Insights from Structural Models of Human Capital Formation: measurement error and predictive validity

Orazio P. Attanasio

UCL, EDePo@IFS & NBER

EDePo @ IFS
Evaluation of Development Policies at the Institute for Fiscal Studies

ECD and Nutrition Measurement during the first 1000 days
World Bank - February 4th 2015

Outline

Introduction

'OK', I said,'You win. Its a good theory...'
Randall smiled wryly: 'I don't like it myself. I was just trying it out. It fits the facts as far as I know them. Which is not far.'
'We don' t know enough to even start theorizing'
Raymond Chandler, Farewell, My Lovely

- Theory needs measurement.

Introduction

- Theory needs measurement.
- Measurement tools need to be designed to address the needs of theory.
  - Example: Keynesian model and development of National Income and Product Account Statistics.

Introduction

- Theory needs measurement.
- Measurement tools need to be designed to address the needs of theory.
  - Example: Keynesian model and development of National Income and Product Account Statistics.
- Measurement error is pervasive:
  - Perfect measures do not exist.
- Valid inference need to recognise this and explicitly model the presence of measurement error.

Introduction

- Theory needs measurement.
- Measurement tools need to be designed to address the needs of theory.
  - Example: Keynesian model and development of National Income and Product Account Statistics.
- Measurement error is pervasive:
  - Perfect measures do not exist.
- Valid inference need to recognise this and explicitly model the presence of measurement error.
- 'Are Two Cheap, Noisy Measures Better Than One Expensive, Accurate One?'
  - Browning and Crossley (AER, 2009)

Introduction

- The intuition for several independent measures is simple:
- By averaging different measures, one can circumvent the presence of measurement error.

Introduction

- The intuition for several independent measures is simple:
- By averaging different measures, one can circumvent the presence of measurement error.
- The logic is the same as that of finding a good instrument for a variable affected by measurement error.
  - One measurement can be used as an instrument for the other.
- See also Schennach (Econometrica, 2004).

Introduction

- Human capital is difficult to measure, especially among young children.

Introduction

- Human capital is difficult to measure, especially among young children.
- It is also recognised that human capital is a multi-dimensional object.
  - Different domains are relevant for well-being.
  - Different skills command different prices in the labour market.
  - Different components of HK play different roles in the process of development.
  - Different components interact with different inputs in the process of development

Introduction

- Human capital is difficult to measure, especially among young children.
- It is also recognised that human capital is a multi-dimensional object.
  - Different domains are relevant for well-being.
  - Different skills command different prices in the labour market.
  - Different components of HK play different roles in the process of development.
  - Different components interact with different inputs in the process of development
- Different domains are captured by different measurements.
- Different measurements capture different domains.
- A given measure can be influenced by different domains.

Introduction

- A useful strategy for the modelling of Human Capital and its growth will tackle these issues explicitly.
- Propose a model of human capital accumulation, in its various dimensions.
  - A production function of human capital.
  - Investment behaviour.

Introduction

- A useful strategy for the modelling of Human Capital and its growth will tackle these issues explicitly.
- Propose a model of human capital accumulation, in its various dimensions.
  - A production function of human capital.
  - Investment behaviour.
- Explicitly assess measurement issues.
  - Measurement error.
  - What domains are captured by what measures.

Introduction

- A useful strategy for the modelling of Human Capital and its growth will tackle these issues explicitly.
- Propose a model of human capital accumulation, in its various dimensions.
  - A production function of human capital.
  - Investment behaviour.
- Explicitly assess measurement issues.
  - Measurement error.
  - What domains are captured by what measures.
- Cunha et al. (2010) is a useful starting point.

Outline

- A model of human capital formation.
  - A production function for human capital.

Outline

- A model of human capital formation.
  - A production function for human capital.
  - Investment Function
- Mesurements.
  - Measurement error and identification.
  - Different domains.
  - Assembling the right tools.
- Directions for the future.

Outline

A model of human capital formation.

- Assume parents maximise utility, which is a function of consumption and their children HK.
- Assume that HK evolves according to a production function that depends on past HK and various inputs (as well as parental background).
- HK is a multidimensional object.

A model of human capital formation.

$$
\begin{aligned}
& Max_{\{C_{i,t},\mathbf{x}_{i,t}\}} U(C_{i,t}, \mathbf{H}_{i,t+1}) \\
s.t. \quad & C_{i,t} + \mathbf{P}^x_t \mathbf{X}_{i,t} = Y_{i,t} \\
\text{and} \quad & \mathbf{H}_{i,t+1} = g_t(\mathbf{H}_{i,t}, \mathbf{X}_{i,t}, \mathbf{Z}_{i,t}, e_{i,t})
\end{aligned}
$$

where $C_{i,t}$ is consumption and $\mathbf{P}^x_t$ is the vector of prices of investments $\mathbf{X}_{i,t}$.
The variables $\mathbf{H}_{i,t}$, $\mathbf{Z}_{i,t}$ and $\mathbf{X}_{i,t}$ are multidimensional:

$$
\begin{aligned}
\mathbf{H}_{i,t} &= \{\theta^c_{i,t}, \theta^s_{i,t}, \theta^h_{i,t}\} \\
\mathbf{Z}_{i,t} &= \{\theta^m_{i,t}, \theta^f_{i,t}, \theta^r_{i,t}\} \\
\mathbf{X}_{i,t} &= \{\theta^M_{i,t}, \theta^T_{i,t}\}.
\end{aligned}
$$

Model estimation and identification

- A first objective of this research agenda is to estimate the production function of human capital.

$$\mathbf{H}_{i,t+1} = g_t(\mathbf{H}_{i,t}, \mathbf{X}_{i,t}, \mathbf{Z}_{i,t}, e_{i,t})$$

Model estimation and identification

- A first objective of this research agenda is to estimate the production function of human capital.

$$\mathbf{H}_{i,t+1} = g_t(\mathbf{H}_{i,t}, \mathbf{X}_{i,t}, \mathbf{Z}_{i,t}, e_{i,t})$$

- This involves several problems:
  - endogeneity of investment choices.
  - unobservability of the conceptual constructs we are modelling.
    - Components of human capital
    - Investment
    - Background variables

Model estimation and identification

- A first objective of this research agenda is to estimate the production function of human capital.

$$\mathbf{H}_{i,t+1} = g_t(\mathbf{H}_{i,t}, \mathbf{X}_{i,t}, \mathbf{Z}_{i,t}, e_{i,t})$$

- This involves several problems:
  - endogeneity of investment choices.
  - unobservability of the conceptual constructs we are modelling.
    - Components of human capital
    - Investment
    - Background variables
- Estimation of the investment function.
  - important per se
  - it solves the endogeneity problems

Outline

Measurement system

- Cunha et al. (2010) work with a factor model which is very useful.

$$m_t^{kj} = \alpha_t^{jk}\theta_t^j + \epsilon_t^{kj}, \quad j = \{c, s, h, m, f, r, M, T\}, \quad k = \{1, 2, ...\}$$

where:

  - m_t^{kj} is measurement k corresponding to factor j
  - α_t^{jk} are the loading factors
  - ϵ_t^{kj} are measurement errors

- The aim is to identify the distribution of the unobservable θ_t^j's from the observations on m_t^{kj}.

Identification

Assume:

- Measurement errors of different measures are independent.
- Each measurement is affected by only one factor.
  - dedicated measurement system.
- We have at least **3 measurements** per factor.

Identification

Assume:

- Measurement errors of different measures are independent.
- Each measurement is affected by only one factor.
  - dedicated measurement system.
- We have at least **3 measurements** per factor.

Then, from the empirical distribution of **the measurements** m_t^{kj}, it is possible to identify the distribution of **the unobserved factors** θ_t^j and of measurement errors non-parametrically.

Extensions and practicalities

- It is possible to allow for correlation between measurement errors of different measures but we need at least two uncorrelated measures per factor.

Extensions and practicalities

- It is possible to allow for correlation between measurement errors of different measures but we need at least two uncorrelated measures per factor.
- It is possible to allow more than one factor to affect certain measures (non dedicated measurement system) but we need some measures affected exclusively by a factor (exclusion restrictions)

Extensions and practicalities

- It is possible to allow for correlation between measurement errors of different measures but we need at least two uncorrelated measures per factor.
- It is possible to allow more than one factor to affect certain measures (non dedicated measurement system) but we need some measures affected exclusively by a factor (exclusion restrictions)
- While identification does not require functional form assumptions, it is often useful to make specific assumptions to gain efficiency.
  - Advisable to use flexible specification.
  - They should be consistent with the theoretical structure under study.
  - Robustness analysis

Extensions and practicalities

- It is possible to allow for correlation between measurement errors of different measures but we need at least two uncorrelated measures per factor.
- It is possible to allow more than one factor to affect certain measures (non dedicated measurement system) but we need some measures affected exclusively by a factor (exclusion restrictions)
- While identification does not require functional form assumptions, it is often useful to make specific assumptions to gain efficiency.
  - Advisable to use flexible specification.
  - They should be consistent with the theoretical structure under study.
  - Robustness analysis
- How many factors? Which measures to which factors?

Extensions and practicalities

- It is possible to allow for correlation between measurement errors of different measures but we need at least two uncorrelated measures per factor.
- It is possible to allow more than one factor to affect certain measures (non dedicated measurement system) but we need some measures affected exclusively by a factor (exclusion restrictions)
- While identification does not require functional form assumptions, it is often useful to make specific assumptions to gain efficiency.
  - Advisable to use flexible specification.
  - They should be consistent with the theoretical structure under study.
  - Robustness analysis
- How many factors? Which measures to which factors?
  - Exploratory factor analysis.
  - Prior knowledge and theory.
  - ... available data.

Outline

Estimating the production function in Colombia

joint work with S. Cattan, E. Fitzsimons, C. Meghir and M. Rubio-Codina.

- Data from a RCT to evaluate a stimulation intervention in Colombia.

Estimating the production function in Colombia

joint work with S. Cattan, E. Fitzsimons, C. Meghir and M. Rubio-Codina.

- Data from a RCT to evaluate a stimulation intervention in Colombia.
- Observations available at two dates (ages) t and $t+1$.
  - age 12-14 at baseline
  - age 30-42 at follow up.

Estimating the production function in Colombia

joint work with S. Cattan, E. Fitzsimons, C. Meghir and M. Rubio-Codina.

- Data from a RCT to evaluate a stimulation intervention in Colombia.
- Observations available at two dates (ages) t and $t+1$.
  - age 12-14 at baseline
  - age 30-42 at follow up.
- Assume two factors:
  - Cognitive c
  - Socioemotional s

Estimating the production function in Colombia

joint work with S. Cattan, E. Fitzsimons, C. Meghir and M. Rubio-Codina.

- Data from a RCT to evaluate a stimulation intervention in Colombia.
- Observations available at two dates (ages) t and $t+1$.
  - age 12-14 at baseline
  - age 30-42 at follow up.
- Assume two factors:
  - Cognitive c
  - Socioemotional s
- Rich data sets including many measures on children development, investments, parental background.

Estimating the production function in Colombia

joint work with S. Cattan, E. Fitzsimons, C. Meghir and M. Rubio-Codina.

- Data from a RCT to evaluate a stimulation intervention in Colombia.
- Observations available at two dates (ages) t and $t+1$.
  - age 12-14 at baseline
  - age 30-42 at follow up.
- Assume two factors:
  - Cognitive c
  - Socioemotional s
- Rich data sets including many measures on children development, investments, parental background.
- Assume production function:

$$\theta^k_{i,t+1} = A^k_d[\gamma^k_{1,d}{\theta^C_{i,t}}^{\rho_k} + \gamma^k_{2,d}{\theta^S_{i,t}}^{\rho_k} + \gamma^k_{3,d}{P^C_{i,t}}^{\rho_k} + \gamma^k_{4,d}{P^S_{i,t}}^{\rho_k} + \gamma^k_{5,d}{I^M_{i,t+1}}^{\rho_k} + \gamma^k_{6,d}{I^T_{i,t+1}}^{\rho_k}]^{\frac{1}{\rho_k}} e^{\eta^k_{i,t}} \qquad k \in \{C, S\}$$

Measures on the target child

- Bayley Scales of Infant and Toddler Development, third edition (Bayley-III)
- MacArthur-Bates Communicative Development Inventories I, II and III - Spanish Short Forms
- Infant Characteristics Questionnaire (ICQ) (Bates et al., 1979)
- Early Children's Behavior Questionnaire (ECBQ)

Measures on the mother

- Peabody Picture Vocabulary Test (PPVT)
- Standard Progressive Matrices (RPM) (Raven, 1981)
- Center for Epidemiological Studies Depression scale (CES- D)
- Education attainment

Measures of parental investment

- Family Care Indicators (FCI)
- Time use data (mother)
- Time use data (target child)

Selecting the number of factors

- Kaisers eigenvalue rule
- Cattells scree plot
- Velicers minimum average partial (MAP) correlation rule
- Horns parallel analysis

Selecting the number of factors

Table: Exploratory factor analysis to determining the number of factors

	Number of factors according to the following methods:			
Dimensions to measure:	Kaiser's eigenvalue rule	Cattell's scree plot	Velicer's MAP rule	Horn's parallel analysis
Child's skills at *t+1*	2	2	2	3
Child's skills at *t*	1	2	1	3
Parental investments at *t+1*	2	2	2	3
Mother's skills	2	2	2	4
Wealth	1	1	1	3

Measurement system

Factor	Measures	% Signal Controls	% Signal Treated
Child's cognitive skills *(t+1)*	Bayley Cognitive	76%	77%
	Bayley Receptive Language	71%	72%
	Bayley Expressive Language	78%	79%
	Bayley Fine Motor	55%	57%
	Mac Arthur-Bates Vocabulary	55%	56%
	Mac Arthur-Bates Complex Sentences	38%	39%
Child's cognitive skills *(t)*	Bayley Cognitive*	74%	67%
	Bayley Receptive Language*	80%	74%
	Bayley Expressive Language*	80%	73%
	Bayley Fine Motor*	68%	60%
	Mac Arthur-Bates Vocabulary*	43%	35%
Child's socio-emotional skills *(t+1)*	Bates Difficult sub-scale (-)	69%	67%
	Bates Unsociable sub-scale (-)	21%	20%
	Bates Unstoppable sub-scale (-)	62%	60%
	Rothbart Inhibitory Control sub-scale	70%	68%
	Rothbart Attention sub-scale	25%	24%
Child's socio-emotional skills *(t)*	Bates Difficult factor* (-)	67%	72%
	Bates Unsociable factor* (-)	19%	23%
	Bates Unadaptable* (-)	34%	40%
	Bates Unstoppable* (-)	23%	28%

Measurement system

Factor	Measures	% Signal Controls	% Signal Treated
Material investments	Number of different play materials	96%	97%
	Number of colouring books	44%	46%
	Number of toys bought	65%	67%
	Number of toys that require movement	73%	75%
	Number of toys to learn shapes	73%	75%
Time investments	Number of different play activities	95%	98%
	Times told a story to child in last 3 days	67%	83%
	Times read to child in last 3 days	70%	85%
	Times played with child and toys in last 3 days	64%	81%
	Times labelled things to child in last 3 days	65%	82%
Mother's cognitive skills	Mothers' years of education*	64%	63%
	Mother's vocabulary	70%	69%
	Number of books for adults in the house*	40%	39%
	Number of magazines and newspapers	18%	17%
	Revane's score ("IQ") **	60%	59%

The production function: cognitive skills

	Without control function	*With control function*
Child's cognitive skills at *t*	**0.591**	**0.566**
	(0.043)	(0.057)
	[0.527,0.67]	[0.489,0.674]
Child's socio-emotional skills at *t*	**0.03**	**0.038**
	(0.043)	(0.050)
	[-0.037,0.106]	[-0.035,0.126]
Mother's cognitive skills	**0.194**	**0.037**
	(0.049)	(0.131)
	[0.107,0.264]	[-0.194,0.223]
Mother's socio-emotional skills	**0.06**	**0.051**
	(0.045)	(0.049)
	[-0.016,0.126]	[-0.028,0.127]
Material investments at *t+1*	**0.082**	**0.397**
	(0.033)	(0.208)
	[0.036,0.144]	[0.128,0.765]
Time investments at *t+1*	**0.008**	**-0.138**
	(0.035)	(0.142)
	[-0.056,0.057]	[-0.421,0.039]
Number of children in household at *t+1*	**0.035**	**0.049**
	(0.026)	(0.030)
	[-0.009,0.076]	[0.002,0.1]
Control function for material investments	-	**-0.33**
		(0.218)
		[-0.715,-0.023]
Control function for time investment	-	**0.156**
		(0.151)
		[-0.037,0.453]
Complementarity parameter	**0.123**	**0.07**
	(0.082)	(0.060)
	[-0.025,0.243]	[-0.032,0.161]
Elasticity of substitution	**1.141**	**1.075**
	(0.106)	(0.070)
	[0.976,1.321]	[0.969,1.192]
Productivity parameter (A)	**0.984**	**0.993**
	(0.012)	(0.011)
	[0.966,1.005]	[0.972,1.008]

The production function: Socioemotional skills

	Without control function	*With control function*
Child's cognitive skills at *t*	**0.11**	**0.122**
	(0.044)	(0.059)
	[0.039,0.185]	[0.024,0.222]
Child's socio-emotional skills at *t*	**0.435**	**0.413**
	(0.055)	(0.059)
	[0.374,0.552]	[0.354,0.537]
Mother's cognitive skills	**-0.054**	**0.116**
	(0.066)	(0.142)
	[-0.168,0.046]	[-0.201,0.276]
Mother's socio-emotional skills	**0.151**	**0.161**
	(0.058)	(0.058)
	[0.047,0.233]	[0.046,0.235]
Material investments at *t+1*	**0.14**	**-0.32**
	(0.043)	(0.198)
	[0.079,0.219]	[-0.529,0.108]
Time investments at *t+1*	**0.119**	**0.434**
	(0.041)	(0.133)
	[0.043,0.181]	[0.17,0.591]
Number of children in household at *t+1*	**0.099**	**0.073**
	(0.026)	(0.027)
	[0.048,0.136]	[0.025,0.113]
Control function for material investments	-	**0.477**
		(0.204)
		[0.043,0.711]
Control function for time investment	-	**-0.336**
		(0.136)
		[-0.506,-0.068]
Complementarity parameter	**0.049**	**0.006**
	(0.077)	(0.056)
	[-0.085,0.158]	[-0.059,0.12]
Elasticity of substitution	**1.051**	**1.006**
	(0.088)	(0.063)
	[0.921,1.187]	[0.944,1.137]
Productivity parameter (A)	**0.987**	**0.992**
	(0.016)	(0.012)

The production function: summary of result

- The production function seems to be well approximated by a Cobb Douglas production function.

The production function: summary of result

- The production function seems to be well approximated by a Cobb Douglas production function.
- Initial conditions matter.
  - Socio emotional skills at t matter for socio-emotional skills at $t+1$.
  - Cognitive skills at t matter for cognitive skills at $t+1$.
  - Cognitive skills at t matter for socio-emotional skills at $t+1$.

The production function: summary of result

- The production function seems to be well approximated by a Cobb Douglas production function.
- Initial conditions matter.
  - Socio emotional skills at t matter for socio-emotional skills at $t+1$.
  - Cognitive skills at t matter for cognitive skills at $t+1$.
  - Cognitive skills at t matter for socio-emotional skills at $t+1$.
- Parental investments also matter.
  - Material investments matter for cognition.
  - Time investment matters for socio-emotional skills.
  - Investment seems to be compensatory.

The production function: summary of result

- The production function seems to be well approximated by a Cobb Douglas production function.
- Initial conditions matter.
  - Socio emotional skills at t matter for socio-emotional skills at $t+1$.
  - Cognitive skills at t matter for cognitive skills at $t+1$.
  - Cognitive skills at t matter for socio-emotional skills at $t+1$.
- Parental investments also matter.
  - Material investments matter for cognition.
  - Time investment matters for socio-emotional skills.
  - Investment seems to be compensatory.
- Parental background only matter through investment.
- The parameters of the production function are not affected by the intervention.

Outline

Future research and conclusion

- Measurement is key to the testing (and elaboration) of theories of child development.
- Measurement is key to the evaluation and design of intervention.

Future research and conclusion

- Measurement is key to the testing (and elaboration) of theories of child development.
- Measurement is key to the evaluation and design of intervention.
- Measurement is difficult.
  - Measurement tools have to be designed carefully to address the needs of evaluation and theory.
  - Researchers should not shy away from the design of new tools, rigorously tested and piloted.
  - We should go 'native' and let the raw data talk: careful of standardisation procedures, aggregation.

Future research and conclusion

- Measurement is key to the testing (and elaboration) of theories of child development.
- Measurement is key to the evaluation and design of intervention.
- Measurement is difficult.
  - Measurement tools have to be designed carefully to address the needs of evaluation and theory.
  - Researchers should not shy away from the design of new tools, rigorously tested and piloted.
  - We should go 'native' and let the raw data talk: careful of standardisation procedures, aggregation.
- Much exciting research is going on:
  - use of new technologies (EGG, fNRES, eye-tracking, etc.).
  - attempts to measures beliefs, expectations, attitudes.
  - validation and cross validation.