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On aggregating human capital across heterogeneous cohorts☆

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HIGHLIGHTS

- Mincerian log-linear relation between human capital, years of schooling, experience.
- We assume that the relation holds at micro level and study it upon aggregation.
- The exact relation is lost upon aggregation, except under implausible demographics.
- Numerically, the macro-Mincer equation is a good approximation of the true relation.
- We allow heterogeneity in years of schooling, retirement age and demographics.

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ABSTRACT

This paper studies the question: Can the microeconomic Mincerian (log-linear) functional relationship between human capital, years of schooling and work experience be recovered in some similar form at the macroeconomic level? A large macroeconomic literature assumes so, warranting that the question is of interest. We first examine the question at a theoretical level and find that except under very special assumptions, the answer is in the negative. On the other hand, we also show numerically that a macro-Mincer relationship can nevertheless be perceived as a quantitatively reasonable approximation of the theoretically derived "true" relationship, at least if the observed heterogeneity comes only from differences in the number of years of schooling, retirement age, or demographic survival laws.

1. Introduction

The Mincerian equation where the logarithm of individual wages (or human capital stocks) is explained by years of schooling and work experience (henceforth the *micro-Mincer* equation) is a cornerstone of a large body of microeconomic literature (Mincer, 1974; Heckman et al., 2003). Numerous studies have then carried it forward to country-level data on aggregate human capital stocks, average years of schooling, and average work experience in the population (e.g., Klenow and Rodríguez-Clare, 1997, Krueger and Lindahl, 2001, Bloom et al., 2004). The aim of the present paper is to examine whether such simple aggregation is warranted. On the one hand, we formulate the necessary and sufficient conditions admitting the microeconomic Mincerian (log-linear) functional relationship to be theoretically recovered in some similar form at the macroeconomic level. On the other hand, since we find that the necessary conditions are very restrictive, we also add a quantitative edge to our analytical results. Based on a numerical study we evaluate that the macro-Mincer relationship can nevertheless be perceived as, to a large extent, a quantitatively reasonable approximation of the theoretically derived, more complex aggregate relationship.

At the theoretical level the standard micro–macro analogy has already been shown to rest on the following questionable simplifying assumptions:

- the macro-Mincer approach requires perfect substitutability between unskilled and skilled labor (Pandey, 2008; Jones, 2014a,b),

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- it assumes that each individual's skill level can be summarized by a single number and thus there is no heterogeneity in tasks (e.g., Jones, 2014b),
- it neglects the fact that maintaining a constant aggregate level of human capital in the society across time requires replacement investment because human capital is embodied in people whose lifetimes are finite (Growiec, 2010).

Violation of any of the above assumptions has been shown to lead to departures from the baseline macro-Mincer relationship between the aggregate human capital stock and average years of schooling and work experience, even if the micro-Mincer relationship holds perfectly at the individual level.

The current paper concentrates on the last of the above points. Thus, our analysis maintains the simplifying assumption that skill levels are perfectly substitutable, there is no intra-cohort heterogeneity of tasks or skills, and returns to schooling and experience are equal across countries. We only allow for heterogeneity in individuals' human capital levels following from the fact that people are born at different times and gradually accumulate human capital across their lives. By choosing such a restrictive framework, we isolate the effects coming from the heterogeneity of human capital due to demographics alone.

The contribution of the current paper to the literature is twofold. First, having clarified the outstanding problems related to the definitions of the aggregate human capital stock, aggregate years of schooling, and aggregate work experience under heterogeneity across population cohorts, we carry out a theoretical study leading to the conclusion that even if the micro-Mincer functional relationship holds exactly in a cross-section of individuals, the macro-Mincer (log-linear) equation generally does not. The only exceptions to this rule which we are able to identify are: (a) cases *inconsistent with heterogeneity*, insofar they require all aggregated individuals to have equal human capital stocks; (b) under the scenario where individuals first attend school full time and then work full time (and there are positive returns from work experience), the macro-Mincer equation can be recovered in the unique case where the demographic survival law has the "perpetual youth" property (Blanchard, 1985), which is empirically implausible. Under the scenario where people also retire at a certain age (and there are positive returns from work experience), the macro-Mincer equation cannot be recovered under any admissible survival law. For the cases where the macro-Mincer equation does not hold, we derive the true aggregate relationships.

Second, based on a numerical Monte Carlo study of the general theoretical model we find that, although theoretically misspecified, the macro-Mincer equation can nevertheless be perceived as an empirically reasonable approximation of the theoretically derived "true" relationship between the aggregate human capital stock, average years of schooling, and average work experience. We conclude that distortions to the log-linear shape of the macro-Mincer relationship caused by aggregating human capital across heterogeneous cohorts are quantitatively minor, at least under standard calibrations. Moreover, we also confirm numerically that average social returns to schooling are typically correctly identified with private returns (net of human capital depreciation).

The remainder of the article is structured as follows. In Section 2, we lay out the framework and discuss our theoretical results. We begin by discussing three particularly tractable special cases and then move on to our most general theoretical result. Section 3 complements this analysis with a numerical study. We begin with a presentation of the design of our Monte Carlo exercise and then present its results. Section 4 concludes. Proofs of propositions, further details and various extensions have been relegated to Appendices A–D.

2. Aggregation of human capital across population cohorts

2.1. Framework

We are concerned with human capital as a production factor. We consider human capital as a one-dimensional stock of productive skills embodied in an individual and accumulated through schooling and on-the-job learning. Our main focus is on productivity of this stock and not on its remuneration – wages – under different market forms.

We denote the current calendar time as t, and a person's age as τ. A person who is τ years old in year t must have thus been born at $t-\tau$. At time t, there is a continuum of mass $N(t)$ of individuals. We make the following assumption.

Assumption 1. Human capital of an individual τ years old, born at time j, is accumulated using a *linear* production function:

$$\frac{\partial}{\partial \tau} h(j,\tau) = [\lambda \ell_h(j,\tau) + \mu \ell_Y(j,\tau)] h(j,\tau), \tag{1}$$

where $\lambda \geq 0$ denotes the unit productivity of schooling, and $\mu \geq 0$ denotes the unit productivity of on-the-job learning (experience accumulation). $\ell_h(j,\tau) \in [0,1]$ is the fraction of time spent by an individual born at j and aged τ on formal education, whereas $\ell_Y(j,\tau) \in [0,1]$ is the fraction of time spent at work. We assume $\ell_h(j,\tau) + \ell_Y(j,\tau) \leq 1$ for all $j, \tau \geq 0$, and take $h(j,0) \equiv h_0 > 0$.

Even though the current framework singles out the time spent on education and work only, it can easily accommodate other uses of time, such as leisure or childrearing. We thus also allow for retirement. We say that these alternative possibilities are exercised when $\ell_h(j,\tau) + \ell_Y(j,\tau) < 1$.[1]

Integrating Eq. (1) with respect to the individual's age yields the formula for the human capital stock of an individual born at $t-\tau$, aged τ:

$$h(t-\tau,\tau) = h_0 \exp\left[\lambda \underbrace{\int_0^\tau \ell_h(t-\tau,s)ds}_{\text{years of schooling}} + \mu \underbrace{\int_0^\tau \ell_Y(t-\tau,s)ds}_{\text{work experience}}\right]. \tag{2}$$

This is directly the micro-Mincer equation, signifying the log-linear relationship between the individuals' human capital and their cumulative stocks of education and work experience. The quadratic experience term, typically also included in Mincerian equations (cf. Heckman et al., 2003), does not appear here because in Eq. (1) we have assumed human capital accumulation to be linear and not concave in work experience.[2]

Assumption 2. At every age $\tau \geq 0$, the individual may either survive or die. The unconditional survival probability is denoted by $m(\tau)$, with $m(0) = 1$, $\lim_{\tau\to\infty} m(\tau) = 0$ and with $m(\tau)$ weakly decreasing in its whole domain. The survival probability does not depend on calendar time t.

[1] The current framework can be also straightforwardly generalized to allow for (exponential) human capital depreciation, without altering any of the qualitative results. Please consult Appendix B.

[2] Although there exist models providing microfoundations for the quadratic experience term in Mincerian equations, Hamlen and Hamlen (2012) claim that it is actually inconsistent with the usual assumptions of utility maximization. These authors argue that other functional forms should be used instead.