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The Timing of Parental Income and Child Outcomes: The Role of Permanent and Transitory Shocks

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1 Introduction

How do shocks to parental income drive adolescent human capital, such as university attendance, IQ and health? Unexpected changes to family income may have a predictable effect on child adolescent outcomes, by shifting the money parents spend on human capital investments in their children. The extent to which consumers insure themselves against changes in income has been well documented in the economics literature,[2] however little is known about how the evolution of household income drives the human capital of their children. This paper fills the gap and makes two important innovations by firstly estimating the effect of shocks across the life cycle of childhood, from age 1-16 and secondly distinguishing between income shocks that are permanent and transitory.

Does human capital acquisition respond to income shocks in a similar manner as consumption? Theory posits that income shocks which are persistent have distinct effects on consumption from shocks that are purely transitory[3]. According to the Permanent Income Hypothesis (PIH), an income shock transmits to consumption through its change in lifetime household wealth. Consider a permanent shock of a promotion, for example. This shock will raise contemporaneous income but also income in all future periods. This means that an early permanent income shock will have a larger effect upon parental investment (and therefore child outcomes) than one realised later in the child's lifetime. The reason is that *ceteris paribus,* a permanent shock realised at birth will drive more future income realisations than a shock at age 16.

On the other hand, the PIH predicts a different transmission of transitory income shocks to child human capital. A transitory shock such as a bonus changes contemporaneous income and potentially income for a few future periods but is mean reverting. Under incomplete insurance, unexpected fluctuations in transitory income alter lifetime wealth by the product of 1/T and the value of the shock.[4] These shocks are absorbed through borrowing or saving and, both consumption and parental investment are smoothed. Consequently, the effect of transitory income shocks to the eventual stock of child human capital is lower than that for permanent shocks, but this difference decreases across child age. If human capital accumulation behaves similarly to consumption, I expect to find that permanent income shocks have an effect on adolescent outcomes which declines in the age of the child when shocks are realised and transitory income shocks have a small but constant effect.

[2] Deaton (1992) provides a good summary. Blundell & Preston (1998), Attanasio *et al* (2002), Blundell *et al* (2008) examine consumption responses to income changes and Adda *et al* (2009) look at health responses to income shocks.

[3] See Friedman (1957).

[4] T denotes the total periods of labour market participation of parents.

The PIH thus predicts heterogeneous effects across the child life cycle. Indeed, a recent literature suggests that the determinant of adolescent college enrolment is not contemporaneous income, but rather the flow of parental income across childhood. Cameron & Heckman (2001), Keane & Wolpin (2001) and Cameron & Taber (2004) argue that it is not the presence of credit constraints at the point in time when individuals decide to enter college that drives that decision, but rather a binding lifetime credit constraints which alter human capital investment throughout childhood. As such this paper analyses the role of income shocks at every age of childhood, from birth up until age 16.

I explore heterogeneity in the time profile of the effect of transitory income shocks upon outcomes, by focusing on liquidity constrained households. With imperfect access to credit markets, liquidity constrained agents are unable to borrow or save in order to smooth transitory income shocks sufficiently. Consequently I would expect to find a larger effect of transitory income shock in liquidity constrained households.

The decomposition of the effect of family income shocks upon child outcomes by the durability of the shock and the age of the child, has not currently been explored by literature. One potential reason is a lack of adequate data. The data in this paper takes the population of around 600,000 Norwegian children, born in the 1970s and tracked through to 2006, which provides in depth information on annual household income plus a range of adolescent outcomes, including years of schooling, high school dropout, university attendance and IQ and health test scores from a set of army tests for males.

There are of course contributions from the empirical literature along several relevant dimensions. A literature suggests that a potential mechanism through which parental income shocks drive child outcomes is through a shift in parental investments in child human capital.[5] The effect of specific shocks to the household upon child outcomes has been investigated in a number of papers[6]. Akee *et al* (2010) found that the age of the child when the shock was realised strongly conditioned the effect of that shock. In particular, the effect of an exogeneous and permanent government transfer to households had a larger effect on schooling and crime outcomes for children with six, rather than two years exposure to the higher income.

Interestingly, the predictions of the effect of timing of income *levels* differs markedly from the timing of income *shocks*. In the absence of credit constraints, a simple model predicts

[5] Cunha & Heckman (2007, 2008) and Cunha *et al* (2010) distinguish between financial such as books, private tuition and time investments such as reading to children and trips to a museum. A negative income shock of unemployment could lead parents to change money or time spent on their children, e.g. cancel a private tutor in the one case or help the child with homework in the other. Ginja (2009) finds that investment goods are responsive to an unexpected change in family income.

[6] There are many examples. One is by Chen *et al* (2009), who explore the effect of unexpected parental death upon the probability of enrolling in college, in Taiwan.

that parental investment in human capital does not respond to the timing of income, given permanent income. Parents would optimally borrow and save to smooth the effect of the timing of income.[7] However, in this paper the model is extended to allow for income uncertainty. Unexpected changes in income lead to predictable changes in parental investment (which depend upon the durability of the income shock and child age) and therefore child adolescent outcomes.

Finally, it is worth noting that a component of the effect of income shocks is parental insurance. If children are fully insured against the income shock, the data will reveal a zero effect across child age. A number of papers have established that the human capital of young adults is partially insured by their parents.[8] For example, Kaplan (2007) finds that youths faced with labour market risk call upon both financial transfers and co-residence as insurance mechanisms and Rosenzweig & Wolpin (1993) suggest that parental insurance is required in addition to government insurance, even against anticipated income shocks.

There are important policy implications inherent in this study. Cunha (2005) and Cunha & Heckman (2007, 2008) posit that parental investment will be more effective early in the lifetime of a child. Firstly, neurological arguments suggest that early investments into cognitive ability will have a higher return than later investment[9]. This combined with the suggestion that there are dynamic complementarities in the return to investment, such that the return to early (late) investment is increasing in the level of late (early) investment, points effective policy making towards the early years. Family income is arguably easier to target by governments than parental investment and as such, this paper estimates the value of government insurance for households with children, against unexpected changes to income. As noted above, the largest effect is expected for permanent shocks early in the lifetime of a child. However, it is transitory shocks which provide the relevant policy experiment, as they are insurable by government whereas permanent shocks in general, are not.[10]

The methodology used in this paper follows two stages. Firstly, a structural model of the parental income process decomposes income shocks into permanent and transitory components. Secondly, the reduced form effects of the separate shocks, experienced at different ages in the child's life, on their eventual child capital levels are estimated.[11]

[7] Carneiro *et al* (2010) do indeed find evidence of a relatively flat profile of the effect of the timing of income, although there is some evidence of dynamic complementarity in the return. On the other hand, Jenkins & Schluter (2002) find a higher return to late, and Levy & Duncan (2000) finds a higher return to early years income.

[8] See for example Hayashi *et al* (1996), Martins & Villanueva (2009) and Becker *et al* (2010).

[9] For example, the cohort-ranking of IQ is set very early, at around age 5.

[10] There are of course exceptions, such as governments tend to guarantee a subsistence level of income and additionally insurance against loss of income through disability.

[11] Paxson (1992), Shapiro & Slemrod (1995), Parker (1999) and Souleles (1999) adopt an alternative methodology by exploiting exogeneous variation in income to identify the role of transitory income shocks

A necessary first step therefore is to gather empirical evidence as to the income process that is applied to the structural model. I use a panel of around 400,000 parents observed across a 30 year period to estimate the autocovariances of income growth. Permanent income is assumed to follow a random walk and the evidence suggests that transitory income is best described by an MA(1) or MA(2) process. Next, deviations of household income from the life cycle trend are predicted in each year of child life. Moment conditions from the income process allow a decomposition into permanent and transitory income shocks from early childhood to adolescence. These are estimated at the level of the cohort within a labour market.[12] Finally, the effect of both types of shock, realised across the child life cycle, is estimated in a reduced form equation on the eventual stock of adolescent human capital outcomes. The model allows for correlation between an initial condition in household income and a parental fixed effect in child human capital. The identification assumption in the first stage decomposition is that second order moments of the permanent and transitory income shocks differ across child age, cohorts and labour markets, but that the effect of these shocks varies only across child age. The second stage identification assumption is that estimated income shocks are exogeneous and unexpected by households. The former is based upon evidence from 400,000 households across 30 years and the latter is tested in two robustness checks.

The data indicate a strong and significant correlation between the initial condition and child outcomes. A rise in initial income levels by 1 standard deviation raises child human capital by up to 0.4 standard deviations (equivalent, for example, to nearly a year of schooling). This shows that family background matters - there is significant dispersion in outcomes for the sample of Norwegian children, determined at the start of their lifetime. For all outcomes except health, the effect of a household permanent income shock is significant and declines across child age, as predicted by the PIH. However there is volatility in this relationship, which may be picking up changes in maternal labour supply. Mothers have less attachment to the labour market and their labour supply is more sensitive, for example to children starting school. By focusing just on paternal income, noise in the decline is smoothed out for all outcomes. The difference in the health outcome is likely due to crude measurement in the data.[13] In general, permanent shocks to paternal income have a large effect early in the lifetime of the child and this effect falls across child age, to zero at age 16.

upon consumption. For this paper, it would be very cumbersome, if not impossible, to find strong instruments for both permanent and transitory income shocks throughout the lifetime of children.

[12] The method is a slight adaptation to Moffitt & Gottschalk (1995), Meghir & Pistaferri (2004) and Blundell *et al* (2008) and similar to Jappelli & Pistaferri (2008).

[13] In all specifications, for both permanent and transitory shocks, there is a noisy and insignificant effect of shocks on health.

For all outcomes, transitory income shocks have a small and constant effect across child age. This suggests that parents are optimising, by smoothing parental investment against transitory shocks in a similar manner to consumption smoothing.

However interestingly, for a sample of liquidity constrained parents, child human capital behaves differently to consumption upon receipt of an income shock. It was anticipated that human capital responses to income shocks would be larger for the liquidity constrained sample, as without full access to the credit markets, parents are unable to smooth the effect of the shock. Instead, transitory income shocks have a *smaller* effect on child human capital for a group of households with permanent income in the second decile or below, compared to the total sample.[14] I argue that for this group of parents, investment goods such as books, high quality nursery care or private tuition are not necessities given that children receive free state education. Rather, liquidity constrained parents raise consumption on goods like household utilities, child clothing and food when they receive an income shock.

The results are robust to a change in the income process which extends the MA process of transitory income to second order and also to two tests for the endogeneity of income.

The paper is structured as follows. Section 2 describes the institutional setting in Norway, section 3 discusses the Norwegian data. In section 4, the income process for the sample of parents in Norway is estimated to inform the structural model. The empirical strategy is pursued in section 5, section 6 discusses the results and section 7 the robustness checks. Finally, section 8 concludes.

2 The Norwegian Setting

The population of children born between 1970-1980 form the dataset for this paper. This section explains the relevant institutional setting faced by the parents and children.

In 1969, an educational reform extended the compulsory schooling in Norway from 8 to 9 years, raising the school leaving age from 15 to 16. This means that the parents of the sample children will be composed of those facing the new and the old system. (80% of mums and 91% of dads faced the compulsory age of 16). On average, mothers and fathers report 10.8 and 11.3 years of schooling respectively for themselves (which translates into a leaving age of 17.8 and 18.3).

Although Norway is today known for being a very progressive country, they were quite late in their adoption of family policies. To give an example, prior to 1977 there was a very low level of maternity leave available. Mothers could take up to 12 weeks of leave, but with large variation in the remuneration. In 1977, there was a reform, evaluated by Carneiro *et al*

[14] Permanent income is defined as the sum of income across child age, from 0-18.

(2010b), which changed the system to one where mothers were granted up to a year of leave, with the first 18 weeks paid at the full salary. Tying in with this low level of maternity leave, for the most of the 1970s, there was a very low level of formal child care take up.[15] There was, and still is, no free child care prior to compulsory schooling. The consequence was that during the early 1970s, the majority of mothers did not go to work but stayed at home to look after the children. In the data of this paper, only 30% of mothers were working two years after they had given birth, compared to 60% of mothers in 1980.

Schooling in Norway is now compulsory from age 6 to age 16, although the children of this study started school in the year they turned 7. There was free access to school age education and readily available loans to students attending university. The analysis in this paper considers how income shocks received up to age 16 drive later outcomes and therefore excludes shocks realised after making the decision to extend schooling after the compulsory age.

3 Data

The Norwegian Registry data, an administrative dataset provides information for the analysis. Annual information is recorded for the population of Norway on a range of variables, linking across generations of the same family their records from birth, education, labour market and marriage market status.[16] Table 1 displays the summary statistics for the data, containing 616,210 children born to 399,603 families. The chosen sample contains the population of children born in Norway between 1970-1980.

It is possible to define a wide range of child human capital outcomes, recorded during their adolescence. Educational status is measured as late as 2006, meaning that the youngest children in the sample are aged 26 by this time and likely to have completed their education. Three education variables are defined for the analysis. Firstly, years of completed education is recorded for the full sample, with a mean value of 12.70 years. Secondly, a focus on the bottom of the educational distribution records a dummy variable equal to one if the child dropped out of high school before receiving a certificate for vocational or academic education. Without this certificate, students' future paths are restricted and for example, they will not be able to attend university. 22% of students in the sample are recorded as dropout students.[17] The final educational record is attendance at college/university, which applies to 39% of students. There is clearly polarisation in educational attainment in Norway.

[15] Only 10% for 3-6 year olds in 1975 but almost none for 1-2 year olds, according to Havnes & Mogstad (2009).

[16] For full details on the data, see Møen *et al* (2004).

[17] This outcome is referred to as high school dropout, for simplicity.

Military service is compulsory in Norway for males, who take tests including a measure of IQ and health for entry to the army at around age 18. The IQ score is a composite score from arithmetic, word similarities and Figures tests. The arithmetic and word tests are most similar to the Wechsler Adult Intelligent Scale (WAIS) and the Figures test to the Raven Progressive matrix, which are approved by psychologists as measures of IQ.[18] The continuous scores are banded into a 9 point scale, with a mean of 5.21. Also measured in these is an indicator of physical health. The score is again on a 9 point scale, with 9 indicating perfect health. As the mean value of the score is 8.44, it is clear that this test in fact records perfect physical health for the majority of the sample (85%).[19] Only 90% of individuals take tests aged 18, however Black *et al* (2008) describe a strong and significant relationship between the year individuals turned 18 and the year they took the tests.

I link the child unique identifier from the educational datasets to the mother and father from the birth certificate and match income and years of education for each parent from 1967-2006. Income is deflated to 2000 prices and household income calculated as the sum of paternal and maternal income if both parents are known, or one parent otherwise. Marital status information is available for all relevant years of the sample. If families break up, I continue to measure household income as the sum across biological parents. However, when I come to estimate income shocks, I control for marital status, in order to remove income shocks from marriage break-up.

The paternal identifier is linked to the municipality of residence in each year. If a paternal identifier is missing, the maternal identifier is used instead. There are around 450 municipalities in Norway. However, it is the local labour market identifier that is used in the analysis, so as to appropriately group areas by something similar to a travel-to-work-area (TTWA). Geographers in Norway have defined 90 labour markets in Norway. From the sample of parents contained in the dataset, the labour market size varies between 1,000 and 65,000 households. For a large majority of children in the sample (78%), the labour market observed when the child is born is identical to that at age 16. I keep only these children in our sample, so as to be able to define the local labour market of the child as being constant across the lifetime of the child.[20]

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[18] For more information, see Sundet *et al* (2004, 2005).

[19] In an alternative specification, a dummy variable was equal to one if individuals scored 9 and zero otherwise. The results for this outcome were almost identical to the 9 point scale.

[20] The mean difference in child and parental outcomes for two samples of movers and non-movers is no more than 30% of a standard deviation.

4 Income Process in Norway

In the empirical section below, the effects of transitory and permanent income shocks across child age are identified for a particular income process. This section aims to infer the correct income process using very detailed administrative income data for the population of Norwegian parents, from 1970 to the present. Meghir & Pistaferri (2004) and Blundell *et al* (2008) suggest that in the US, a permanent transitory model of income is appropriate, whereby permanent income is a martingale and transitory income serially uncorrelated or a first order Moving Average process (MA(1)). In the UK, Dickens (2000) estimates a random walk in age for permanent income and a serially correlated transitory component. Bonhomme & Robin (2009) model income in France as a (deterministic component plus) a fixed effect and first order Markov process for transitory income. In Norway the income process is as yet unknown, warranting further investigation before making assumptions in the empirical model.

Two methods are used to understand the time series properties of the income process. A panel of income is constructed for each household across time, from 1970-2000, for those who had a child between 1970-1980. This constitutes nearly 400,000 households. Household income is calculated as the sum of paternal and maternal income, deflated to 2000 prices. First, the variance of income is plotted across the life cycle for the sample of mothers and fathers. If a random walk describes permanent income, the variance of income will be an increasing function of age, assuming independence of the shocks, as each shock lasts for a lifetime. Figures 1a) and 1b) plot the variance of income for the mothers and fathers respectively. For the mothers, there is a clear increasing relationship in the variance of earnings across age for the middle periods. During the early years in the labour market and around retirement, the relationship differs. The same is true of fathers, except for some outliers in the 40s. Of course, there are other reasons why variance of income may increase across time, however this evidence does not rule out a random walk permanent component to income.

The second methodology employed, following MaCurdy (1982), seeks to understand the ARMA transitory income process. Similarly to the aforementioned papers, I assume a permanent component to income and estimate the income process for household transitory income.

Consider the model $\ln w_{it} = Z_{it}'\varphi + P_{it} + v_{it}$ where P and v are the permanent and transitory components respectively of log income ($\ln w$) for household i in period t. Z denotes a set of covariates and φ a vector of coefficients. The permanent component follows a martingale, hence $P_{it} = P_{it-1} + \zeta_{it}$ where ζ denotes the permanent income shock, independently and identically distributed (iid) across i and t. This section estimates the ARMA(p,q) process for the transitory component of income. In a general model, transitory income is given by $v_{it} = -\sum_{j=1}^{p} a_j v_{it-j} + \sum_{j=0}^{q} m_j \varepsilon_{it-j}$ where $m_0 = 1$. a_t and m_t are the lag coefficients and equal zero if there is no persistence in transitory income. ε denotes the transitory income shock to the level of transitory income (v). The orders p and q of the AR and MA components are to be established empirically.

To analyse the persistence of the transitory income component separately to the permanent component, I follow MaCurdy (1982), Meghir & Pistaferri (2004) and Blundell *et al* (2008) and estimate the residuals from first differences in income $\Delta \ln w_{it} = \Delta Z'_{it}\varphi + \zeta_{it} + \Delta v_{it}$, where $\Delta x_t = x_t - x_{t-1}$. The order of the AR process of the first differenced disturbances is the same as in the levels, however first differencing changes the order of the estimated MA process to $(q+1)$.

The first stage is to estimate residuals from a system of equations of first difference log wages in period t for household i. The controls (Z) are a quadratic in maternal and paternal age, maternal and paternal education, marital status and municipality of residence. Results are in column 1 of Table 2. Income growth is decreasing in the age of mothers and fathers, at a decreasing rate and increasing in education. There is additionally a negative coefficient on marital status.

The second stage estimates autocovariances of residuals (γ) at different lags (k) from the equation $E\left(v_t v'_{t-k}\right) = \gamma_k + \omega_t$, where ω is the error in the autocovariance process and $k = \{1,..,8\}$. For each lag k, the autocovariances are estimated in a system of equations across t where the coefficient on the autocovariance is constrained to be constant in each regression. Two potential difficulties with estimating the autocovariances are firstly that the residuals are estimated in a first stage and secondly that there may be serial correlation across time for households. However, MaCurdy (1981) notes that using a seemingly unrelated regression procedure to estimate autocovariances will result in parameters and test statistics that are asymptotically valid.

The results are reported in Table 3. The estimated autocovariances are initially negative at one lag but fall close to zero after the first lag, although it remains significant. Again, between lags 2 and 3 there is another sharp drop in the autocovariances and after lag 3, they are no longer significant. This is suggestive of a low order MA process, of the order of 2 or 3 in differences, or of order 1 or 2 in levels.

In conclusion, permanent income will follow a random walk and transitory income an MA process where I will estimate the model initially for a first order process and test the robustness of results to a second order process. This is the similar income process found in the studies mentioned above, suggesting a similar income process in Norway as in the UK and the US.

5 Empirical Strategy

5.1 Income Process

Log wages ($\ln w$) for the observation i in period t are modelled as a linear function of a permanent and a transitory component (denoted P and v respectively) and a deterministic component of covariates (Z)

$$\ln w_{it} = Z'_{it}\varphi_t + P_{it} + v_{it} \tag{1}$$

where $i = 1, .., N$ and $t = 1, .., T$. The unit of observation is the household-child pair. Permanent income follows a martingale (equation 2) and transitory income is a serially correlated MA(1) process (equation 3), where ζ and ε denote the permanent and transitory income shocks respectively and θ the first order MA coefficient. Section 4 provided evidence that this is a good representation of the true income process for the sample of Norwegian parents.

$$P_{it} = P_{it-1} + \zeta_{it} \tag{2}$$

$$v_{it} = \theta\varepsilon_{it-1} + \varepsilon_{it} \tag{3}$$

Both permanent and transitory shocks are assumed to have a mean of zero and be uncorrelated with each other, $E(\zeta_{it}) = E(\varepsilon_{it}) = E(\zeta_{it}\varepsilon_{it}) = 0$; $t = 1, .., T$, $i = 1, .., N$.

Following Meghir & Pistaferri (2004), define y as log income with the effect of the covariates removed in a first stage, $y_{it} = \ln w_{it} - Z'_{it}\varphi_t = P_{it} + \theta\varepsilon_{t-1} + \varepsilon_{it}$. Substituting in for the permanent income component gives

$$y_{it} = P_{i0} + \sum_{s=1}^{t} \zeta_{is} + \theta\varepsilon_{it-1} + \varepsilon_{it} \tag{4}$$

Income in period t is the sum of P_0, the initial level of permanent income at the start of the child's lifetime, representing an unobservable endowment or initial condition, past and contemporaneous permanent income shocks and transitory shocks current and at one lag.

5.2 Child Human Capital Equation

The stock of child human capital (h) accumulates at the end of a lifetime of parental investment. The reduced form equation (5) shows human capital in the final period, T[21], to be a function of income in each period of life, where a different coefficient is allowed for permanent and transitory components of income, a set of parental traits X, a child level idiosyncratic error u_{iT} and initial endowment, μ_{i0} (for example genes or parental unobservable characteristics).[22] Parents optimise levels of parental investment and consumption to maximise their utility, which is a function of the child's stock of human capital in period T, hence human capital has a subscript i relating both to child and parent. When estimating the coefficients on income across time, it is important to allow for the value of money to change across time, through the interest rate, r. Money received in period 1 will be worth $(1+r)$ times as much in the following period if it is saved. Terminal period human capital is a function of the present value of income at age 0, in each period.

$$h_{iT} = \alpha + \delta X_{it} + \sum_{t=1}^{T} \frac{\beta_t^P P_{it}}{(1+r)^t} + \sum_{t=1}^{T} \frac{\beta_t^T v_{it}}{(1+r)^t} + \mu_{i0} + u_{iT} \tag{5}$$

Repeatedly substituting for P_{it} and substituting for v_{it} gives

$$h_{iT} = \alpha + \delta X_{it} + \sum_{t=1}^{T} \frac{\beta_t^P}{(1+r)^t} \left(P_{i0} + \sum_{s=1}^{t} \zeta_{is} \right) + \sum_{t=1}^{T} \frac{\beta_t^T}{(1+r)^t} \left(\theta \varepsilon_{it-1} + \varepsilon_{it} \right) + \mu_{i0} + u_{iT} \tag{6}$$

Income shocks are assumed to be uncorrelated with u and u has mean zero; $E(u_{iT}\varepsilon_{it}) = E(u_{iT}\zeta_{it}) = E(u_{iT}) = 0$; $t = 1,..,T$, $i = 1,..,N$. However, the initial condition in income is correlated with with the parental fixed effect: $E(P_{i0}\mu_{i0}) \neq 0$. Both P_{i0} and μ_{i0} cannot be separately observed, as they are initial conditions causing an identification problem, the consequences of which can be seen in the identification section below.

5.3 Identification

Cohort-Local Labour Market Level Analysis It is possible to decompose shocks into permanent and transitory components by exploiting variation in the second order moments of income, across cohorts of children in different labour markets. This method is similar to Blundell *et al* (2008) and Adda *et al* (2009), both of whom used time variation in variance of shocks.

[21] measured by schooling outcomes, IQ, teen pregnancy and health

[22] X may include covariates in Z and additional child level variables. Income shocks control for Z and it is assumed that other covarites in X are uncorrelated with shocks.

Meghir & Pistaferri (2004) identify the moments of the income process using information on income alone. Given the income process above, the covariance matrix of income at different lags is given for a cohort and labour market (c) by

$$cov\left(y_{it,c}, y_{it-s,c}\right)_c = \begin{array}{ll} \sigma^2_{P_0,c} + \sum_{l=1}^{t-s} \sigma^2_{\zeta_l,c} + \theta^2 \sigma^2_{\varepsilon_{t-1,c}} + \sigma^2_{\varepsilon_t,c} & if\ s=0 \\ \sigma^2_{P_0,c} + \sum_{l=1}^{t-s} \sigma^2_{\zeta_l,c} + \theta \sigma^2_{\varepsilon_{t-1}} & if\ s=1 \\ \sigma^2_{P_0,c} + \sum_{l=1}^{t-s} \sigma^2_{\zeta_l,c} & if\ |s|>1 \end{array} \tag{7}$$

where $\sigma^2_{\zeta t}$ and $\sigma^2_{\varepsilon t}$ denote the variance of permanent and transitory shocks in period t, respectively. It is the aggregation to cohort-labour market which allows identification of all variance terms, with the exception of $\sigma^2_{\varepsilon_T}, \sigma^2_{\zeta_T}$, which are not separately identifiable. For this reason, an additional year of data is included in the period $T+1$.[23]

The covariance matrix between income in each year of the child's lifetime and human capital is given below.

$$cov\left(y_{it,c}, h_{iT}\right)_c = \begin{array}{ll} \left(\sum_{l=1}^{T} \beta_l^P\right) \sigma^2_{P_0,c} + \sum_{s=1}^{t} \left(\sum_{l=s}^{T} \beta_l^P\right) \sigma^2_{\zeta_s,c} + \theta^2 \beta_t^T \sigma^2_{\varepsilon_{t-1}} & \\ \quad + \left(\beta_t^T + \theta \beta_{t+1}^T\right) \sigma^2_{\varepsilon_t} + \sigma_{\mu_0 P_0} & if\ t=1 \\ \left(\sum_{l=1}^{T} \beta_l^P\right) \sigma^2_{P_0,c} + \sum_{s=1}^{t} \left(\sum_{l=s}^{T} \beta_l^P\right) \sigma^2_{\zeta_s,c} + \theta \left(\beta_{t-1}^T + \theta \beta_t^T\right) \sigma^2_{\varepsilon_{t-1}} & \\ \quad + \left(\beta_t^T + \theta \beta_{t+1}^T\right) \sigma^2_{\varepsilon_t} + \sigma_{\mu_0 P_0} & if\ t=2,..,T-1 \\ \left(\sum_{l=1}^{T} \beta_l^P\right) \sigma^2_{P_0,c} + \sum_{s=1}^{t} \left(\sum_{l=s}^{T} \beta_l^P\right) \sigma^2_{\zeta_s,c} + \theta \left(\beta_{t-1}^T + \theta \beta_t^T\right) \sigma^2_{\varepsilon_{t-1}} & \\ \quad + \beta_t^T \sigma^2_{\varepsilon_t} + \sigma_{\mu_0 P_0} & if\ t=T \end{array} \tag{8}$$

where $\sigma_{\mu_0 P_0}$ denotes the correlation between P_0 and μ_0. For notational ease, the discounting by interest rate r has been omitted, and coefficients in equation (8) have been adjusted to denote present values as at period 0. As noted above, the two initial conditions cannot be separately identified and consequently, the coefficient on P_0 will be interpreted as the correlation between the parental initial condition and the fixed effect. However, all other parameters are identified. θ is estimated empirically.

Identification comes from variance of shocks across cohorts and labour markets. The

[23] This means that $\sigma^2_{\varepsilon_{T+1}}$ and $\sigma^2_{\zeta_{T+1}}$ cannot be distinguished.

inherent identification assumption for the first stage is that second order moments of the permanent and transitory income process differ across cohorts, labour markets and child age, but that the effect of these shocks upon child outcomes differs only across child age. Identification of equation (8) relies on the estimated shocks to income being truly unexpected by households and exogeneous. Endogeneity of income from heterogeneous life cycle profiles and the presence of siblings is explored in Sections 7.2 & 7.3.

Measurement error is omitted from the model to date. Meghir & Pistaferri (2004) estimate that between a quarter and a third of the transitory income shock variation is due to measurement error in the Panel Study of Income Dynamics (PSID). However, the bias is likely to be smaller in the current sample, as income is recorded from administrative data. The variance of permanent shocks is unaffected by the presence of measurement error.

6 Results

6.1 Income Shocks

The first stage of the analysis is to predict annual household income shocks, from the life cycle profile of income. A regression of log household income is run upon a constant, a quadratic in age, education, marital status and dummies for municipality of residence and year. The first stage regressions, in column 2 of Table 2, show log income increasing in parental age, but at a decreasing rate. Additionally, parent's education and marital status raise the household wage. The residuals estimated from these regressions indicate income shocks in the magnitude of 0.3-1% of annual income.

The estimation of household shocks is such that all households experience an income shock, as the annual deviation from their life cycle profile. Hence the incidence of an income shock will be uncorrelated with parental traits. As the variance of the income shocks is used for identification, it is worthwhile to explore any correlation between the variance of income shocks across a lifetime and family traits. A regression at the level of the household, of the standard deviation of lifetime income shocks upon a quadratic in maternal and paternal education shows that households with a low level of education have a relatively high variance of shocks and the slope is increasing across education.[24] The same pattern holds when running the regression at the level of the labour market.

[24] The coefficients (standard deviations) on maternal and paternal education are -0.03(0.00003) and -0.03(0.0006) and on the quadratic terms 0.001(0.00003) and 0.001(0.00003) respectively.

6.2 Distribution of income shocks

A diagonally weighted minimum distance procedure generates estimates for the variances of the initial level of permanent income and per period transitory and permanent income shocks. Details are in Appendix 1.

Table 4 reports the standard deviation of the initial level of permanent income, permanent and transitory income shocks, for each cohort (from 1970-1980) and labour market (of which there are 90) and across the age of the child. This gives in total 36,630 estimates of the standard deviation of income shocks and the MA parameter. The first two columns of the table summarise these estimates, listing the mean and standard deviation across the 990 cohort-labour market cells. A potential worry with aggregating to the level of the cohort-labour market, is that much of the standard deviation in income shocks may exist across, not within labour markets or cohorts. If this were the case, the final estimates of the effect of income shocks on child human capital will not be representative of the population as a whole. Therefore, in column 3, the standard deviations of income shocks estimated on the total sample, allowing comparison of cohort-labour market level and population second order moments.

The first row of Table 4 shows that the standard deviation of log initial permanent income is 0.0480. This means that, even controlling for parental education, a polynomial of age and marital status, the initial condition in permanent income has a standard deviation of 5%. The population level standard deviation is similar to the labour market mean, at 0.0679 (or about 7%), suggesting that exploiting cohort and labour market differences in variances of shocks for identification is reasonable.

The standard deviation of transitory shocks at ages 0-17 are reported in the next rows. These tend to be fairly stable at approximately 0.1 standard deviations until the final years of child age when they fall to 0.03-0.06. The standard deviation of permanent shocks is much smaller, as would be expected. Permanent shocks last for a lifetime, therefore a small shock can be very important. The range is between 0.0051 and 0.0141 across the years. Again, the cohort-labour market variances resemble closely the population variances. Recall from above that it is not possible to identify the final variance of transitory or permanent shocks. The MA parameter is high in the total sample, although falls noticeably in column 4, once maternal income is excluded. The MA coefficient in column 4 is very similar to estimates of the income process for males.[25]

[25] Dickens (2000) estimates an ARMA process for transitory income with an AR coefficient of 0.96 and MA coefficient of -0.57. and Moffit & Gottschalk (1995) estimate the MA coefficient of -0.67. These papers are the natural comparison, decomposing the covariance structure of income levels, whereas other papers in the literature estimate the process for first differences in income.

6.3 Effect of shocks on adolescent outcomes

An innovative aspect of this paper is estimation of the effect of the household permanent and transitory income shocks upon child outcomes. This section documents the results, examining whether the realisation of transitory and permanent income shocks will have a heterogeneous effect upon child outcomes, depending upon the age of the child at realisation. The variances of transitory and permanent income shocks across child age are applied to equation (8) to estimate the effect of the income shocks upon child human capital outcomes. The human capital equation (6) allows the effect of income shocks to vary across child age. Before estimating this complex model, it is interesting to restrict the coefficients to be homogeneous across child age, estimating the following function

$$h_{iT} = \delta_0 + \delta_1 P_{i0} + \delta_2 \zeta_{it} + \delta_3 \varepsilon_{it} + \mu_{i0} + u_{iT}; \qquad t = 1, .., 16.$$

A panel data is constructed at the cohort - labour market - child age level. Regression results are reported in Table 5. There are15840 observations (90 labour markets, 11 cohorts, for ages 1-16).[26] Two different functional forms are estimated. In columns 1, 3, 5, 7 & 9, the human capital outcomes are estimated as a linear function of the initial level of permanent income (P0), a transitory income shock and a permanent income shock. Columns 2, 4, 6, 8 & 10 include an interaction term of permanent (transitory) shocks with child age thus allowing some heterogeneity in the effect of income shocks across child age. The variable high school dropout has been redefined, to indicate completion of high school, to enable ease of comparison with the other outcomes.

The estimates are standardised so that both the income shocks and the outcomes are expressed in terms of a standard deviation. Put another way, the coefficient represents the standard deviation change in the outcome from a standard deviation change in the income shock.

Starting with the first outcome in column 1, a change in P0 by a standard deviation (5%) is correlated with an increase in completed years of child schooling by 1.177 standard deviations. Columns 3, 5, 7 & 9 show that there is a strong and significant effect of P0 for all other outcomes, except health. This effect is similar regardless of the specification of transitory and permanent income shocks. Raising P0 by 5% is correlated with higher values of years of schooling, probability of completing out of high school, college attendance, IQ and health by up to 1.193, 0.206, 0.156, 0.763, and 0.171 standard deviations respectively. This indicates a strong correlate between family background and child outcomes.

The first column of data for each outcome shows that transitory income shocks improve child human capital (columns 1, 3, 5, 7 & 9), however once the interaction between transi-

[26] It is not possible to distinguish transitory and permanent shocks at age 17.

tory shocks and child age is added, the level effect becomes negative or insignificant. The interaction between transitory income shock and child age is positive - initially there is a negative effect of transitory shocks which is increasing across child age. Permanent shocks have a larger effect on education, high school dropout and IQ, as would be expected from the PIH. The interaction between permanent shocks and child age is insignificant.

Next, the fully flexible model is estimated from equation (8) and the age specific coefficients on the permanent and transitory income shocks and initial permanent income are reported in Table 6a and 6b. Again, the coefficients report the effect of a standard deviation change in the specific income shock, upon the standard deviation change in human capital.

The results of the effect of permanent and transitory shocks across child age are easier to see in graphical form hence additionally, Figures 2a-2j plot the coefficients across age, again in standard deviations of the child outcome.

Initial Condition in Income Examining first how the initial condition in income drives child human capital outcomes, in row 1 from Tables 6a and 6b the log initial level of permanent income (reported as age 0, permanent) has a strong and significant value. This picks up the correlation between family background and child achievement. For years of schooling, the coefficient is 0.3795, meaning that a standard deviation increase in the initial condition is correlated with higher schooling by 0.38 standard deviations, equivalent to 0.93 years of schooling. For the other outcomes, a standard deviation increase in P0 is correlated with an increase in the probability of dropping out of high school, college attendance, IQ and health by 0.2668, 0.3494, 0.2895 and 0.0230 standard deviations respectively (equivalent to an increase of 11%, 17.1%, 0.52 points and 0.04 points for dropout, college, IQ and health respectively). The smallest correlate is on the health outcome. As health is measured on a 9 point scale, with a very large majority of participants receiving the top score of 9, it is not surprising that the measure is not highly correlated with the initial condition. The strong correlation between the initial condition and the parental fixed effect indicates significant dispersion in outcomes by family background at birth in Norway.

Permanent Income Shocks Figures 2a, c, e, g & i plot the coefficients on permanent income shocks realised in every year of the child's lifetime, upon the range of child outcomes. These relate to the columns labelled "Permanent" for ages 1-16 in Tables 6a and 6b.

A standard deviation increase in the permanent shock at age 1 raises schooling by 0.0866 standard deviations. This transmission falls initially across child age, albeit nosily, such that a shock at age 16 has a smaller effect than at age 1, raising schooling by only 0.0019 standard deviations. The larger effect of the permanent shock realised during early years is intuitive, given that the early permanent shock shifts household wealth forever and therefore drive income realisations for all future periods.

A very similar pattern between the transmission effect of permanent income shocks realised across child age, upon the probability of completing high school and college completion, is observed in Figure 2c and 2e respectively. The effect is large at age 1 (a 1 standard deviation increase in the shock raises the probability of completing high school (college attendance) by 0.0599 (0.0659) standard deviations) and the transmission effect declines across child age such that a 1 standard deviation shock at age 16 raises the probability of competing high school (college) by 0.0094 (-0.0077) standard deviations. Again the decline is noisy, with jumps in the effect around ages 2, 6, 9 and 15.

For the outcome IQ in Figure 2g (for males only), the effect of permanent income shocks between ages 1-8 is relatively flat, with a decreasing slope from age 9-16. A pure permanent income effect would lead to a declining curve, but for early years the return to income shocks remains high. One interpretation is that the effect does not fall in early years because as Cunha & Heckman (2007, 2008) suggest, cognitive ability is more malleable in early years and therefore more sensitive to parental income shocks.

Figure 2i shows that there is a noisy transmission effect of permanent shocks upon health, with the coefficients all insignificantly different to zero. It cannot be ruled out that the noisy pattern is due to the poor measurement of health as 85% of the boys achieved the highest score of physical health.

A permanent income shock realised when the child is age 1 is realised in all future income and therefore the declining effect of the shock across child age is intuitive. It changes household wealth for all future periods and therefore has a larger effect upon child outcomes. Thus, the transmission effect of permanent shocks to child human capital behave similarly as the effect of consumption.

However the decline across child age is noisy. There tends to be a jump in the year after birth, at ages 6, 9 and 15. These jumps may coincide with maternal labour supply. For example, permanent income would increase if mothers go back to work after having a child. This raises the question of whether the shocks as estimated in this paper, are truly shocks, or anticipated by the households themselves. If the shock just picks up an expected change in labour supply, then the resulting change in child outcomes (through adjusted parental investment) would not be as the model predicted. One way to overcome this problem would be to run the analysis solely on paternal income, which fluctuates less around maternity leave and child schooling. These results are reported in the following section.

Transitory Income Shocks Turning now to the transmission between transitory income shocks and child human capital, Figure 2b, d, f, h, & j plot the estimates of the effect of transitory income shocks for ages 1-16. Again, the coefficients and standard errors have been adjusted for the standard deviation of the transitory income shocks at each child age. The columns labelled "Transitory" in Tables 6a and 6b report the coefficients and standard errors. There is a relatively constant effect of transitory income shocks across child age and the magnitude of the effect is lower than for permanent shocks. A standard deviation shock increase at age 1 and age 16 raises schooling by 0.0327 and 0.0378 standard deviations respectively. Again the effect on health is instatistically different to zero.

To summarise, there is a large coefficient on the initial level of permanent income, or parental fixed effect, suggesting significant heterogeneity in child outcomes which is determined at the birth of the child. This is interesting, as often Norway is considered a very equal country, with a compressed income distribution. However, the evidence suggests large variance in outcomes driven by a family initial condition.

Two findings, that the transmission of transitory shocks to outcomes is constant across age, and of a lower magnitude than permanent shocks, are consistent with the PIH. The annuity value of a permanent income shock at age 1 is greater than for a transitory shock.

Interestingly, the coefficients of the permanent and transitory income shocks converge towards the final period. This is consistent with the idea that a permanent shock in the final period of human capital investment should drive human capital to a similar degree as a transitory income shock in that period. Moving towards the terminal period of human capital accumulation, the annuity value of the permanent and transitory shock aligns and so therefore does the effect of the shocks.

6.4 Paternal Income

The above analysis is repeated using paternal income shocks rather than shocks to the sum of maternal and paternal income. The effect of a household permanent income shock declines noisily across child age. These jumps may coincide with a change in maternal labour supply which shifts permanent income. For example, the age 2 jump could reflect ending maternity leave and at age 7 the children started school, freeing up the mothers to enter the labour market. This section estimates the effect of paternal income shocks, excluding any contribution from maternal income. This method does not remove the endogeneous decision of mothers to enter the labour market, as this decision is made jointly with paternal labour supply. However, paternal labour supply is arguably less sensitive to such changes across the child life cycle

Estimated standard deviations of the shocks are reported in Column 4 of Table 4. The variances are slightly higher than for the total sample.

Figures 3a-3e plot the effect of permanent shocks to both household and paternal income upon child outcomes, across child age. As the variance of income shocks differ across household income and paternal income, the coefficient represents the effect of a standard deviation change in household income shock.[27] Indeed, the figures show that when only paternal income is considered, the effect of permanent income shocks falls more smoothly from the age of 1 to 16 than was observed for household income. The paternal permanent income effect lies slightly below the household effect for early years, however the difference is insignificant.[28]

6.5 Liquidity Constrained Sample

If parents face binding liquidity constraints, they will be unable to borrow and save in order to smooth transitory income shocks. Consequently, the effect of transitory shocks will be larger for a liquidity constrained sample. It is interesting to see whether the accumulation of child human capital of liquidity constrained parents responds similarly to consumption, by repeating the above analysis on a group of poor parents, most likely to face credit constraints. To do so, I define a household to be liquidity constrained if their permanent income is in the second decile or below.[29] Permanent income is defined as the sum of real income when the child is aged 0-18.

The standard deviations of shocks for the liquidity constrained sample are reported in Column 5 of Table 4. The standard deviation in the initial condition is lower, as this is a more homogeneous group in terms of income. Variances of the shocks are slightly larger than in the total sample. Again, to compare the effect of transitory income shocks for the liquidity constrained sample, normalisation is by the total sample variance.

Results are in Figures 4a-4e which plot the coefficients for the total sample and for the liquidity constrained (or "constrained") sample. What is instantly obvious from the figures is that, for four outcomes - years of schooling, high school dropout, college attendance and IQ - the effect of the transitory income shocks is *larger* in magnitude than for the liquidity constrained sample, although this difference is insignificant for the latter outcomes. The higher effect is contrary to expectations and suggests that human capital accumulation behaves differently to consumption, for liquidity constrained households. To give an example,

[27] The results are not significantly changed by this normalisation.

[28] There is no statistical difference in the effect of transitory shocks to paternal income compared to household shocks.

[29] Following Souleles (1999).

the effect of a 1 standard deviation increase in transitory income shock at ages 1 and 16 upon years of schooling, is around 0.0327 and 0.0378 standard deviations for the total sample, but is 0.0187 and 0.0168 for the liquidity constrained sample. For the health outcome the effect is again instatistically different to zero.[30]

One interpretation is that when faced with an unexpected change in income, poor households do raise their consumption by a larger proportion than a household in which a liquidity constraint does not bind. However, the types of goods purchased may be different. Attanasio *et al* (2005) analyse the expenditure patterns of parents in receipt of a cash transfer, conditional upon their child's attendance school, in the Familias en Accion programme in Colombia. They find parents use the additional funds to raise consumption of protein rich food and child clothing. Surprisingly, similar findings emerge from studies in more developed countries. Gregg *et al* (2006) found that the result of numerous government policies to raise household income was to enable poor families to catch up their richer counterparts, in terms of clothing and housing costs. Indeed, a report by Farrell & O'Connor (2003) interviewed 37 households receiving the UK Working Family Tax Credit and additionally a survey by Romich & Weisner (2000) on a sample of household receiving the Earned Income Tax Credit in the US, found that recipients spend the additional money on household food consumption and heating homes - necessity goods. As described above, a mechanism through which income shocks are transferred into child human capital is through parental investment. Most developed (and even developing) countries offer a free state education. Therefore, in receipt of an unexpected change in income, the evidence suggests that these poorer household do not raise investment on books and private tuition for their children, as they are not necessities, but rather heat the house, buy clothes and food. This would explain why a shock to income raises schooling outcomes to a lesser extent for poor households than for rich households. Of course, feeding children can also be seen as investment in children and the income shocks have statistically similar effects on IQ in the constrained and the non-constrained households. This interpretation is observationally equivalent to the idea that poorer parents have lower tastes for education.

This finding warrants further research, as there are other explanations which include that the welfare state in Norway insures poor families against income shocks or that poorer households have higher discount rates. It is however unclear why these mechanisms would insure all outcomes except for IQ, as for this outcome there was homogeneity in the effect of both permanent and transitory income shocks for the poor households as for the total sample.

[30] Permanent income shocks have a smaller magnitude between ages 0-4 and 12-16 in the liquidity constrained sample for the outcomes years of schooling, dropout, college and IQ, but no difference for health.

The finding that the stock of adolescent or adult human capital responds less to income shocks for liquidity constrained parents is consistent with existing literature which find high returns from interventions which raise investments in child human capital. For example, Heckman *et al* (2009) find returns of 7-10% from the Perry Preschool Programme, which provided quite intensive treatment for a randomly selected group of disadvantaged African American families. Such a high return could be interpreted to indicate that this group of families are not optimally investing in the human capital of their children. An alternative explanation is that poorer families cannot prioritise investment in child human capital, but rather choose to consume necessity goods. Hence, they are optimising but subject to binding constraints and consequently direct intervention to raise the human capital of children can be very effective.

7 Robustness Checks

A structural model for income generates the results presented above. Section 4 ascertained the correct income process for the sample of parents in Norway, as an MA(1) or MA(2) process for transitory income. This was well identified from a panel of around 400,000 families across 30 years. As a robustness check the effect on results from changing to the income process to an MA(2) in transitory income is analysed in Section 7.1. Sections 7.2 and 7.3 explore the endogeneity of family income, by life cycle profiles of income and the presence of siblings.

7.1 Assuming MA(2) Process for Transitory Income

Section 4 estimated a process for transitory income that was described by an MA(1) or an MA(2). This section tests the sensitivity of the effect of permanent and transitory income upon child human capital to the order of the MA process, by extending to a second order process. That is, $v_{it} = \varepsilon_{it} + \theta_1 \varepsilon_{it-1} + \theta_2 \varepsilon_{it-2}$.

For all outcomes, the results are not statistically different with the two processes for transitory income. The results of the paper are robust to a substantial change in the assumed income process used to decompose shocks into permanent and transitory components.

7.2 Are the shocks unexpected?

The methodology assumes that permanent income shocks are not foreseeable by families. It may be however that fluctuations in income which seem to an econometrician to be a permanent shock were in fact predictable. If parents expected an increase (decrease) in their permanent income in the future, the families may raise (lower) contemporaneous investment in child human capital. Consequently the response of human capital to the realised change in permanent income will be subdued and the estimated effect of the true permanent shock prone to a downward bias.

It is not possible to directly test whether changes in income which are defined as unexpected accord with true expectations. However, it is possible to understand under which conditions the misclassification of income changes would generate the results in the main paper and subsequently test the sensitivity of these results to a change in these conditions.

Take a family which expects an upwards sloping life cycle profile of permanent income conditional on age, education and marital status.[31] The PIH predicts that *ceteris paribus,* this family would borrow early in life and save later in life to optimally smooth investment in child human capital. Interpreting these changes in permanent income as unexpected would lead human capital to seemingly "over-respond" to early low income and "under-react" to later high income. This example would generate exactly the downward sloping profile estimated for the effect of permanent income shocks across child age.

Using the panel on household income I am able to categorise parents into different life cycle profiles and analyse the heterogeneity in the effect of permanent income shocks across groups. If the above results for the effect of permanent income hold for households with non-increasing life cycle profiles, it will be indicative that the methodology does not misclassify foreseeable permanent income fluctuations as unexpected.

Using a randomly selected sample of 40% of households, I run regressions of log household income on the age of the child and the age squared. From the coefficients, I categorise the income profile of each observation (of a parent-child pair) into an increasing profile, decreasing, inverse u-shaped and u-shaped. Then, I repeat the estimation from the bulk of the paper, on the sample of households with an increasing life cycle profile and all other households.

The first point to note is that only 12.37% of households have an increasing life cycle profile, meaning that these are unlikely to be driving the result that permanent income has a declining effect across child age. For the other households, 1.23%, 64.16% and 22.23% of households were categorised as having decreasing, inverse-u and u-shaped profiles respectively.[32]

Results, available upon request, show that for households with a non-increasing profile, there is no statistical difference in the relationship between permanent income shocks and

[31] They may expect a promotion in the following year or know of planned cuts to wage increases.

[32] This does not require the profiles to be significant. If the restriction is added that the profiles are significant, the sample sizes change to 16.23%, 0.52%, 34.70% and 9.15% with the remaining households having a flat profile across age.

child outcomes as in the total sample. The results are robust to the life cycle profile and therefore to the test of the assumption that shocks are unexpected.

7.3 Siblings

Having a child can be seen as an income shock. With another mouth to feed, equivalised income falls and there are spill-overs in investment goods bought for a child. For example, a second child can read the book or learn from the tuition purchased for the first. If this is the case, the effect of an income shock on human capital will be confounded by the presence of other children in the household.

A step to test the bias from multiple children within a household is to select one child families for analysis. With access to the population of Norwegian households, the remaining sample size of 250,440 is sufficiently large to repeat the analysis.

The results show statistically similar effects of permanent income shocks upon all child outcomes.

It is worth noting that in Figures 5a-5e, the age profile of transitory income shocks shows that whilst, from the age of 7 or so, there is a homogenous effect of transitory income shocks, in early years the effect for the total sample lies above the effect for the sample of families having no more children. For health, again, there is an insignificant effect of transitory income shocks for both samples. The results are suggestive that parents who do not have more children are better able to insure their child against early transitory income shocks.

8 Conclusion

This paper has estimated the income process in Norway, for the population of parents having children in the 1970s. Similarly to studies of other countries, Norwegian households' income process is best described by the sum of a deterministic, permanent and transitory component where the permanent component follows a martingale and the transitory a moving average process of order 1 or 2. Given this model for income, the next stage was to estimate annual deviations of log household income from a life cycle profile, and decompose these into yearly permanent and transitory income shocks.

The effect of the shocks was estimated upon a range of cognitive and non-cognitive child outcomes, to understand in which stages of child development the income shocks drive the stock of adolescent human capital. Permanent income shocks have a stronger effect on child outcomes early in life, and the effect falls to zero as the child ages. The reaction of IQ to permanent shocks was slightly different, as the effect failed to fall across the early years of child development. One reason could be that as suggested in the literature, IQ is more malleable in the first five years of a child's life and more sensitive to income shocks. For all outcomes, there was volatility in the declining effect of permanent shocks across child age and running the analysis using just father's income led a large effect of an age 1 permanent shock, which declined more smoothly across age for all outcomes. This result is intuitive, because a permanent shock drives the household wealth and should drive human capital investment by the annuity value of the shock. Therefore, a positive early shock will raise this investment for more periods than a later shock.

There is a small and constant effect of transitory income shocks across child age. The health outcome showed an insignificant effect across child age of both the permanent and transitory shocks, likely due to the crude measurement of health in the data. With the exception of health, in response to household permanent and transitory income shocks therefore, the accumulation of human capital behaves similarly to consumption.

A divergence was noted however, when analysing a sample of liquidity constrained households. Whilst the consumption response to an income shock is expected to be larger for liquidity constrained households, for four outcomes the human capital response is instead smaller (although this difference is significant only for schooling and high school dropout). An interpretation using evidence from numerous studies that suggest when faced with an unexpected income change, poorer households raise their consumption on necessity goods, such as clothing, heating and food. Indeed, with a free state education, investment goods such as high quality schooling or books are not necessities. The policy implication from this finding is that there is market failure in the investment into human capital of children from poorer families. Consequently, direct government intervention to raise outcomes for this group of children can potentially yield a high return, such as that estimated for the Perry PreSchool Programme.

There is a question of generalisability, as Norway is richer and has a lower level of inequality than average. However, as the results still pointed to an effect of income shocks on child outcomes, even this government is not fully insuring the households against income shocks. Therefore, whilst a future research agenda is to carry out the same analysis on countries with a less supportive welfare state, this paper still provides evidence of a lack of full insurance against household income fluctuations, albeit for a sample of households with access to a relatively generous government insurance mechanism.

One caveat with this study is that whilst I observe income shocks and can infer financial investment in children, I do not measure time investment. An appropriate model would see two investment goods, which are potentially substitutes. Parents could respond to a negative income shock by increasing the time or financial investment in their children, therefore insuring the child against the shock. This paper estimates the total effect, leaving analysis of the mechanisms to future work.

Figure 1a

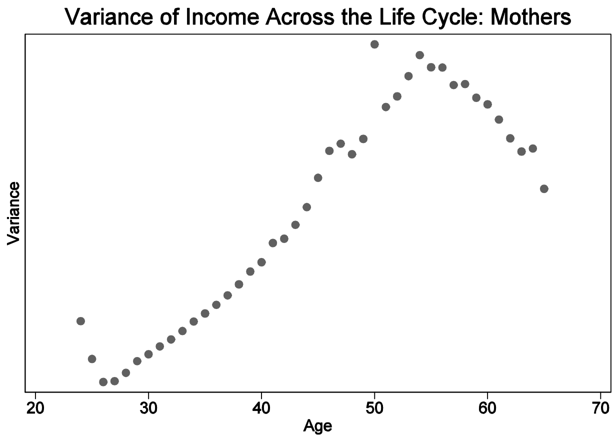
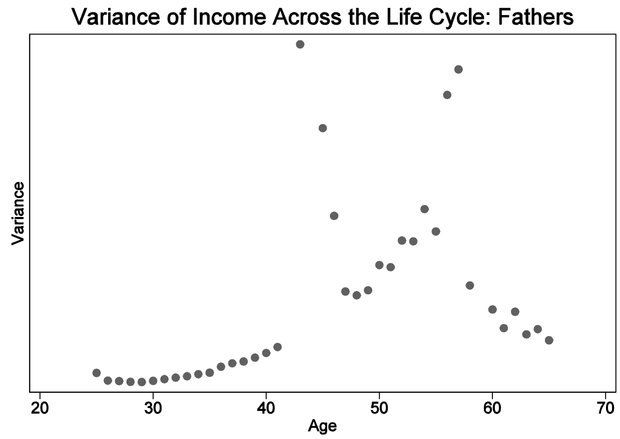


Figure 1b



Note: The life cycle variance for mothers and fathers of the sample.

Figures 2a-2j. The Effect of Permanent and Transitory Income Shocks at ages 1-16 Upon Child Human Capital Outcomes. Household Income.

Figure 2a

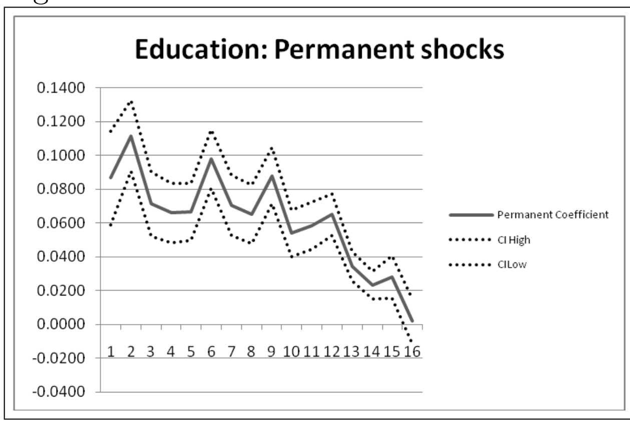


Figure 2b

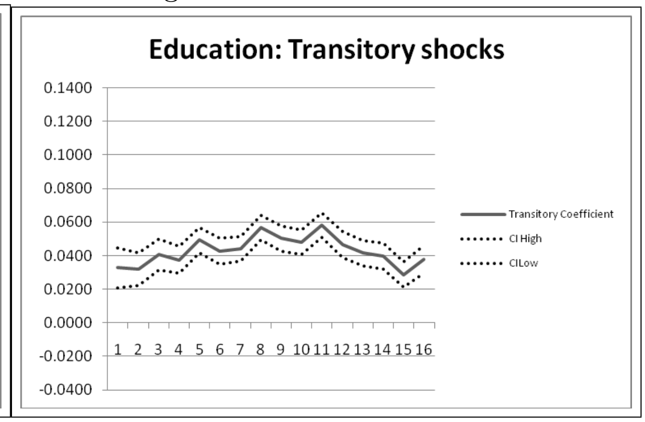


Figure 2c

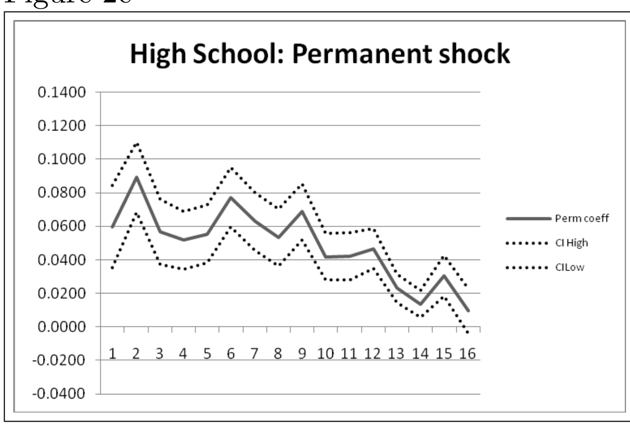


Figure 2d

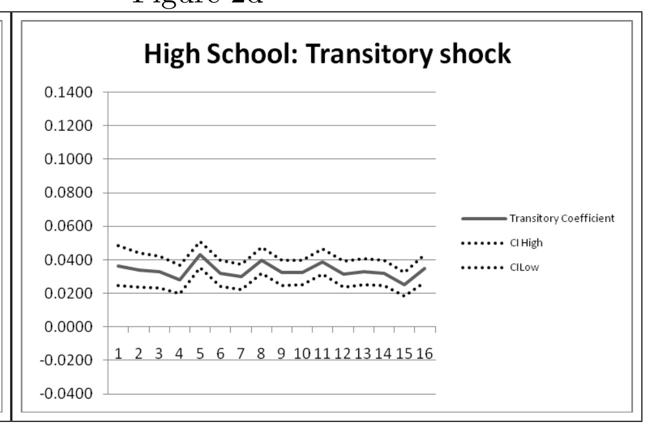


Figure 2e

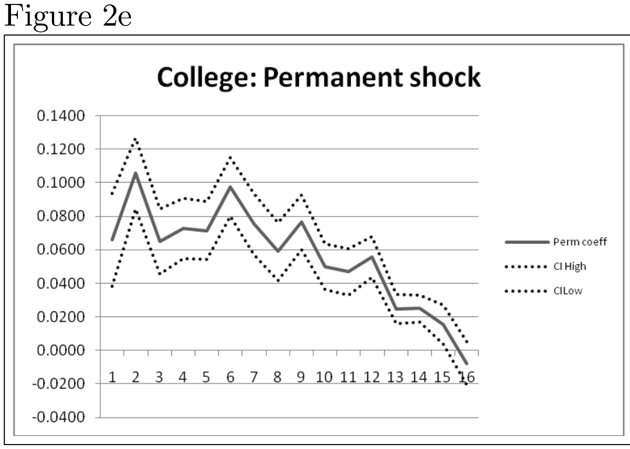
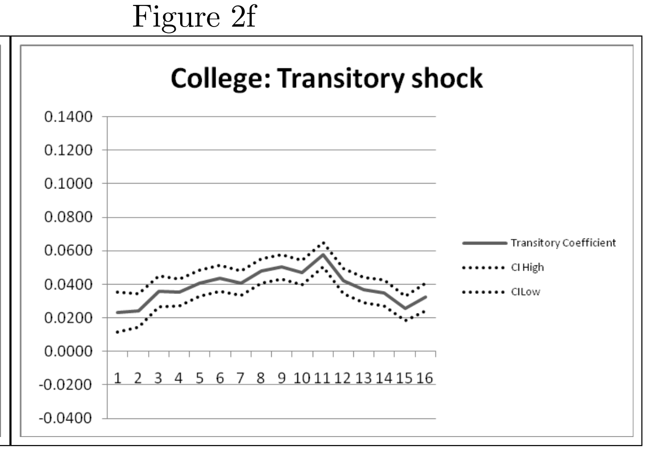


Figure 2f



Note: DWMD model based upon permanent income following a random walk and transitory income MA(1) estimates income shocks. Coefficients represent standard deviations in the child outcome and a 1 standard deviation change in the income shock. Education denotes years of schooling, dropout indicates not leaving school at the compulsory age and college attendance at college/university.

Figures 2a-2j. The Effect of Permanent and Transitory Income Shocks at ages 1-16 Upon Child Human Capital Outcomes. Household Income continued

Figure 2g

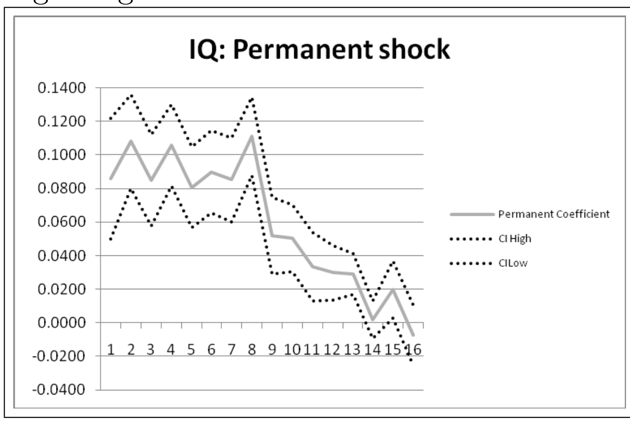


Figure 2h

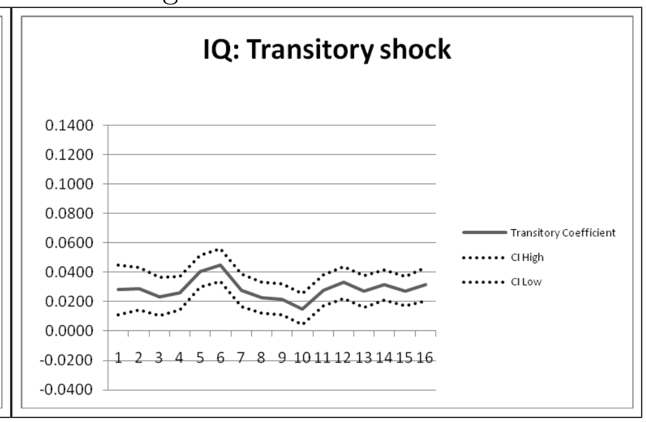


Figure 2i

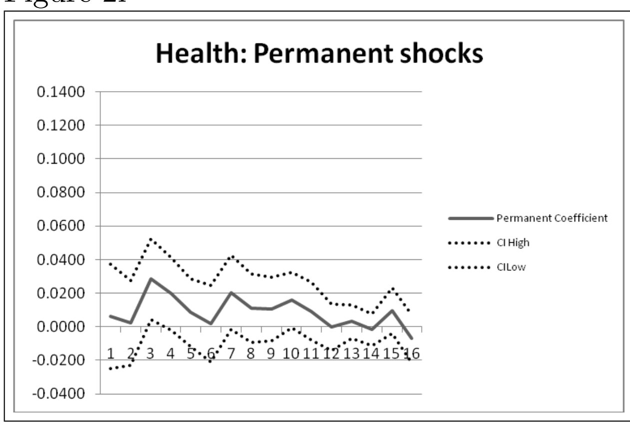
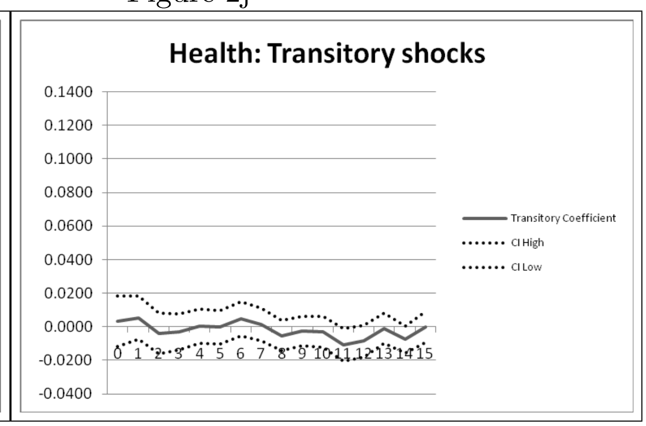


Figure 2j



Note: DWMD model based upon permanent income following a random walk and transitory income MA(1) estimates income shocks. Coefficients represent standard deviations in the child outcome and a 1 standard deviation change in the income shock. IQ and health were measured for males in the Armed Forces Test.

Figures 3a-3e. The Effect of Permanent Income Shocks at ages 1-16 Upon Child Human Capital Outcomes. Paternal and Household Income.

Figure 3a

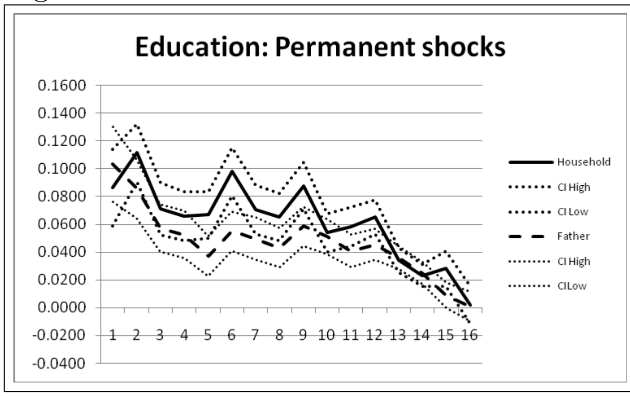


Figure 3b

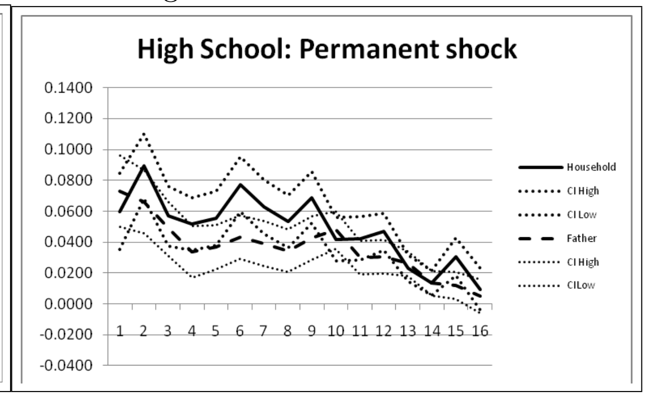


Figure 3c

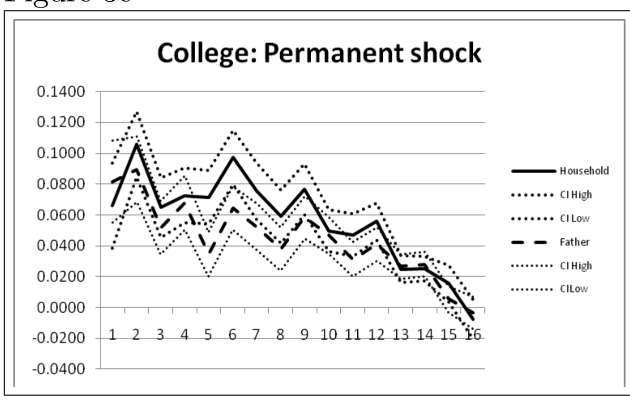


Figure 3d

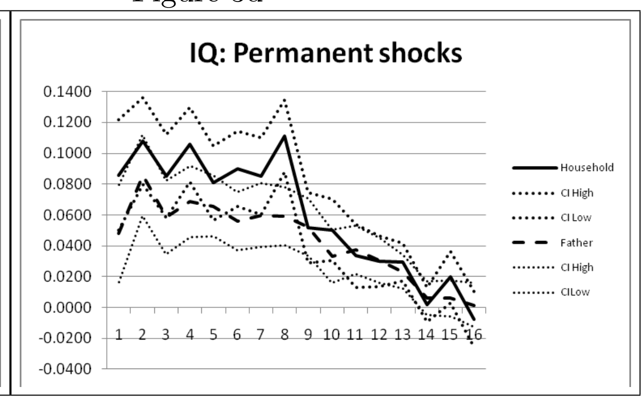
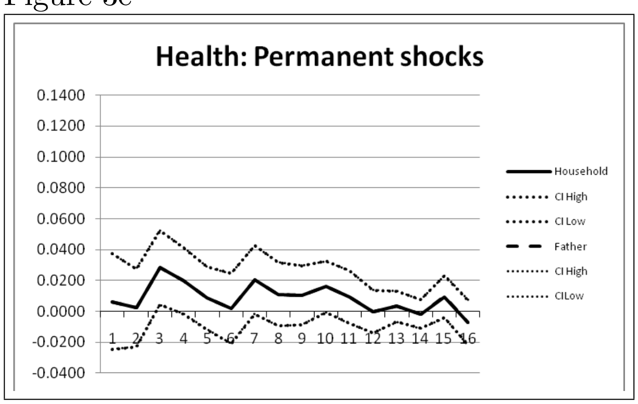


Figure 3e



Note: DWMD model based upon permanent income following a random walk and transitory income MA(1) estimates income shocks. Coefficients represent standard deviations in the child outcome and a 1 standard deviation change in the income shock.

Figures 4a-4e. The Effect of Transitory Income Shocks at ages 1-16 Upon Child Human Capital Outcomes. Liquidity Constrained and Total Samples.

Figure 4a

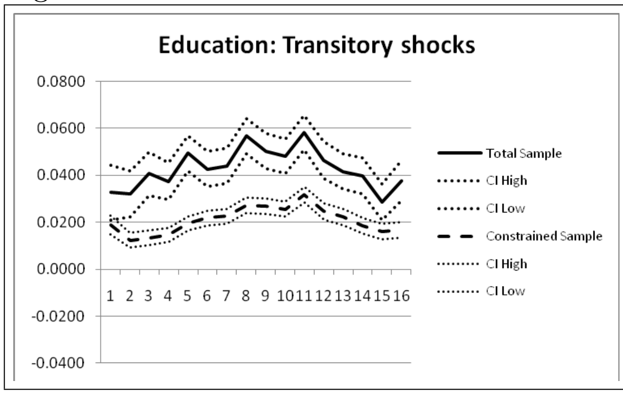


Figure 4b

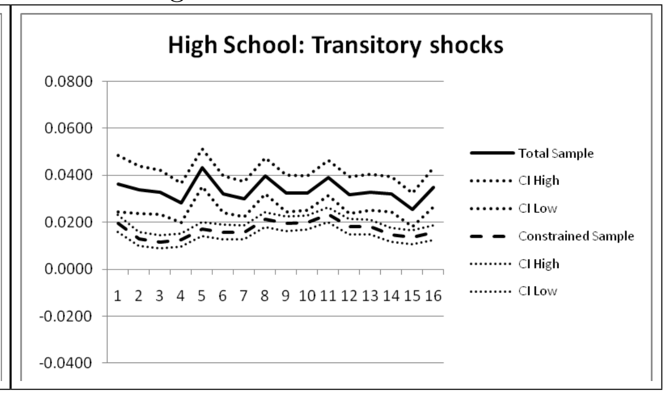


Figure 4c

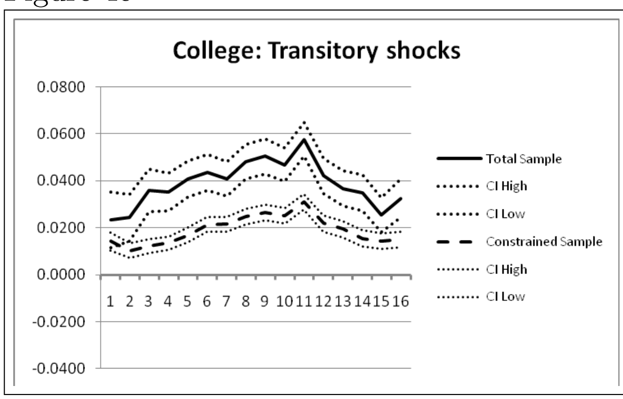


Figure 4d

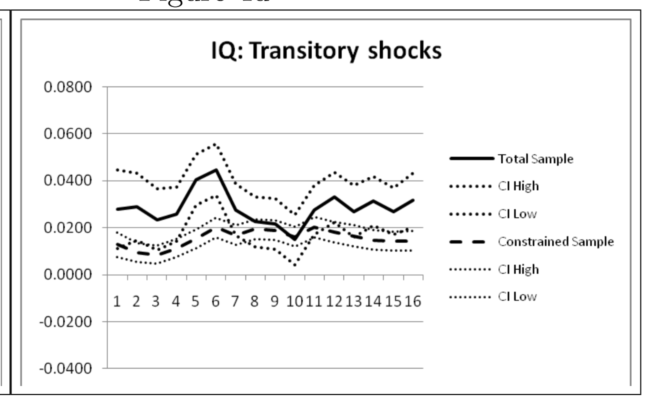
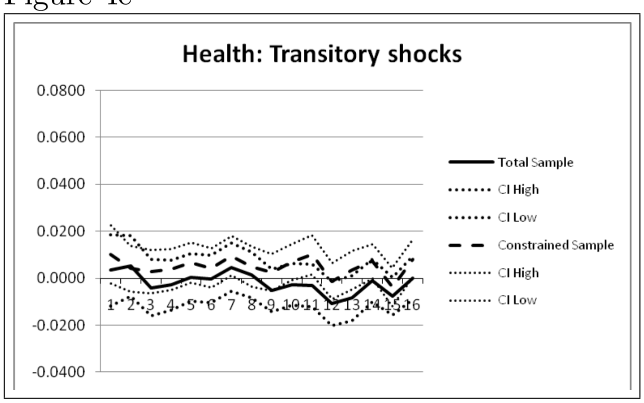


Figure 4e



Note:DWMD model based upon permanent income following a random walk and transitory income MA(1) estimates income shocks. Coefficients represent standard deviations in the child outcome and a 1 standard deviation change in the income shock. Liquidity constrained sample: permanent income in decile 2 or below.

Figures 5a-5e. The Effect of Transitory Income Shocks at ages 1-16 Upon Child Human Capital Outcomes. Total Sample and Single Child Sample

Figure 5a

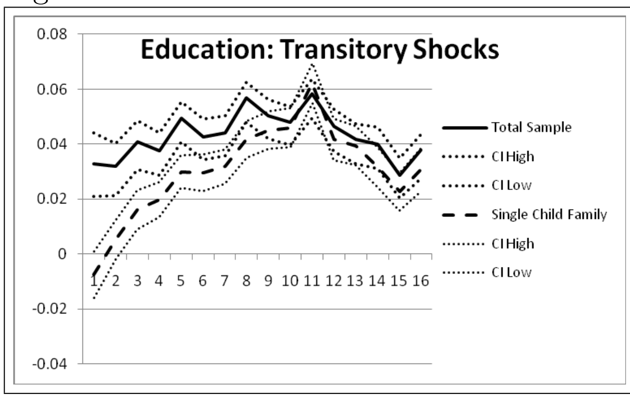


Figure 5b

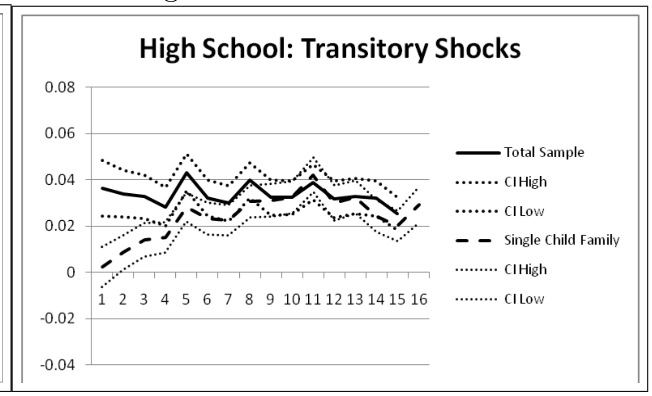


Figure 5c

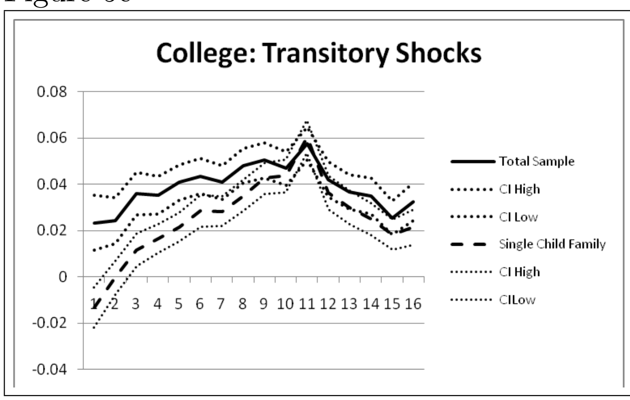


Figure 5d

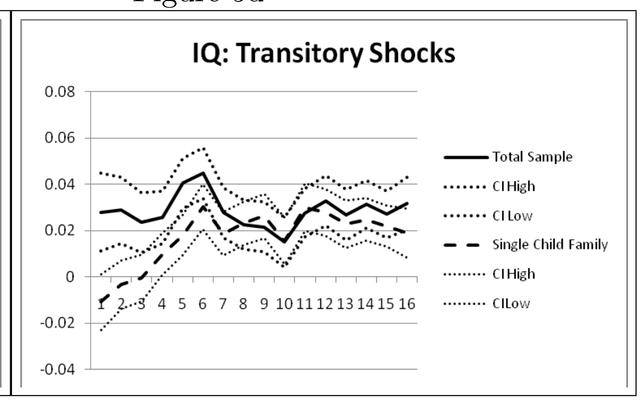
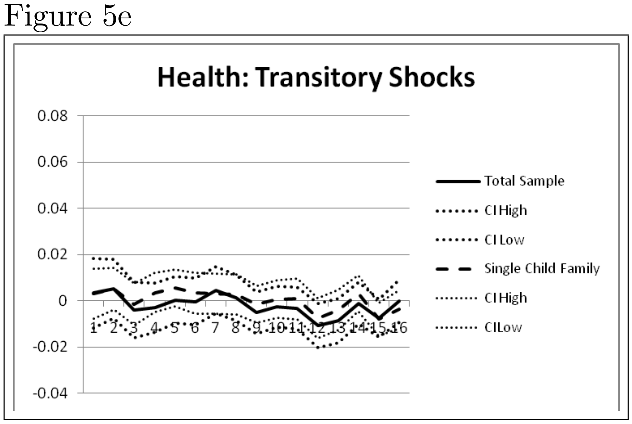


Figure 5e



Note: Single children sample includes 250,440 children. DWMD model based upon permanent income following a random walk and transitory income MA(1) estimates income shocks. Coefficients represent standard deviations in the child outcome and a 1 standard deviation change in the income shock.

Table 1: Sample Descriptives.

Variable	N	Mean	Std. Dev.	Min	Max
Child's education	613522	12.7026	2.4450	8	21
Drop out High School	616210	0.2245	0.4172	0	1
College	616210	0.3893	0.4876	0	1
IQ (males)	290883	5.2081	1.8025	1	9
Health (males)	311163	8.4399	1.5237	1	9

Table 2: First stage regressions of the life cycle profile of income.

	(1) Income First Difference	(2) Income Level
Mother's age	-0.0010	0.0138
	(0.0001)	(0.0002)
Father's age	-0.0058	0.0037
	(0.0001)	(0.0002)
Mother's age squared	0.0000	-0.0001
	(0.0000)	(0.0000002)
Father's age squared	0.0001	-0.00004
	(0.0000)	(0.0000002)
Mother's Education	0.0007	0.007
	(0.0000)	(0.00008)
Father's Education	0.0011	0.0084
	(0.0000)	(0.00007)
Married	-0.0043	0.0006
	(0.0001)	(0.0004)

Note: the dependent variable for column (1) is household first difference log income and for column (2) is household log income. Standard errors in parentheses. Sample includes the 399,603 parents of children born in Norway, 1970-1980. Wage regressions from 1971-2004 in column 1 owing to the first difference specification and between 1970-2004 in column 2. Additional control for municipality of residence.

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Table 3: Autocovariances of residuals from log income differences $\Delta \ln w_{it} - \Delta Z'_{it}\beta$.

Lag	*k*=0	*k*=1	*k*=2	*k*=3	*k*=4	*k*=5	*k*=6	*k*=7	*k*=8
Autocovariance	0.0610**	-0.0145**	-0.0041**	-0.0028**	-0.0009	-0.0011	-0.0001	-0.0005	0.0012
Standard error	(0.0044)	(0.0018)	(0.0012)	(0.0010)	(0.0011)	(0.0010)	(0.0010)	(0.0011)	(0.0009)

Note: The residuals are estimated from a regression of log income on paternal age, education, education squared, marital status and dummy variables for municipality of residence. Each column represents a regression for each lag, estimated in a system of equations across t. Autocovariances restricted to be homogeneous across years. N=399,603 households, between 1971-2000.

Table 4: Variances of Initial Permanent Income, Transitory and Permanent Income Shocks: Household Income.

	Cohort-Labour Market Variances		Total sample	Father Income	Liquidity Constrained Sample
	Mean	Standard Deviation	Mean	Mean	Mean
P_0	0.0480	0.0211	0.0679	0.0494	0.0284
ε_0	0.1093	0.0592	0.1283	0.1250	0.1831
ε_1	0.0780	0.0472	0.1052	0.0893	0.1377
ε_2	0.0842	0.0561	0.1090	0.1008	0.1528
ε_3	0.0821	0.0597	0.1076	0.0991	0.1512
ε_4	0.0915	0.0742	0.1120	0.1096	0.1642
ε_5	0.0998	0.0789	0.1124	0.1135	0.1784
ε_6	0.1064	0.0943	0.1102	0.1277	0.1841
ε_7	0.1123	0.0905	0.1095	0.1454	0.1886
ε_8	0.1168	0.0977	0.1088	0.1596	0.1974
ε_9	0.1157	0.1006	0.1051	0.1607	0.1973
ε_{10}	0.1202	0.0987	0.1007	0.1688	0.2086
ε_{11}	0.1147	0.0968	0.0966	0.1751	0.1908
ε_{12}	0.1086	0.0938	0.0891	0.1676	0.1831
ε_{13}	0.0949	0.0918	0.0785	0.1608	0.1558
ε_{14}	0.0786	0.0829	0.0724	0.1436	0.1306
ε_{15}	0.0580	0.0722	0.0640	0.1219	0.0996
ε_{16}	0.0387	0.0696	0.0496	0.0924	0.0691
ε_{17}	0.0310	0.0394	0.0330	0.0676	0.0597
ζ_1	0.0051	0.0077	0.0036	0.0061	0.0055
ζ_2	0.0065	0.0087	0.0098	0.0071	0.0066
ζ_3	0.0063	0.0089	0.0076	0.0077	0.0063
ζ_4	0.0060	0.0097	0.0070	0.0071	0.0068
ζ_5	0.0056	0.0086	0.0063	0.0074	0.0064
ζ_6	0.0058	0.0093	0.0050	0.0077	0.0072
ζ_7	0.0056	0.0085	0.0041	0.0074	0.0068
ζ_8	0.0063	0.0117	0.0045	0.0086	0.0085
ζ_9	0.0060	0.0101	0.0048	0.0080	0.0087
ζ_{10}	0.0069	0.0127	0.0057	0.0095	0.0102
ζ_{11}	0.0071	0.0145	0.0053	0.0110	0.0111
ζ_{12}	0.0098	0.0191	0.0070	0.0122	0.0159
ζ_{13}	0.0125	0.0301	0.0077	0.0178	0.0193
ζ_{14}	0.0141	0.0347	0.0099	0.0203	0.0212
ζ_{15}	0.0111	0.0268	0.0031	0.0196	0.0225
ζ_{16}	0.0066	0.0210	0.0000	0.0093	0.0131
ζ_{17}	0.0310	0.0394	0.0330	0.0676	0.0597
θ	-0.8336	0.1927	-0.7772	-0.6913	-0.8020

Note: DWMD model based upon permanent income following a random walk and transitory income MA(1).

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Table 5: The Effect of The Timing of Household Transitory Shocks, Initial Permanent Income (P0) and Permanent Shocks upon Child Outcomes: With Restrictions on Coefficients Across Child Age.

	Education		Complete High School		University/College		IQ		Health	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
P0	1.177***	1.193***	0.204***	0.206***	0.153***	0.156***	0.754***	0.763***	0.170	0.171
	(0.152)	(0.151)	(0.021)	(0.021)	(0.035)	(0.034)	(0.145)	(0.146)	(0.103)	(0.103)
Transitory	0.304***	-0.120**	0.048***	-0.011	0.055***	-0.023***	0.181***	-0.088**	0.030	-0.036
	(0.028)	(0.047)	(0.006)	(0.011)	(0.006)	(0.008)	(0.025)	(0.044)	(0.023)	(0.027)
Transitory*age		0.047***		0.007***		0.009***		0.030***		0.007***
		(0.004)		(0.001)		(0.001)		(0.004)		(0.002)
Permanent	0.408***	0.132	0.068***	0.048	0.027**	-0.034	0.240***	0.447*	0.022	0.373**
	(0.055)	(0.253)	(0.013)	(0.044)	(0.011)	(0.048)	(0.082)	(0.258)	(0.056)	(0.182)
Permanent *age		0.008		-0.000		0.002		-0.025		-0.030**
		(0.020)		(0.004)		(0.004)		(0.021)		(0.013)
N	15,840	15,840	15,840	15,840	15,840	15,840	15,840	15,840	15,840	15,840

Note: N=90 labour markets, 11 cohorts, 16 years of child age. Standard errors in parentheses. Dependent variables have been standardised such that the coefficients are expressed in standard deviations of the outcomes. The coefficients on transitory (permanent) income shocks are restricted to be constant across child age in the first specification, and include an additional term of the interaction between the shock and child age in the second.

Table 6a: The Effect of The Timing of Transitory Shocks, Initial Permanent Income (Period 0) and Permanent Shocks upon Child Outcomes: Without Restrictions on Coefficients Across Child Age. Household Income.

	Education		High School		College	
Child Age	Permanent	Transitory	Permanent	Transitory	Permanent	Transitory
0	0.3795		0.2668		0.3494	
	(0.0085)		(0.0080)		(0.0086)	
1	0.0866	0.0327	0.0599	0.0364	0.0659	0.0234
	(0.0141)	(0.0060)	(0.0126)	(0.0061)	(0.0141)	(0.0061)
2	0.1116	0.0320	0.0892	0.0340	0.1056	0.0243
	(0.0107)	(0.0050)	(0.0106)	(0.0051)	(0.0108)	(0.0051)
3	0.0712	0.0407	0.0568	0.0328	0.0649	0.0360
	(0.0097)	(0.0047)	(0.0099)	(0.0048)	(0.0099)	(0.0047)
4	0.0659	0.0375	0.0517	0.0283	0.0726	0.0353
	(0.0089)	(0.0041)	(0.0088)	(0.0042)	(0.0091)	(0.0041)
5	0.0668	0.0494	0.0554	0.0432	0.0715	0.0408
	(0.0086)	(0.0038)	(0.0088)	(0.0040)	(0.0087)	(0.0039)
6	0.0980	0.0426	0.0774	0.0320	0.0975	0.0435
	(0.0089)	(0.0039)	(0.0091)	(0.0040)	(0.0090)	(0.0039)
7	0.0705	0.0441	0.0629	0.0299	0.0755	0.0408
	(0.0091)	(0.0038)	(0.0089)	(0.0039)	(0.0093)	(0.0037)
8	0.0653	0.0567	0.0534	0.0398	0.0591	0.0481
	(0.0088)	(0.0038)	(0.0087)	(0.0039)	(0.0088)	(0.0037)
9	0.0879	0.0503	0.0688	0.0323	0.0765	0.0504
	(0.0085)	(0.0038)	(0.0085)	(0.0039)	(0.0084)	(0.0038)
10	0.0539	0.0480	0.0419	0.0325	0.0498	0.0469
	(0.0071)	(0.0037)	(0.0071)	(0.0037)	(0.0070)	(0.0037)
11	0.0584	0.0582	0.0422	0.0389	0.0469	0.0576
	(0.0072)	(0.0037)	(0.0072)	(0.0039)	(0.0070)	(0.0037)
12	0.0651	0.0465	0.0468	0.0316	0.0558	0.0421
	(0.0063)	(0.0040)	(0.0062)	(0.0040)	(0.0061)	(0.0038)
13	0.0344	0.0416	0.0231	0.0329	0.0249	0.0368
	(0.0045)	(0.0038)	(0.0044)	(0.0039)	(0.0045)	(0.0038)
14	0.0232	0.0398	0.0137	0.0320	0.0250	0.0350
	(0.0041)	(0.0040)	(0.0040)	(0.0038)	(0.0041)	(0.0039)
15	0.0281	0.0286	0.0306	0.0254	0.0155	0.0255
	(0.0063)	(0.0038)	(0.0062)	(0.0037)	(0.0060)	(0.0037)
16	0.0019	0.0378	0.0094	0.0349	-0.0077	0.0325
	(0.0068)	(0.0043)	(0.0069)	(0.0043)	(0.0066)	(0.0042)

Note: standard errors in parentheses. Coefficients and standard errors represent standard deviations in dependent variables and a 1 standard deviation change in the income shock. The permanent shock in year 0 represents P0, the initial level of permanent income. Estimates using household income. DWMD estimates income shocks. Permanent income follows a martingale and transitory income a MA(1) process. Education denotes years of schooling, dropout indicates not leaving school at the compulsory age and college attendance at college/university.

Table 6b: The Effect of The Timing of Transitory Shocks, Initial Permanent Income (Period 0) and Permanent Shocks upon Child Outcomes: Without Restrictions on Coefficients Across Child Age. Household Income.

	IQ		Health	
Child Age	Permanent	Transitory	Permanent	Transitory
0	0.2895		0.0230	
	(0.0114)		(0.0102)	
1	0.0859	0.0280	0.0063	0.0034
	(0.0184)	(0.0085)	(0.0158)	(0.0077)
2	0.1080	0.0288	0.0023	0.0053
	(0.0143)	(0.0073)	(0.0129)	(0.0065)
3	0.0850	0.0235	0.0285	-0.0040
	(0.0138)	(0.0066)	(0.0123)	(0.0061)
4	0.1056	0.0258	0.0197	-0.0029
	(0.0124)	(0.0058)	(0.0110)	(0.0055)
5	0.0808	0.0406	0.0085	0.0003
	(0.0123)	(0.0055)	(0.0103)	(0.0051)
6	0.0900	0.0448	0.0018	-0.0003
	(0.0124)	(0.0056)	(0.0116)	(0.0051)
7	0.0852	0.0277	0.0205	0.0047
	(0.0127)	(0.0056)	(0.0113)	(0.0052)
8	0.1110	0.0226	0.0111	0.0014
	(0.0119)	(0.0054)	(0.0105)	(0.0050)
9	0.0519	0.0216	0.0105	-0.0052
	(0.0117)	(0.0054)	(0.0097)	(0.0046)
10	0.0504	0.0150	0.0160	-0.0026
	(0.0102)	(0.0054)	(0.0085)	(0.0045)
11	0.0335	0.0276	0.0094	-0.0031
	(0.0104)	(0.0053)	(0.0087)	(0.0046)
12	0.0298	0.0330	-0.0002	-0.0108
	(0.0084)	(0.0055)	(0.0071)	(0.0049)
13	0.0293	0.0269	0.0032	-0.0085
	(0.0062)	(0.0056)	(0.0051)	(0.0049)
14	0.0018	0.0313	-0.0017	-0.0010
	(0.0057)	(0.0053)	(0.0048)	(0.0046)
15	0.0198	0.0270	0.0095	-0.0076
	(0.0086)	(0.0051)	(0.0070)	(0.0041)
16	-0.0076	0.0317	-0.0071	0.0001
	(0.0092)	(0.0058)	(0.0074)	(0.0047)

Note: standard errors in parentheses. Coefficients and standard errors represent standard deviations in dependent variables and a 1 standard deviation change in the income shock. The permanent shock in year 0 represents P0, the initial level of permanent income. Estimates using household income. DWMD estimates income shocks. Permanent income follows a martingale and transitory income a MA(1) process. IQ and health were measured for males in the Armed Forces Test.

9 Appendix 1. Estimation by DWMD

Estimation is by minimum distance. For each observation, I observe the scalar h_{iT} and define the dummy variable d_i^h to equal 1 if human capital is non-missing for this observation, and 0 otherwise. Define observations over parental income y_i and the relevant non-missing dummy variable d_i^y as follows

$$y_i = \begin{pmatrix} y_{1,i} \\ y_{t,i} \\ . \\ . \\ y_{T,i} \end{pmatrix} \quad d_i^y = \begin{pmatrix} d_{1,i} \\ d_{t,i} \\ . \\ . \\ d_{T,i} \end{pmatrix} \tag{A6}$$

I define the vector x_i and d_i by

$$x_i = \begin{pmatrix} h_i \\ y_i \end{pmatrix} \quad d_i = \begin{pmatrix} d_i^h \\ d_i^y \end{pmatrix} \tag{A7}$$

The empirical moments are given by

$$\mathbf{m} = vech\left\{\left(\sum_{i=1}^{N} x_i x_i'\right) \oslash \left(\sum_{i=1}^{N} d_i d_i'\right)\right\} \tag{A8}$$

There are $\frac{T(T+3)}{2}$ unique moments. The vector of theoretical moments is given by $f(\Lambda)$ where $\Lambda = \{\sigma_{P_0}^2, \sigma_{\varepsilon_0}^2, \sigma_{\varepsilon_1}^2, .., \sigma_{\varepsilon_T}^2, \sigma_{\zeta_1}^2, \sigma_{\zeta_2}^2, .., \sigma_{\zeta_T}^2, \beta_0^P, \beta_1^P, .., \beta_T^P, \beta_0^T, \beta_1^T, .., \beta_T^T)$.

$$f(\Lambda) = \begin{pmatrix} v*(y_1) \\ cov*(y_1, y_2) \\ cov*(y_1, y_3) \\ . \\ . \\ cov*(y_1, y_T) \\ cov*(y_1, h_T) \\ v*(y_2) \\ . \\ . \\ cov*(y_2, h_T) \\ . \\ . \\ cov*(y_T, h_T) \end{pmatrix} \tag{A9}$$

Choose parameter values to minimise the difference between the theoretical moments, given in the identification section above, and the empirical moments contained in $\mathbf{m}$.

$$\min_{\Lambda} \left(\mathbf{m} - f\left(\Lambda\right)\right)' - \mathbf{A}\left(\mathbf{m} - f\left(\Lambda\right)\right)$$

The weighting matrix $(\mathbf{A})$ is the diagonal from $\left(V^{-1}\right)$, where V is the variance-covariance matrix of $\mathbf{m}$, consequently estimation is diagonally-weighted minimum distance (DWMD).

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