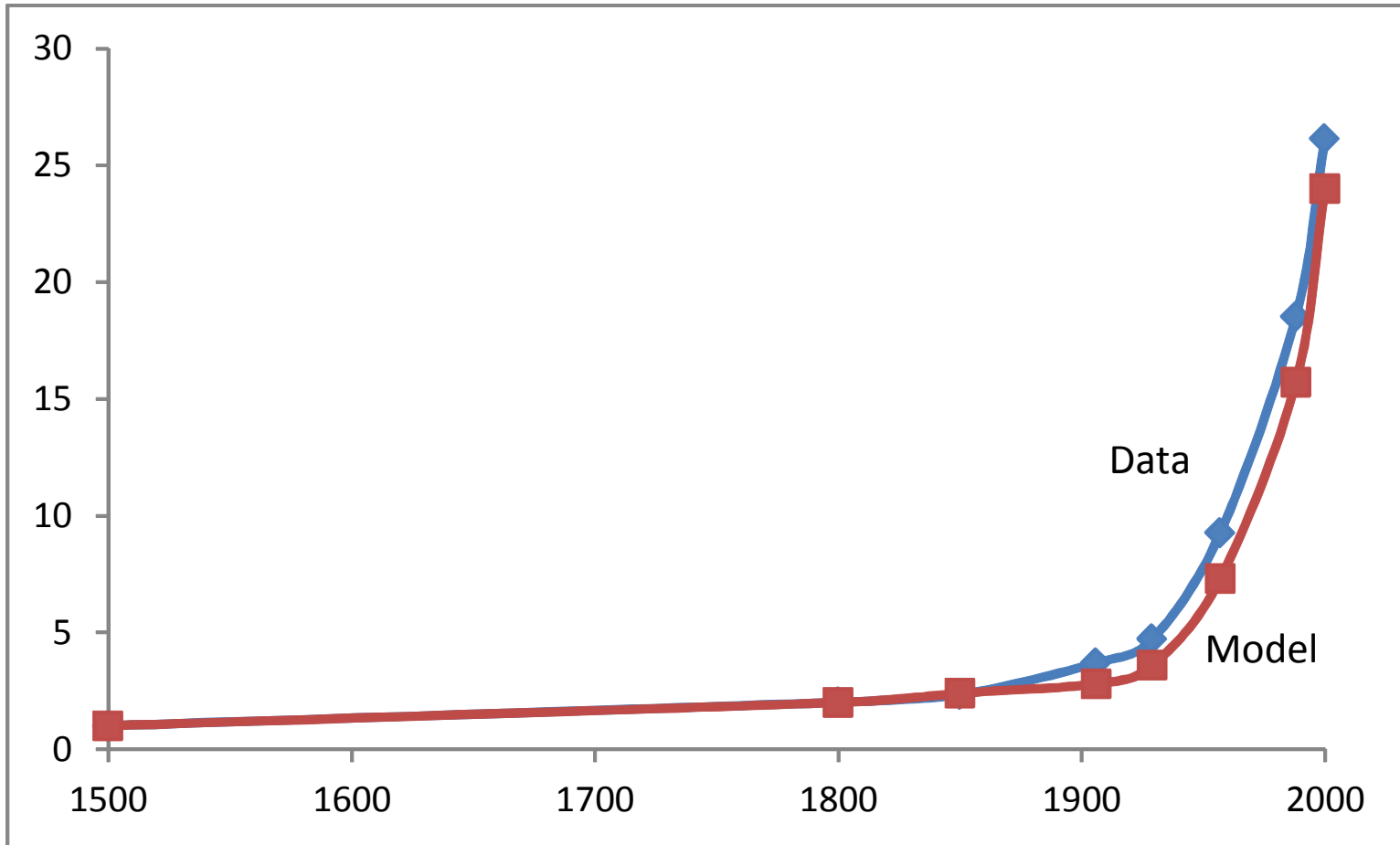


Figure 4: GDP per capita: Endogenous Fertility Model

# The Fertility Transition

- Prior to 1800, bequest constraint binds. Not a strong link between real interest rates and fertility rates
- After 1800, fertility declines rapidly. Has implications at the micro level
  - Before 1800 fertility and income positively related. Children are costly and the bequest constraint binds - Wealth Effect
  - After 1800, parents spend more on their children and fertility and income in the cross-section are negatively related - Substitution Effect
- This change in the cross-sectional relationship over time between fertility and income has been well documented
  - Clark (2005) and Galor (2005)

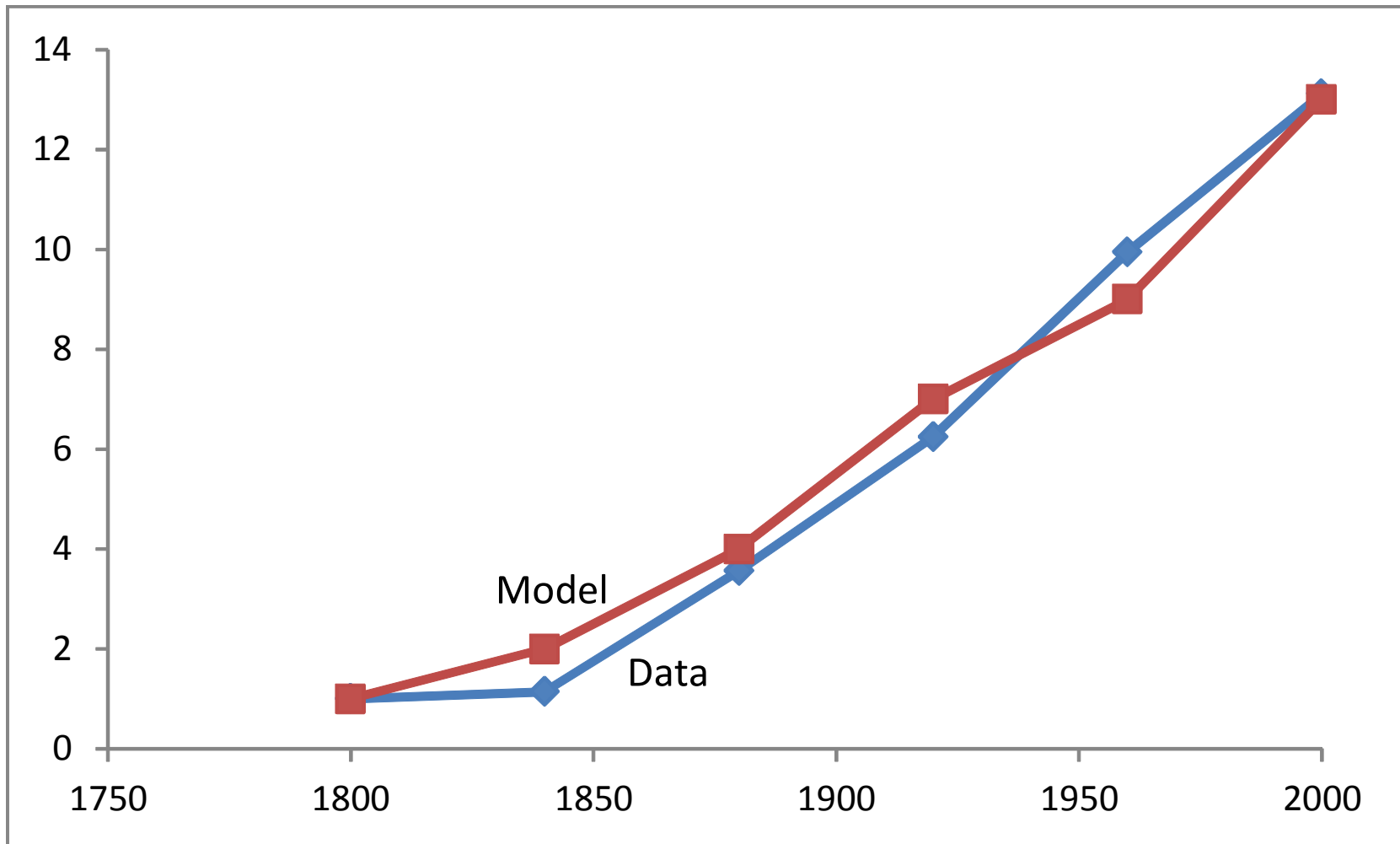


Figure 5: Years of Schooling: Endogenous Fertility Model

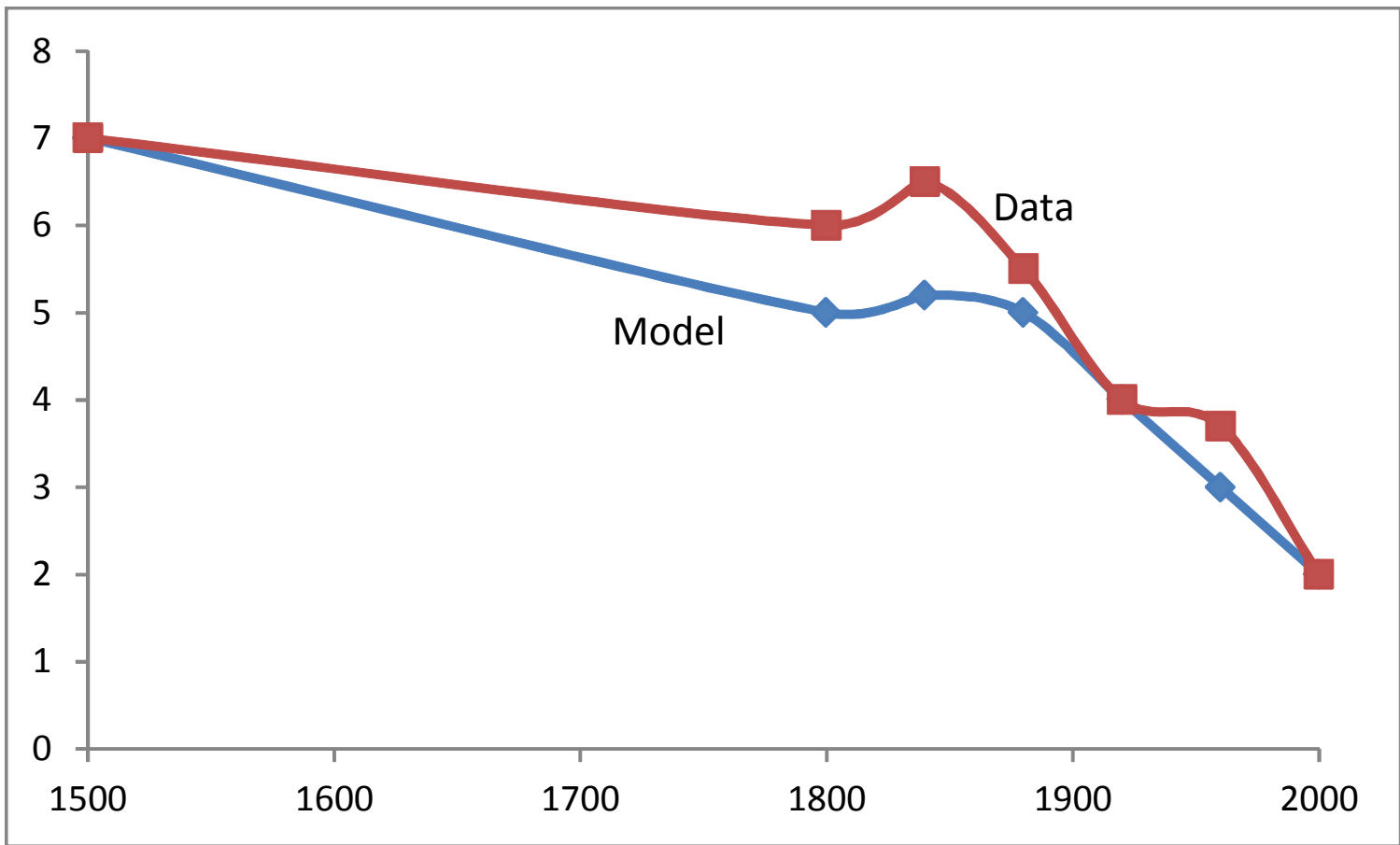


Figure 6: Total fertility Rates: Model versus Data

## The Effect of Initial Conditions

- A large body of work examines the effect of initial conditions on long run development paths
  - Glaseser et. al. (2004) argue human capital is an important driving force
  - Others have argued that geography/institutions plays a central role
- Two recent papers argue that proxies for human capital circa 1500 are strongly related to eventual development
- Interesting to examine the impact of differential initial stocks of human capital on development

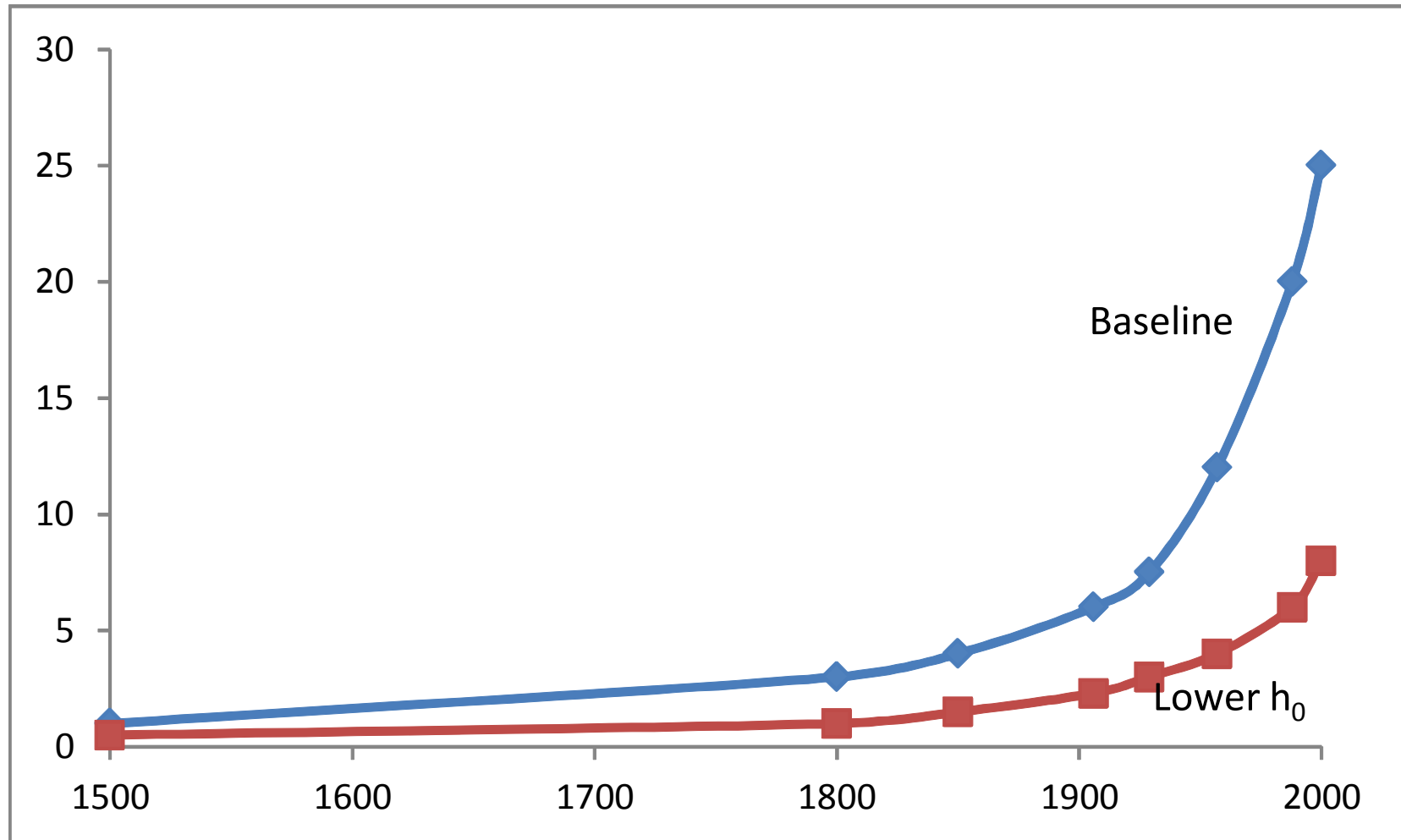


Figure 7: Impact of lower initial human capital on development paths



## Are the parental spillover values reasonable?

- One of the virtues of this model lies in the ability to check the empirical validity of some of the key parameters
- Recall that  $\gamma_1 + \gamma_2 = 0.9$  ( $\frac{1}{1-\gamma_1-\gamma_2} = 10$ )
- What do different values of  $\gamma_3$  and  $\gamma_4$  imply for micro evidence?

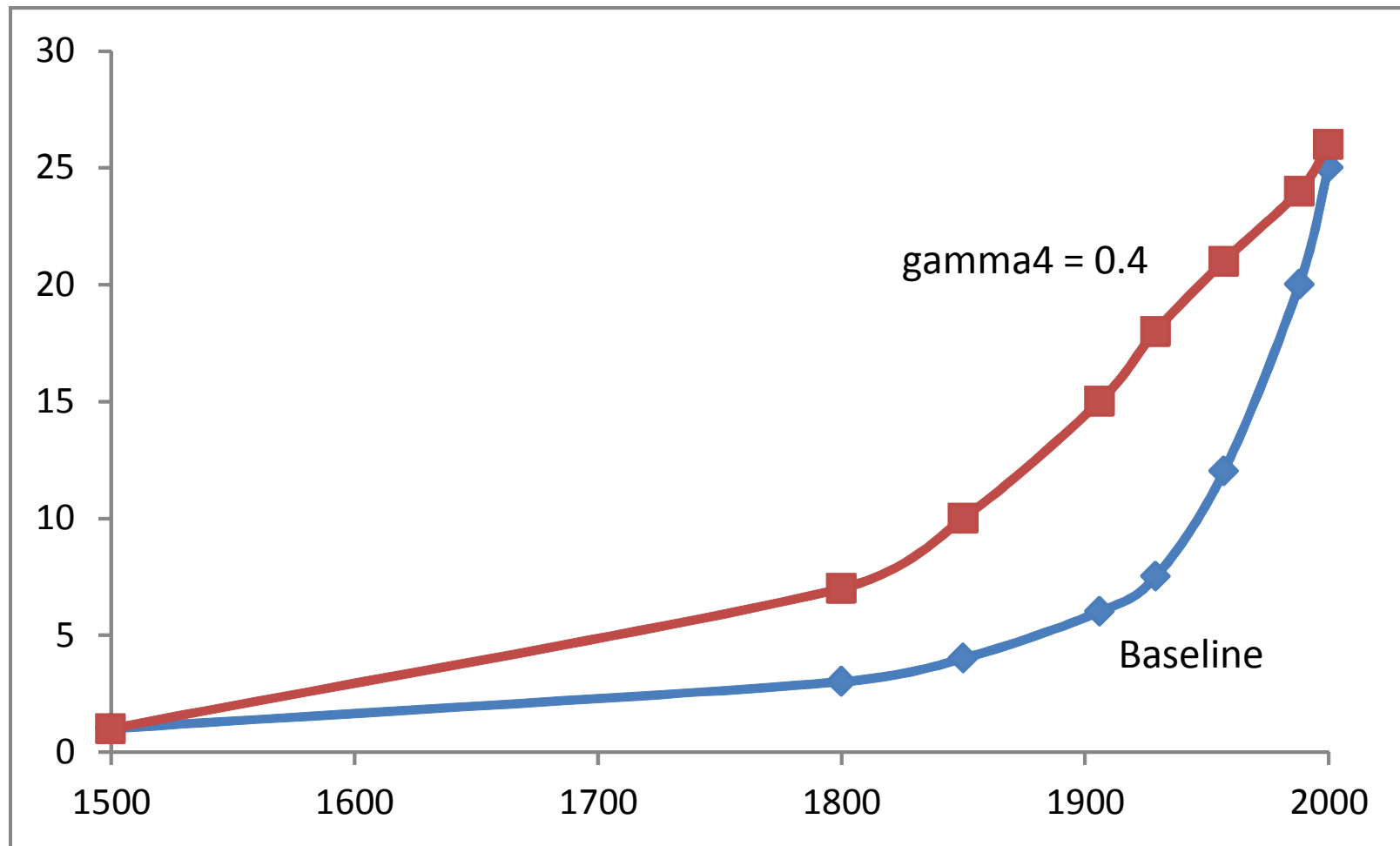


Figure 8: Effect of Lowering the Parental Spillover Term on the Transition Path

- Consider two individuals with the same schooling level - one with a higher parental human capital.

$$\frac{z_{h_1} h_{P_1}^{\gamma_3}}{h_{P_1}^{\gamma_4/10}} = \frac{z_{h_2} h_{P_2}^{\gamma_3}}{h_{P_2}^{\gamma_4/10}}$$

$$\text{Effective ability} = z_h h_P^{\gamma_3}$$

$$\text{Effective Initial human capital} = h_P^{\gamma_4/10}$$

Proposition: Conditional on schooling, earnings proportional to  $h_P^{\gamma_4}$

Suggests the following regression

$$\log w_i = \alpha_0 + \alpha_1 E_i + \alpha_2 E_i^2 + \alpha_3 S_i + \alpha_4 S_i^p + \alpha_5 S_i \times E_i + \alpha_6 S_i^p \times E_i + \beta X_i + \epsilon_i$$

## Two key predictions

1. Lifetime earnings differentials between these individuals would shed light on the value of  $\gamma_4$  ( $\alpha_4 > 0$ )
  - Estimates from SSA data indicate that extra year of parental schooling is associated with 1.5% higher earnings for the child, holding fixed the schooling of the child.
2. Conditional on schooling levels, parental human capital should not affect the steepness of the age earnings profiles ( $\alpha_6 = 0$ )
  - Altonji and Dunn (1990) show that schooling level of the parents have no effect on return to schooling
  - Also data from SSA confirm this prediction

## Estimating $\gamma_4$

- An extra year of parental schooling is associated with 1.5% higher wages for the child, *conditional* on the schooling of the child.
- Divide data into lifetime earnings deciles for those with 12 years of schooling
- For each of these deciles, we calculate the mean maternal schooling level. This gives us an estimate of  $h_p = \exp(s_p)$
- We then vary  $z_h$  so that the optimal schooling level is precisely 12
- We ask what value of  $\gamma_4$  allows us to obtain a 1.5% estimate
- The estimate of  $\gamma_4$  is 0.79

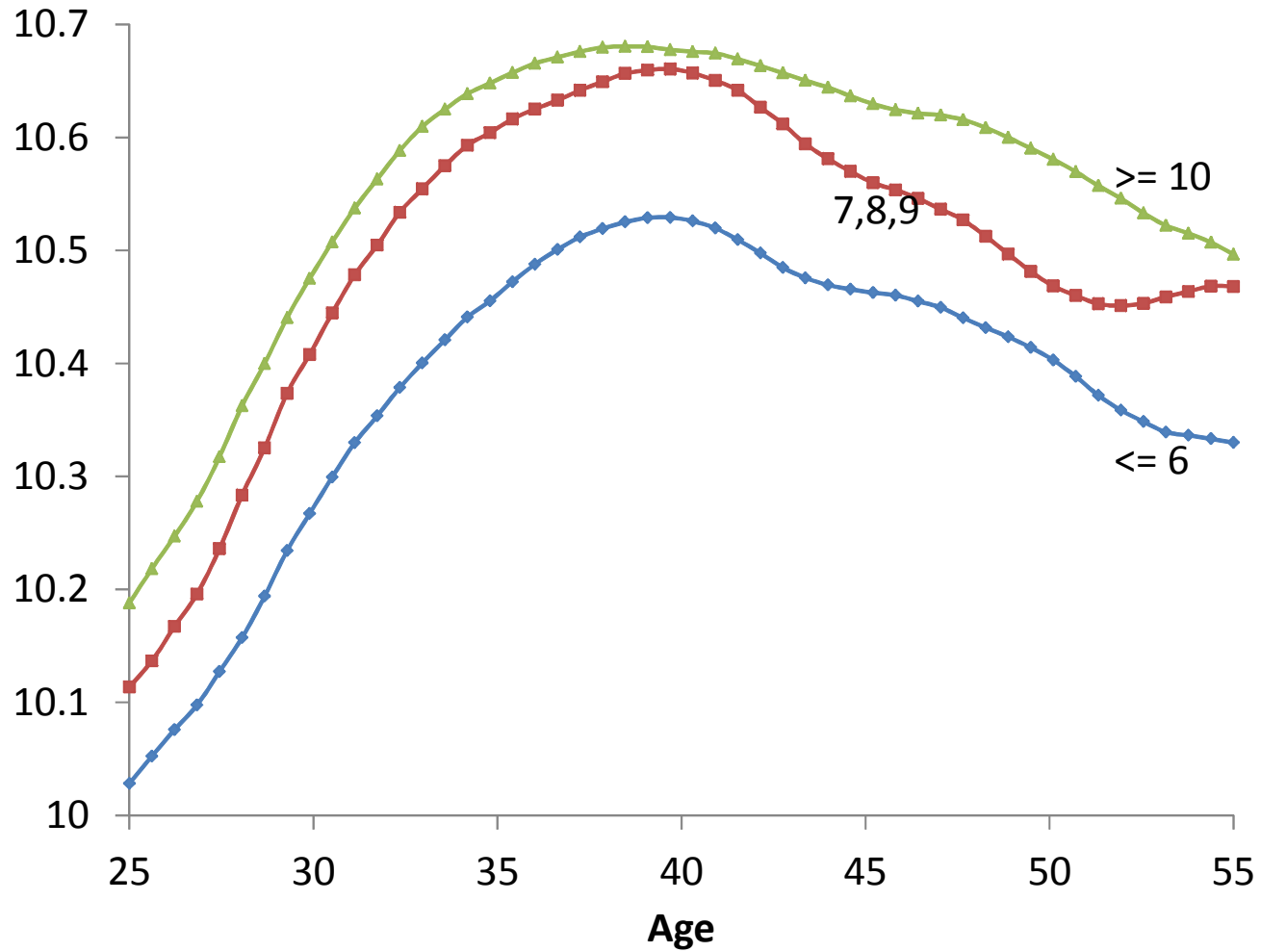


Figure 9: Earnings Profiles of High School Graduates by Mother's Schooling Level: 1931-1941 Birth Cohort

## Estimating $\gamma_3$

- Look at data on individuals with 12 and 16 years of schooling
  - Those with 12 years of schooling had mothers with 9.35 years of schooling
  - Those with 16 years of schooling had mothers with 11 years of schooling
- The difference in log earnings between college and high school grad at age 45 is 0.3
- Given the estimate of  $\gamma_4$  above, we ask what value of  $\gamma_3$  can precisely rationalize this earnings differential. The estimate of  $\gamma_3$  is 0.06

## Other attempts to estimate parental spillovers

- Black, Devereux and Salvanes (2005): No causal effect of parents education on childrens' education (IV estimate is zero)
  - Use compulsory schooling laws to argue that parents who acquired more schooling than they had planned on (due to a shift in government policy) did not have children with appreciably more schooling.
  - Consider a parent who is forced to acquire more schooling than he optimally chooses. The effect is to cut back human capital accumulation on the job.
  - Even though this parent had more years of schooling, he will possess the same human capital level at age 25 (the median age of child birth).
- Bottomline: The parent transmits human capital across generations and not schooling



## Conclusion

- Modeling parental spillovers in human capital helps generate a long transition from stagnation to growth
- Can simultaneously account for evolution of schooling as well as fertility
- Initial conditions can have long lasting effects on development paths