Does economic development drive fertility rebound in OECD countries?

Angela Luci[£], **Olivier Thévenon**[¥]

INED
Institut National d'Etudes Démographiques
133, Boulevard Davout
75980 Paris Cedex 20

First draft.
Please do not quote or cite.
Comments highly welcome.

This version: February 22, 2010

Abstract

We are concerned about the importance of economic development related to fertility in OECD countries. Knowing about the J-shaped relationship between the human development index (HDI) and total fertility rates that was recently found by Myrskylä, Kohler and Billari (2009), we single out the impact of economic development on fertility. We empirically test the hypothesis of a convex impact of economic advancement on fertility, implying a U-shaped pattern of fertility along the process of economic development, using data from the OECD area that spans the years 1960 to 2007. We use a range of econometric techniques, including 2SLS, Fixed Effects and System GMM to deal with left-out variable bias, unobserved heterogeneity, non-stationarity and endogeneity. The empirical results confirm our hypothesis even when controlling for postponement of birth and suggest that the U-shaped pattern between economic development and fertility is dominated by within-country variation. Moreover, we designate a clear turning point in the relationship between economic development and fertility. However, we find that economic development is not sufficient to explain the fertility rebound that could have been observed recently in several highly developed OECD countries.

Keywords: fertility, economic development, gender, endogeneity, stationarity

JEL codes: J11, O1

[£] angela.luci@ined.fr
[¥] olivier.thevenon@ined.fr

1. Introduction

The consequences of economic development on fertility dynamics have given rise to controversial but often negated predictions. An example of this is the pioneering thesis of Malthus who anticipated a more rapid growth in population size than economic development, unless preventive action or economic shocks refrains from having large families. While Malthus predicts a pro-cyclical evolution of fertility, posterior trends showed that long-term increases in economic wealth and income per capita, somewhat boosted by the “industrial revolution”, has combined with a decline in birth rates, a phenomenon that is generally referred as the demographic transition. Hence, newer theories suggesting declining fertility rates during periods of economic prosperity speak rather in favour of counter-cyclical trends in fertility behaviour.

The divergent trends between economic growth and fertility rates are also investigated empirically. Butz and Ward (1979), for example, find that whereas in the USA fertility trends were pro-cyclical before 1960, they turned counter-cyclical from the 1960s on mainly due to a dominating substitution effect caused by rising employment opportunities and wages for women.

However, within the recent decade in many developed countries, a reversal of fertility trends has been occurring and can be observed simultaneously with continuing economic growth. Myrskylä, Kohler and Billari (2009), for example, find a J-shaped relationship between the human development index (HDI) and total fertility rates, suggesting a fertility rebound from a certain level of human development on. However, the use of a composite measurement of human development masks the particular contributions of each of the indicator’s components (GDP per capita, life expectancy and school enrolment). In addition, Myrskylä, Kohler and Billari (2009) do not provide clear empirical estimates for the level of HDI leading to a reversal of the fertility trend.

In order to specifically capture the relationships between economic development and fertility, we leave out the educational and life-expectancy dimensions of welfare that are captured by the HDI and estimate only the impact of GDP per capita (in PPP) on total fertility rates in OECD countries. Based on the findings of Myrskylä et al. (2009) and our descriptive data analysis, we set up the hypothesis of a convex impact of economic advancement on fertility, implying a U-shaped pattern of fertility along the process of economic development. We empirically test our hypothesis using data for OECD countries that spans the years 1960 to 2007.

The novelty our contribution is fourfold. Firstly, we filter out the impact of GDP per capita variations on fertility rates in OECD countries. We use a range of econometric techniques to test the existence of a reversal in the relationship between fertility and economic development. In particular, System GMM is implemented to control for left-out variable bias, unobserved heterogeneity, non-stationarity and endogeneity at the same time. Secondly, we clearly distinguish between within-country trends and between- country variations by using a fixed effects estimation model. Thirdly, our all-in one estimation model allows quantifying a clear minimum level of GDP per capita and fertility at which further economic advancement leads to a rebound of fertility. Fourthly, by designating a clear turning point in the relationship between economic development and fertility, we find that for a series of OECD countries, economic development is not sufficient to explain the fertility rebound that was observed recently.

The outline of the paper is as follows: Section II presents an overview of the existing literature on the relationships between macroeconomic outcomes and population growth in theory. We especially emphasize the two way causal processes linking these two dimensions and the need to control for the endogeneity of economic development to properly assess its impact on fertility rates. In section III, we present the hitherto existing empirical findings of the impact of macroeconomic outcomes on fertility. Section IV discusses our data. In section V, we empirically test our hypothesis that economic development is a key driver for the rebound of fertility in OECD countries. Our empirical investigation is designed to capture within country as well as between country trends. We also control for changes in childbirth timing that can be correlated with a rebound of fertility rates. Finally, section VI concludes by summarising the main findings, by outlining shortcomings and by identifying axes of future research.

2. The links between macroeconomic outcomes and population growth in theory

Over the last decades, in many industrialised countries population growth was characterised by an end of acceleration. A large number of observers consider declining fertility rates as a positive step to increase income per capita. At the same time, some concerns are also conveyed about the negative effects of a continuous decline in fertility rates and an ageing population on economic outcomes and Welfare State sustainability. Yet, a rebound of fertility rates, which can be observed in some highly developed countries, is perceived as positive for welfare state and long-term economic development, provided sufficient resources are invested in human capital.

However, the two-way relationship between population growth and economic development makes it difficult to designate a clear impact of economic outcomes on population growth. Then, to keep track of the possible effects of economic outcomes on population growth, it is necessary to consider also the inverse effects of economic development on population growth. This applies to the theoretical analysis not less than to the empirical investigation.

Let us start discussing the impact of population growth on economic outcomes in theory. While in neoclassical analysis, economic theory suggests a rather negative impact of population growth on economic outcomes, newer growth models suggest a rather positive impact.

The variation in population size stands as a key parameter of the dynamics of economic growth in neoclassical model of "exogenous" growth, going back to the seminal analysis by Solow (1956) His model predicts a negative impact of population growth on macroeconomic outcomes as GDP per capita, which is produced by only two factors: capital and labour. The negative relation is here due to the process of capital "dilution": with a fixed supply of capital and diminishing returns of labour, population growth leads to a "dilution" of capital and hence lowers GDP per worker. In the same line, Coale and Hoover (1958) underline the positive aspects of a reduction of the population size on income levels per capita by emphasising that lower dependency ratios, increased private savings and more capital per worker (capital deepening) make more investments in each individual possible. These arguments are in line with the Malthusian "population trap" argument, which suggests that population growth leads to poverty and pauperisation due to a fixed amount of land for cultivation and the finiteness of natural resources. With the same kind of argument, the World Bank (1984) underlines that the scarcity of resources, generated by rapid population growth, raises competition among individuals and the probability of social conflict and war, as observed in some developing countries during the 1970s. More recent studies mention the deleterious effects of population growth on the environment, which reduce living standards and human welfare (c.f. Kennedy and Cheng, 2007).

The neoclassical arguments suggesting a negative impact of population growth on economic outcomes are counterbalanced by newer *endogenous growth models*. By defining human capital, innovations and technical advancement as a key element of economic growth, these models emphasise the importance of population growth, as population growth increases not only the number of workers available to the economy but also technology transfer and knowledge exchange (c.f . Arrow 1962, Phelps 1966, Lucas 1988, Simon 1981, 1986). In the same line, Boserup (1965, 1981) highlights the human capacity of overcoming resource scarcity by innovations, which stimulates productivity and income growth and consequently reverses the process of “capital” dilution. Robinson and Srinivasan (1997) develop this argument by saying that the environmental degradation caused by population growth can stimulate ecological innovations, which enable sustainability and economic growth to be attained in the middle and long run.

More recent theoretical studies speak in favour of a positive impact of population growth on economic outcomes by accentuating the role of the age structure for a nation’s economic advancement. Changes in the age structure are in fact found to be key drivers of growth patterns but it is not all clear whether the impact is either negative or positive. Empirical researches suggest that an increase of the mean age of society has positive outcomes for economic growth in the short run, while the impact may turn to negative in the long run if the ageing process is accentuated. Even though in the neoclassical framework, an *ageing population* leads to higher savings per capita, which implies a rising GDP per capita (c.f. Artus and Legros, 1999), most recent studies suggest a negative impact of the *demographic transition* on growth. Beaudry and Green (2000), for example, emphasise that an ageing population runs the risk of slowing down the motor for technical innovations which initiate economic growth, as an ageing population disposes of fewer younger generations that adapt new technologies more easily. Furthermore, a demographic transition with fertility levels under replacement level implies very high dependency ratios, which financially strain a country’s social protection system due to an increase in health and pension expenditure (c.f. Blanchet, 1991). Lindh and Malmberg (1996) find that growth patterns of GDP per worker (labour productivity) in the OECD countries are to a large extent explained by age structure changes. The 50±64 age group has a positive influence while the group above 65 contributes negatively to growth, while younger age groups have ambiguous effects.

Finally, knowing about the arguments suggesting a positive as well as a negative impact of population growth on economic outcomes, the *“theory of a country’s optimum population size”* suggest that population growth first increases economic outcomes and then decreases it. This leads to an inversed U-curve for the impact of population growth on economic development. At suboptimal levels of population, there is not enough labour supply to utilise efficiently the available non-labour resources, and hence population growth has a positive impact on economic outcomes as it increases a nation’s work force. At levels above the optimum, population growth negatively impacts outcome levels because a fixed supply of non-labour resources and diminishing returns of labour encounter as population expands. Dynamic effects (new natural resources, capital accumulation or technical change) can shift the curve upward. In the line of the optimum theory, Klasen (1999), Knowles, Lorgelly and Owen (2002) and Galor and Weil (1996) strengthen that there exists a trade-off between the quantity and the quality of the labour force. On the one hand, population growth increases a nation’s “talent pool” and the spill over effects within the workforce, but on the other hand, decreasing fertility sets more money free to invest in the human capital of each individual and enables women to participate in the labour force, which is positive for economic growth.

Let us now discuss the inverse impact of economic outcomes on population growth. Whereas Malthus (1798) suggests that population size increases with increasing food supplies and income levels, main parts of Post-Malthusian demographic theory suggest a negative impact of economic outcomes on population growth. Most studies refer to *microeconomic theory* when it comes to explain the fall in the birth rate with increasing income in developed countries. In general, three main arguments are provided: Firstly, fertility becomes less socially acceptable; secondly, reduced fertility is seen as an advantage providing social and economic benefits; thirdly, effective techniques of fertility reduction are available (c.f. Teitelbaum, 1977, for example).

Becker (1960) interprets fertility reduction in growing countries as a rational behaviour of individuals by explaining that the impact of an increase in income on completed fertility is characterised by the *standard income and substitution effects* of consumer theory: economic growth brings a positive income effect for the demand of children (because the explicit costs are more easily borne) and a negative substitution effect (because the implicit opportunity costs increase). After Becker, rising income leads to a dominating substitution effect, which decreases fertility.

According to *time allocation models* by Mincer (1963), Becker (1965) or Willis (1973), an increase in women's wage income is associated with a higher cost of female time for childcare. Given that child care is relatively time intensive, an increase in the price of time input leads to an increase in the relative cost of the time intensive input. Boserup (1970) highlights that with economic development inducing industrialisation and urbanisation, family networks weaken or dissolve and children become a barrier to women's wage employment.

Quality-quantity models by Becker and Lewis (1973) or Willis (1973) add that an income increase also raises the direct costs of children in terms of education, because in modern societies parents set more focus on children's "quality" to rise the chances of their children, which induces a substitution effect against the number of children in favour of the "quality" per child.

Nevertheless, *life cycle models of fertility (dynamic approach)* highlight that fertility declines might partly be due to a postponement of births, because the opportunity costs of reduced education and professional experience are the highest at relatively early stages in life. Nevertheless, the postponement does not necessarily affect the total number of children a woman has (c.f. Happel et al., 1984).

To sum up, most theoretical models show a variety of plausible opposite mechanisms suggesting ambiguous relationships between economic growth and fertility trends. On the one hand, both the increased "opportunity" cost and the dynamic of growth in the knowledge-based society are clear incentives for parents to postpone births or to invest in children human capital rather than extending family size. However, it is also true that an increase in the average income may boost fertility because of relaxing income constraints binding households' fertility decision and/or because of increased investments in reconciliation policies. Hence, we may expect the first "restraining" effect of growth on fertility to be dominant up to a certain level of economic development and be dominated at a later stage. Different sequences in the dynamic linking between economic development and fertility can so be anticipated and explain recent trends in fertility rates: While in OECD countries restraining effects have been dominant over the last decades, a rebound of fertility has been observed recently in several highly developed countries; leading to a U-shaped pattern of fertility along the process of economic development.

3. Previous empirical findings

The existence of divergent trends between economic growth and fertility rates are also assessed on the empirical side. Butz and Ward (1979), for example, observe that in the US fertility rates were pro-cyclical until the 1960s, but started to decline in a period of persistent economic growth from the 1960s on until the late 1970s, implying an inverse U shaped pattern of fertility along the process of economic development. In the same line, An and Seung-Hoon (2006) find an inverted U-shaped relationship between demographic and economic growth in 25 OECD countries for the years 1960 to 2000.

Butz and Ward (1979) borrow to the New home (neoclassical) economics in order to explain the emergence of counter-cyclical fertility, arguing that the distinction between income and price effects are successful in explaining changes of fertility over time (at least in the US). They propose a unified framework where both pro-cyclical and counter-cyclical variations in fertility are considered, depending on women's position in the labour market. They show that when few women are employed, annual changes in family income consist mainly of changes in the earnings of men. To the extent that the costly activity of childbirth is chosen to occur when family income is high, high-income periods will be high-fertility periods. Alternatively, if a large proportion of the work force is women, annual changes in the earnings, like husbands' earnings, are expected to have a positive income effect on fertility. However, women's earnings also represent a cost of childbearing and rearing, for they come at the expense of time spent at home for childcare that could be used for labour market activities. Hence, when female wages rise, a substitution effect comes to dominate and families substitute against children and in favour of items that require less of the women's time. Good times economically are the most expensive times to have children for women who are employed or about to enter in the labour force. The larger proportion of such women in the population, the greater is the probability that economic growth will be associated with low fertility rates. This is what Butz and Ward (1979) observe in the late 1970s in the US. The authors predict that the process would continue, unless having a substantial increase in the supply of preschool or day-care facilities which might weaken the link between market wages and the opportunity costs of having children.

These arguments have been challenged, however, for several reasons. While some studies like for example by Mocan (1990) still provide figures of persistent counter-cyclical fertility patterns, other studies raise objections to the empirical strategy pursued by Butz and Ward (1979) and propose different estimates that do not confirm the negative impact of real wages and income on forecasted fertility rates proposed by Butz and Ward. (c.f. McDonald, 1983; Krämer and Neusser, 1984; Macunovich, 1995). Moreover, Butz and Ward's (1979) prediction of a continuous fertility decline that goes hand in hand with further economic advancement accommodates only with a limited number of countries. In many highly developed countries, a reversal of fertility trends has been occurring during the recent decade and a rebound of fertility rates back to replacement levels can be observed simultaneously with continuous economic growth and with a continuous increase in women's labour market participation. In many European countries, the negative relationship between fertility and economic advancement has weakened within the last decade even if fertility decisions still conflict with female labour supply and an expansion of family-friendly policies would be necessary to further enhance fertility and women's labour supply (c.f. Ahn and Mira, 2002; Kögel, 2004; D'Addio and Mira d'Ercole, 2005).

Most recently, Myrskylä, Kohler and Billari (2009) argue that a fundamental change has occurred during the last quarter of the last century in the relationships between fertility and human development. Based on both cross-sectional and longitudinal data covering more than 100 countries and the years 1975 to 2005, Myrskylä et al. (2009) estimate the impact of human development (measured by the Human Development index HDI) on total fertility rates using a difference-in-difference estimator which provides stationary time series as well as lagged exogenous variables controlling for endogeneity. They find that the previously negative relationship between human development and fertility has become J-shaped, implying a rebound of fertility from a certain level of human development on. They show that in highest developed countries like the USA, Norway and Ireland, the Human Development Index is positively associated with total fertility rates, although human development continues to promote fertility decline at low and medium development levels. However, as their assessment relies on a composite measure of human development, it is unclear which of the components (GDP per capita, life expectancy and school enrolment) initiates the fertility rebound. Moreover, the difference-in-difference estimators used by Myrskylä et al. (2009)

indeed control for non-stationarity and endogeneity, but do not provide an all-in-one estimation model that allows estimating the turning point in the relationship between development and fertility.

To identify which one of the HDI elements is the driving factor behind the fertility rebound, we estimate the impact of each of the three components of the HDI on fertility separately for OECD countries between the years 1960 and 2007 (see appendix 1 for descriptive data and regression results). We find that among the components of the HDI, GDP per capita has the most important impact on total fertility rates in OECD countries. Therefore, we now want to verify whether in OECD countries, there is a reversal of the relationship between total fertility rates and GDP per capita and if yes, what is the exact minimum level of GDP per capita and fertility.

4. Data discussion

To verify whether highly developed countries are trapped in a downward spiral of low fertility or whether further economic growth implies a rebound back to replacement level, we empirically estimate the impact of GDP per capita on total fertility rates for OECD countries. We use a large macroeconomic panel data set that combines cross country and time series data, including observations of all 30 OECD countries and over four decades.

Data on total fertility rates (births per woman) and GDP per capita in purchasing power parities (in constant 2005 US $) are drawn from the OECD data sets. The total fertility rate represents the ratio between the number of births in a given year and the average number of women of reproductive age. In all OECD countries, the age considered for the calculation of total fertility rates spans from 15 to 49 years. Observations of total fertility rates (*TFR*) and GDP per capita (*GDPpc*) cover the years 1960 to 2007. Table 1 provides an overview of the data.

Table 1: descriptive statistics

variable	obs.	nb.of countries	key time period	mean	std. dev.	min.	max.
TFR	1418	30	1960-2006*	2,19	0,96	1,08	7,26
GDPpc	1072	30	1970-2007'	19812,53	8234,63	2859,9	65001,25

* 2007: obs. from 8 countries only

' 2008: obs. from 1 country only, before 1960: obs. from 3 countries only

Source: OECD datasets

4.1. Trends in total fertility rates in OECD countries

On average for all OECD countries, one can observe a decline in total fertility rates since the 1960s until the 2000s. The mean fell from 3.23 in the year 1960 to 2.71 in the year 1970. In the year 2006, the mean of fertility for the 30 observed OECD countries was 1.65.

The highest fertility can be observed in Mexico in the 1960s (around 7), followed by Turkey in the 1960s (around 6) and Korea in the 1960s (around 5). The lowest fertility can be observed in Korea in 2005 (1,08), followed by the Czech Republic in 1999 (1.13), in Spain in 1995 (1.15) and in Italy, Poland and Germany in 1994 (1.24).

Until the end of the 1990s, in all 30 countries, a continuous fertility decline is observable. Whereas in most countries the most rapid fertility decline happened in the 1960s and 1970s, in Eastern European countries the most significant fertility decline can be observed during the 1990s. In addition, the magnitude of the fertility decline is not homogenous across countries. In some countries like in Mexico, Turkey and Korea, fertility declines from remarkably high levels on whereas in the Nordic countries, fertility declines from much lower levels on.

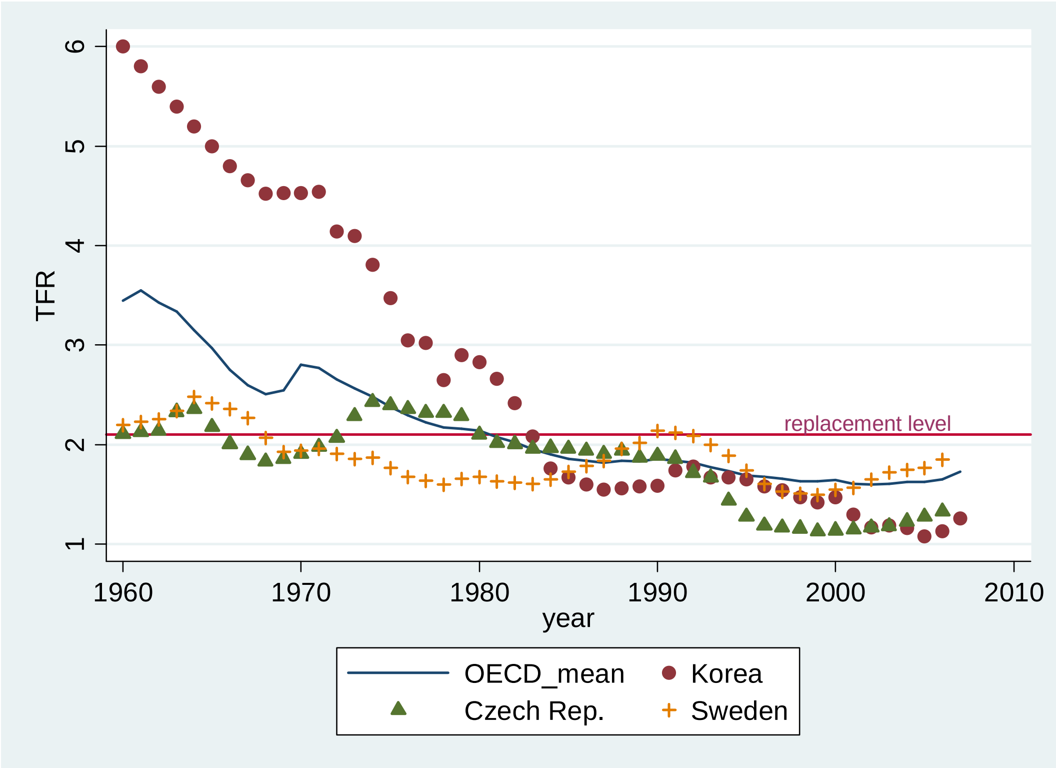
With a mean of 1.65 in 2006 for the 30 OECD countries, fertility is quite far below the replacement level. The replacement level ensures the replacement of the previous generation and therefore population stability under assumptions of no immigration and of no change in mortality rates and corresponds to a total fertility rate of 2,1 children per woman. However, in most observed countries, fertility is on a light rebound since the last decade. Actually, only in Mexico and Turkey, fertility rates fell continuously until 2006, but they remain much higher than in other countries. In Korea - the country with the most remarkable fertility decline - fertility fell from 6 in 1960 to 1.08 in 2005, but since 2005 fertility is on a light rebound (1.13 in 2006; 1.26 in 2007). In most Eastern European countries like the Czech Republic, Poland, Hungary and the Slovak Republic as well as in Germany, Austria, Italy, Ireland, Portugal, Japan and Switzerland, fertility levels are below the replacement level since the middle of the 1990s and stagnate more or less, but in all these countries, one can observe very light sights of an increase in fertility since the most recent years.

In the rest of the countries, increases in fertility rates are clearly observable since the last decade, even though in Belgium, Denmark, Finland, Greece, Spain and Canada, fertility rates were still clearly under replacement level in 2006. However, in France, Luxembourg, the Netherlands, Norway, Sweden, Iceland, the UK, Australia, New Zealand and the USA, fertility rates came back to somewhat around the replacement level in recent years.

Figure 1 shows the evolution of total fertility rates for three selected OECD countries compared to the OECD mean.

In 2006, the lowest low-fertility countries are Korea, the Slovak Republic, Poland, Japan and Germany and the Czech Republic (fertility rates below 1.34). In the same year, the highest fertility can be observed in Turkey, Mexico and the United States (slightly over the replacement level of 2.1). However, whereas in Turkey and Mexico, total fertility rates decline over the whole sample period, total fertility rates in the USA have been on the rebound for the last couple of years.

Figure 1: Fertility trends in Korea, the Czech Republic and Sweden compared to the OECD mean



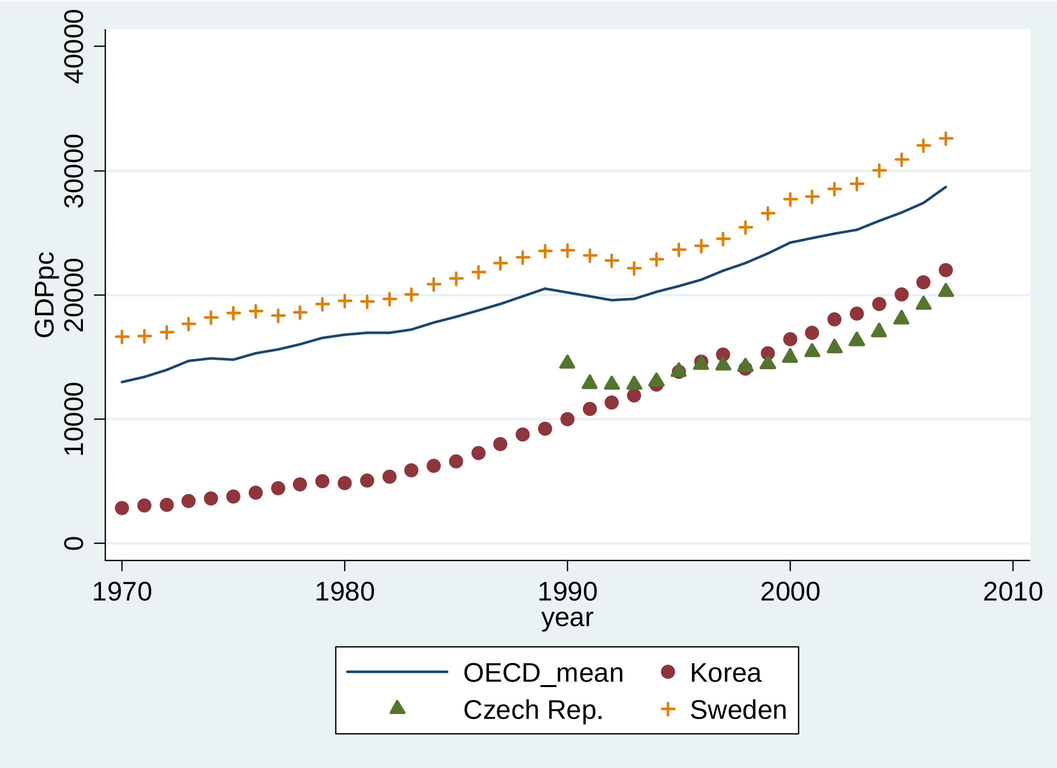
Source: OECD Family Data Base (2009)

4.2. Trends in GDP per capita in OECD countries

On average in all 30 OECD countries, GDP per capita measured in PPP increased from 11915 US $ in 1970 to 28134 US $ in 2007. In all countries, the increase is rather continuous with common breaks around 1975, 1980, 1990 and 2000 due to several economic shocks that touched all countries at the same time, as for example the oil crisis in 1974 and 1979, the Latin American debt crisis in the 1980s, the speculative attacks on currencies in the European exchange rate mechanism, the Gulf crisis and the Eastern Bloc crisis in the early 1990s, the Asian financial crisis in 1997 or the dotcom bubble in 2000.

The highest GDP per capita level can be observed in Luxembourg for the year 2007 (65001,25 US $ PPP). Luxembourg's GDP per capita level significantly overtops the GDP levels of the other observed countries since the early 1990s. Countries with high GDP levels somewhat closer to the average level are Norway, the United States and Sweden, with highest levels in the years 2000. The lowest levels of GDP per capita can be observed in Korea, Turkey and Mexico in the 1970s, followed with some distance by Poland in the 1990s and Portugal in the 1970s. Figure 2 shows the evolution of GDP per capita (in PPP) for three selected OECD countries compared to the OECD mean.

Figure 2: Trends in GDP per capita in Korea, the Czech Republic and Sweden compared to the OECD mean



Source: OECD Family Data Base (2009)

The descriptive analysis shows that whereas until the late 1980s in all observed countries economic advancement went hand in hand with fertility decline, since the early 1990s the picture is threefold: Generally speaking, countries with the lowest income levels record continuous declining fertility rates. Countries with medium income levels record stagnant fertility levels below replacement levels and countries with the highest income levels record a fertility rebound. This observation supports the hypothesis of a U-shaped pattern of fertility along the process of economic development and suggests a convex impact of economic advancement on fertility.

In order to see whether the U-shaped pattern can be observed graphically, we plot the observations of GDP per capita against those of total fertility (figure 3). For this data plot, we drop out some countries with outstanding high and low levels of fertility and of GDP per capita, which are Luxembourg, Korea, Mexico and Turkey, as these countries would over-accentuate the U-shaped pattern. Yet, even without these countries, the data plot suggests a rather U-shaped pattern of fertility along the economic development path, indicating that at low income levels, economic growth lowers fertility whereas form a certain higher level of income on, income growth increases fertility. The data plot also suggests that the negative relationship between fertility and economic development is rather dominated by observations of the 1960s, 1970s and 1980s, whereas the positive relationship is clearly dominated by observations from the 2000s.

Figure 3: GPD per capita against TFR for 26 OECD countries, 1960-2007

Source: OECD Family Data Base (2009)

5. Empirical analysis

Our empirical strategy addresses several challenges. One is to properly isolate country-specific trends from other cross-country differences, and another is deal at best with potential endogeneity of economic development. A large range of econometric specifications are declined for that: OLS, IV-, fixed-effect and System GMM models. Another purpose is to control our estimates for appropriate changes in the timing of fertility. Age at motherhood is introduced as a control variable to test the robustness of our estimates. Moreover, the relationship between fertility and economic development is tested using estimates of fertility trends which are adjusted from tempo variations. Spurious variations in fertility rates and fertility rebound are minimised by using these adjusted estimates and by using moving averages of time series variables.

5.1. Econometric specification

To empirically estimate the impact of GDP per capita on total fertility rates, we propose an estimation model that contains total fertility rates as endogenous variable and GDP per capita as exogenous variable. We use the full data set with observations of all 30 OECD countries, spanning the years 1970 to 2006.

We start estimating a simple linear model with the log of total fertility rates (*lnTFR*) as endogenous variable and the log of GDP per capita (*lnGDPpc*) as exogenous variable, based on pooled OLS. We use the natural logarithm of the total fertility rate (*lnTFR*) and the natural logarithm of GDP per capita (*lnGDPpc*) in order to capture proportional rather than absolute differences in the distribution of total fertility rates and GDP per capita levels, which is standard in most macro-econometric works. The national logarithm reduces absolute increases in the levels of GDP per capita and fertility, but does not represent their growth rates. Only the difference of the natural logarithm would approximate their year to year relative changes. We do not use growth rates but GDP and fertility levels in order to avoid that our estimation results are biased due to an underdevelopment effect. High GDP per capita growth rates can be signs of economic underdevelopment (convergence mechanism) and therewith might be rather associated with a fertility decline than with fertility rebound. Therefore, no clear statements can be made about the impact of GDP growth rates on population growth rates.

In a next step, we add the square of lnGDPpc *(lnGPDpc²)* as exogenous variable to the regression model in order to control for a U-shaped pattern of fertility along the process of economic development.

Our estimation equation for this quadratic model is:

$$\ln TFR_{i,t} = \beta_1 + \beta_2 * \ln GDPpc_{i,t} + \beta_3 * \ln(GDPpc_{i,t})^2 + \varepsilon_{i,t}$$

This all-in-one estimation model allows designating a clear turning point in the relationship between economic development and fertility. To confirm the U-shaped pattern, the estimated coefficient of *lnGDPpc²*, which is β_3, must be significantly positive as an indicator of the curve's convexity (when β_2 is negative). A positive coefficient implies that there is a minimum in the data curve. Furthermore, the estimated coefficients of *lnGDPpc* and its square serve to calculate the minimum level of GDP per capita and fertility at which further economic advancement leads to a rebound of fertility.

Here, we do not only use a pooled OLS regression, but also an instrumental variables estimator (IV) that allows us to control for possible endogeneity. We use lagged variables of *lnGDPpc* as instruments for *lnGDPpc* and lagged variables of *lnGDPpc²* as instruments for *lnGDPpc².* Instead of simply using lagged exogenous variables directly in the estimation equation, we perform the IV-regression in two steps (Two Stage Least Squares Estimator, see appendix 2 for mathematical documentation). We use one-year lags as well as five-year lags. The use of lagged exogenous variables lessens the risk of obtaining biased and inconsistent estimators due to inverse causality between the endogenous and the exogenous variables, because it impedes that *lnTFR* inversely affects *lnGDPpc*. For example, it is not possible that *lnTFR* observed in 2006 impacts *lnGDPpc* in 2001. On the other hand, it is very likely that variations of fertility which lead back to changes in the economic environment appear time-lagged.

However, both the OLS- and the IV-estimation do not account for unmeasured country-specific factors. Consequently, the estimated OLS- and IV-coefficients may be biased and inconsistent due to omitted exogenous variables. Hence, we also use a fixed effects estimation model (FE). By including country specific dummy variables, the FE model allows the exclusion of variables that vary from country to country but are constant over time. Moreover, the fixed effects model captures only within-country variation and therefore does not control for level-differences (between groups of countries of different income levels). However, by introducing country dummies in the estimation equation, the fixed effects model can weaken the significance of the estimated coefficients due to a dummy variable trap. In order to avoid the pitfalls of a fixed effects model, it would be conceivable to use a random effects model. The random effects model captures both within and between-country variation by assuming that country-specific effects that are constant over time are random factors and that the exogenous variables are uncorrelated with the random effect. If this is the case, unobserved country specific variables that are constant over time are captured by an additional residual and the estimators are unbiased and asymptotically consistent. However, a Hausman (1978) test suggests that the difference of the estimation results of the fixed and the random effects models is systematic and that the hypothesis that the country specific variables have no impact on the endogenous variable must be rejected. Hence, for our data the fixed effect specification is superior to a random effects specification in controlling for unobserved country-heterogeneity in the magnitude of the time-series relationship between fertility and economic development. However, the OLS-, IV- and FE-models do not allow controlling for time specific effects. We could use a two way fixed effects model that includes not only dummy variables for every country but also for every year. Yet, this procedure would significantly increase the risk of over-identifying the estimation model (dummy variable trap). Consequently, our estimated coefficients risk being insignificant because the number of instruments is too large relative to the number of observations. In other words, the model would be less efficient due to the increase in the number of parameters that must be estimated.

This is why we also use a one step System Generalized Method of Moments (System GMM) estimator. A GMM estimator is a dynamic panel-data estimator, appropriate to capture both between-country and within-country variation. GMM not only allows omitting unobserved variables that are constant over time like the FE estimator, but also considers possible endogeneity and non-stationarity at the same time. Hence, System GMM reduces the risk of obtaining biased estimators caused by an inverse causality between the endogenous and the exogenous variables and controls for time trends. The control for time trends is important as our OLS, IV- and FE-estimation methods are based on the hypothesis that the time series are stationary. Time series that are marked with a trend would lead to spurious regression and therewith to biased estimates. Graphical tests (correlogram, partial correlogram), an augmented Dickey Fuller (1979) and a Phillips Perron (1988) test for unit root in time series and a Levin, Lin and Chu (2002) test for unit root in panel data suggest the existence of an autocorrelation in some of the time series of *lnTFR* and *lnGDPpc* (graphs and tests not shown here). The tests also suggest that all series are difference stationary.

The GMM method goes back to Arellano and Bond (1991), who obtain additional instruments by introducing first differences of the endogenous and exogenous variables (difference GMM). The differencing process allows leaving out country specific variables that are constant over time and obtains stationary time series. However, differencing magnifies gaps in panels with missing observations. As our data sample contains several missing observations in the time series, we use a one step System GMM estimator that makes orthogonal deviations instead of differencing (based on Arellano and Bover, 1995; Blundell and Bond, 1998). Instead of subtracting the previous observation from the current one, it subtracts the average of all future available observations of a variable to minimise data loss. The System GMM combines the level equation and the difference equation as a "system". The introduction of orthogonal deviations as instruments reduces the risk that the stochastic processes of the exogenous variables are non-stationary and corrects for the endogeneity of the dependent at the same time.

In a last step, we include a lagged endogenous variable ($lnTFR_{i,\ t-1}$) as regressor in the System GMM specification. This allows controlling for the dynamics of adjustment.

5.2. Estimation results

Table 2 shows the estimation results for pooled OLS, IV, FE and System GMM.

Table 2: Estimation results

Endogenous variable:	total fertility rate (**lnTFR**)					
Type of regression:	Pooled OLS	Pooled OLS	IV (2SLS)	Fixed Effects	System GMM	System GMM
Regressors:						
lnGDPpc	-0.380***	-5.484***	-5.574***	-6.081***	-5.485***	-0.222***
	(-22.76)	(-12.83)	(-12.44)	(-20.88)	(-118.03)	(-4.32)
lnGDPpc²		**0.266*** **	**0.271*** **	**0.288*** **	**0.266*** **	**0.0127*** **
		(11.95)	(11.63)	(19.15)	(109.94)	(4.79)
lnTFR$_{t-1}$						0.985***
						(284.25)
constant	4.333***	28.80***	29.19***	32.51***	28.80***	0.951***
	(26.51)	(14.03)	(13.54)	(23.04)	(129.04)	(3.79)
Nb. of observations:	1050	1050	1020	1050	1050	1049
R-squared:	0.33	0.41	0.39	0.41		

t statistics in parentheses, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

When comparing the linear estimation model in the first column to the quadratic estimation model in the second column, we observe that the goodness of fit is much higher for the quadratic model, suggesting that the impact of economic development on fertility is not strictly negative but rather convex. Even though the significantly negative coefficient of *lnGDPpc* in the first column suggest a dominating negative relationship between fertility and economic development, the comparison of the goodness of fit of the two models shows that the quadratic model is more appropriate for our data than the linear model, indicating that the negative relationship turns into a positive one from a certain level of economic development on.

To illustrate this finding more clearly, we re-estimated the linear and the quadratic model based on data without observations of *lnGDPpc* higher than 9.5, as for this reduced data base, a data plot suggest that there is a strictly negative relationship between the two variables. Appendix 3 shows the regression results. Here, the coefficient of *lnGDPpc²* in the second column is not significant, indicating that for this reduced database, the linear model is more appropriate (even though the goodness of fit are somewhat the same in the two models). Following this logic for the full data base, the significant coefficient of *lnGDPpc²* in table 2 indicates that the quadratic model captures the variation between economic development and fertility better than the linear one.

Table 2 further shows that concerning the quadratic model, the coefficient of *lnGDPpc* is significantly negative and the coefficient of *lnGDPpc²* is significantly positive for all estimation methods (column 2 to 6). The positive coefficient of *lnGDPpc²* indicates a minimum in the data area. As *lnGDPpc²* is a function of *lnGDPpc*, the two coefficients can not be interpreted separately. Together, the estimated coefficients indicate a convex process of fertility along economic development, implying that an increase of *lnGDPpc* decreases the fertility for small levels of *lnGDPpc* and increases fertility from a higher level of *lnGDPpc* on.

The IV-estimation results presented in table 2 are based on one-year lags as instruments for the exogenous variables. The estimated coefficients based on five-year lags do not differ much and thus are not presented in particular.

The estimated coefficients of *lnGDPpc* and *lnGDPpc²* of the System GMM estimation in the last column are smaller than those of the other estimation models because lagged levels of *lnTFR* are included as exogenous variable, and therefore around 95% of the variation in total fertility rates is explained by the variation of its own past values. However, the significantly positive coefficient of *lnGDPpc²* of the last column confirms that even when controlling for dynamics of adjustment, the impact of *lnGDPpc* on *lnTFR* is convex.

The fact that the FE regression results are significant indicates that the hypothesis of a convex impact of *lnGDP* on *lnTFR* can be confirmed also for within-country variation only. The goodness of fit of the within-variation is –with 61%- higher than the goodness of fit of the between-variation (19%) and of the overall-variation (41%) of the fixed effects model. It is also higher than the goodness of fit of the OLS- and IV-estimation. The fact that within-country differences in total fertility rates are much larger than differences between countries indicates that the U-shaped curve is dominated by within-country variation. This makes the variation of the total fertility rate vulnerable to time based shocks and periodical deviations.

The descriptive analysis already has shown that measures of GDP per capita are subject to time based shocks and relatively high periodical fluctuations. This also goes for measures of total fertility rates, especially in the former Eastern Bloc. Consequently, we apply a moving average (MA) procedure to flatten these fluctuations. This procedure smoothes out short-term fluctuations and highlights longer-term trends or cycles. The moving average process creates a new series for each variable, in which each observation is an average of the nearby observations in the original series. A simple moving average (SMA) is the un-weighted mean of a certain number of data points and therefore weakens the variation within a certain time period. Furthermore, the moving average procedure reduces the number of missing observations in the data sample. We create uniformly weighted moving average-variables for *lnTFR, lnGDPpc* and *lnGDPpc²* by using two lagged terms and three forward terms of each observation, and by including the current observation in the filter. Then we re-estimate our quadratic model using the MA-variables. Table 3 shows the regression results based on the moving average variables that smooth out short term fluctuations.

Table 3: Estimation results for MA variables

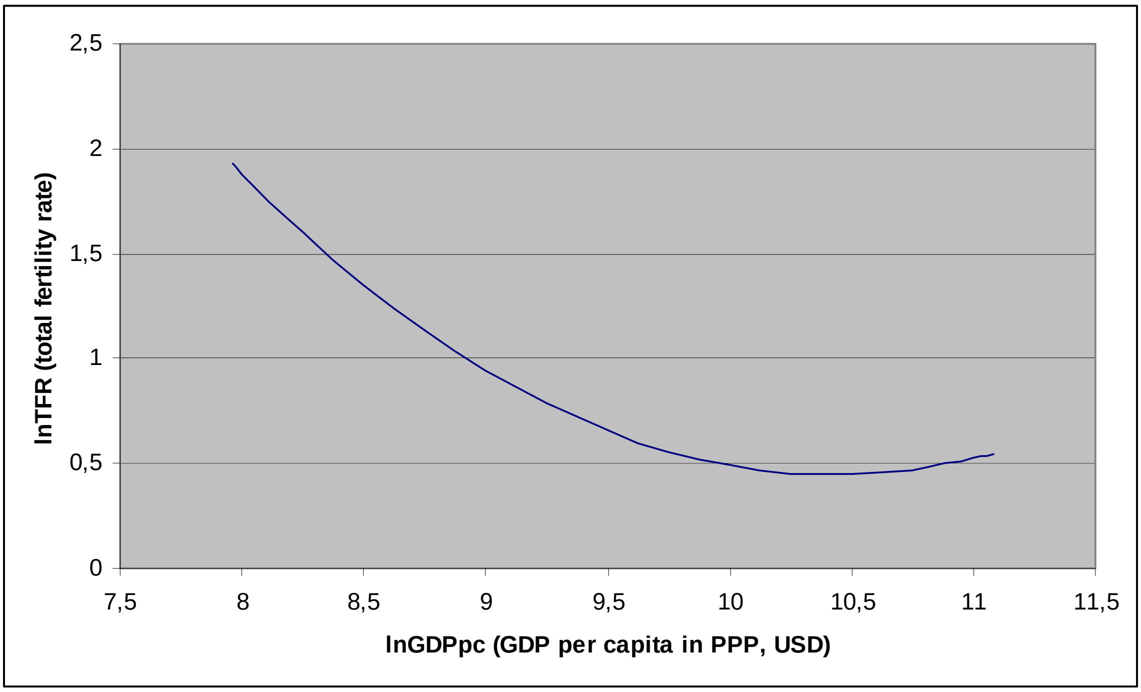
Endogenous variable:	**total fertility rate - Moving Average (*lnTFR_MA*)**				
Type of regression:	Pooled OLS	IV (2SLS)	Fixed Effects	System GMM	System GMM
Regressors:					
lnGDPpc_MA	-5.026***	-5.133***	-5.808***	-5.069***	-0.210***
	(-12.92)	(-12.60)	(-22.30)	(-191.33)	(-21.54)
lnGDPpc²_MA	**0.241*** **	**0.247*** **	**0.271*** **	**0.243*** **	**0.0120*** **
	(11.90)	(11.66)	(20.16)	(176.47)	(23.80)
$lnTFR_{t-1}$_MA					0.989***
					(1439.17)
constant	26.67***	27.15***	31.43***	26.88***	0.901***
	(14.29)	(13.88)	(24.93)	(211.52)	(18.97)
Nb. of observations:	1159	1130	1159	1159	1158
R-squared:	0.43	0.41	0.43		

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

The regression results in table 3 confirm again our hypothesis of a convex impact of economic advancement on fertility, as the coefficients of *lnGDPpc_MA* and *lnGDPpc²_MA* are highly significant.

To illustrate the U-shaped pattern between *lnTFR* and *lnGDPpc,* we calculate the accompanying *lnTFR* for every level of *lnGDPpc* ranging between 7.96 and 11.08, which are the minimum and the maximum of *lnGDPpc* in our data base. Our calculation is based on the estimated coefficients of *lnGDPpc* and *lnGDPpc²* that are shown in column 4 of table 3 (System GMM without a lagged endogenous variable among the exogenous variables). We chose these coefficients because we consider System GMM as the most appropriate estimation model for our panel data due to the simultaneous control for unobserved time-invariant variables, endogeneity and non-stationarity. Figure 4 illustrates a U-shaped pattern between *lnTFR* and *lnGDPpc* with a clear minimum point.

Figure 4: U-shaped pattern between lnTFR and lnGDPpc



Source: own calculations

The figure indicates that the minimum of the curve is located at a *lnGDP*-level of 10.43 and a *lnTFR*-level of 0.44 (see appendix 4 for mathematical documentation). This corresponds to an income of around 34.000 US$ per capita per year (measured in PPP) and a total fertility rate of 1.56 children per woman.

In 2006, only Switzerland, Ireland Iceland, the United States, Norway and Luxembourg have income levels above 34.000 US$ per capita per year (measured in purchasing power parities). Except of Switzerland, in the same year these countries also have total fertility rates above the indicated minimum of 1.56 children per woman.

Among the OECD countries with income levels below 34.000 US$ per capita per year (PPP) in 2006, more than half have total fertility rates below the indicated minimum of 1.56

(Korea, Slovak Republic, Poland, Japan, Germany, Czech Republic, Hungary, Italy, Portugal, Spain, Greece, Austria and Canada).

At the same time, there are a number of countries with income levels below the indicated minimum, which all the same record a fertility rebound above the indicated minimum within recent years (Netherlands, Belgium, Australia, Finland, UK, Denmark, Sweden, France and New Zealand). Among these countries, France, Sweden, Denmark and Finland are the most striking due to their relatively high total fertility rates close to the replacement level, showing that economic development is not sufficient to explain the fertility rebound that can be observed in several OECD countries since a couple of recent years. When discussing other determinants than economic development that are behind the rebound of fertility, several studies emphasise the postponement of childbearing (c.f. Myrskylä, Kohler and Billari, 2009; Bongaarts and Feeney, 1998; Kohler, Billari and Ortega, 2002). These studies suggest that a tempo effect is driving the decline of fertility in developed countries. When women postpone having children, the mean age of childbearing increases and total fertility rates fall - even though the total number of children born by women over their life course might not change. This is why once the process of postponement of childbirth has come to an end, total fertility rates are expected to re-increase.

In order to control for the robustness of our finding of an U-shaped pattern of fertility along the process of economic development with respect to tempo effects, we do our regressions again using the mean age of women at birth and the mean age of women at first birth as control variables. We also re-estimate our regression model using tempo-adjusted fertility rates as endogenous variable. Taking tempo changes into account, tempo-adjusted birth are usually higher than conventional fertility rates.

Data on mothers' mean age at birth (*MAB*) are available for 26 OECD countries, are drawn from the Human Fertility Database[1] and cover the years 1960 to 2007. Data on mothers' mean age at first childbirth (*MA1B*) are available for 29 OECD countries, are drawn form the EUROSTAT database completed by national statistical offices for Japan, Korea, Australia, New Zealand, the USA and Turkey and also cover the years 1960 to 2006. Data on tempo-adjusted total fertility rates are not available form official publications. Therefore, we use data on tempo-adjusted total fertility rates (*adjTFR*) by Bongaarts and Feeney (1998) that are available for 18 OECD countries and cover the years 1961-2005. We use three year moving averages in order to smooth out short-term fluctuations. With 1097 observations that are quite equally distributed over time periods and countries, we consider *MAB* as the variable that allows the most adequate control for postponement in comparison to *MA1B* (702 observations only) and *adjTFR* (519 observations only).

Table 4 shows the regression results for pooled OLS, IV, FE and System GMM with *MAB* as control variable.

[1] The Human Fertility Database (HFD) is a joint project of the Max Planck Institute for Demographic Research (MPIDR) in Rostock, Germany and the Vienna Institute of Demography (VID) in Vienna, Austria, based at MPIDR.

Table 4: Estimation results controlling for mothers' mean age at birth (MAB)

Endogenous variable:	**total fertility rate (*lnTFR*)**				
Type of regression:	Pooled OLS	IV (2SLS)	Fixed Effects	System GMM	System GMM
Regressors:					
lnGDPpc	-2.824***	-2.616***	-10.65***	-2.636***	0.185*
	(-3.93)	(-3.50)	(-20.22)	(-30.32)	(2.02)
lnGDPpc²	**0.140*** **	**0.130*** **	**0.516*** **	**0.130*** **	-0.00809
	(3.83)	(3.44)	(19.28)	(29.51)	(-1.74)
MAB	-0.0310***	-0.0307***	0.00107	-0.0308***	0.00424***
	(-5.01)	(-5.07)	(0.17)	(-39.89)	(5.32)
$lnTFR_{t-1}$					0.973***
					(225.73)
constant	15.65***	14.51***	55.32***	14.72***	-1.151*
	(4.40)	(3.92)	(21.04)	(34.14)	(-2.53)
Nb. of observations:	845	823	845	845	844
R^2	0.08	0.07	0.05		

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

For all estimation methods except of the System GMM estimation including lagged endogenous variables among the exogenous variables (column 5), the coefficient of *lnGDPpc²* stays significantly positive, confirming a minimum in the data area. The estimated coefficients of *lnGDPpc* and *lnGDPpc²* that are shown in column 4 of table 4 indicate a minimum of the curve located at a *lnGDP*-level or around 10 (10.14 to be exact) which is close to the one shown in figure 4 (10.43).

Appendix 5 shows the regression results for pooled OLS, IV, FE and System GMM with *MA1B* as control variable. Despite of the relatively weak number of observations, the coefficient of *lnGDPpc2* stays significant for the Fixed Effects and the GMM model in the third and forth column.

However, taking *MAB* and *MA1B* into the regression model significantly reduces the fit of the model, as the two variables are only weak proxies for mothers' postponement of childbirth. This is why we use the log of tempo-adjusted total fertility rates (*lnadjTFR*) as endogenous variables in the next step, even though the number of available observations is quite limited.

Table 5 shows the regression results with *lnadjTFR* as endogenous variable for our preferred estimation model, which is System GMM without controlling for the dynamics of adjustment. We estimate our model without and with *MAB* and *MA1B* as control variables.

Table 5: Estimation results with tempo-adjusted total fertility rates (3-year MA)

Endogenous variable:	**tempo-adjusted total fertility rates - 3-year moving average (*lnadjTFR*)**		
Type of regression:	System GMM	System GMM	System GMM
Regressors:			
lnGDPpc	-2.743***	-3.163***	-1.949***
	(-14.83)	(-16.48)	(-9.66)
lnGDPpc²	**0.141*** **	**0.166*** **	**0.107*** **
	(14.92)	(16.97)	(10.45)
MAB		-0.0346***	
		(-29.25)	
MA1B			-0.0442***
			(-38.78)
constant	13.96***	16.59***	10.53***
	(15.41)	(17.64)	(10.70)
Nb. of observations:	406	389	358

t statistics in parentheses, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

For all estimations, the coefficient of *lnGDPpc²* stays significantly positive, again confirming a minimum in the data area. Appendix 6 shows that this is also the case when using all exogenous variables as Moving Average variables. The estimated coefficients of *lnGDPpc* and *lnGDPpc²* that are shown in column 1 of table 5 again indicate a minimum of the curve located at a *lnGDP*-level or around 10 (9.73 to be exact). These results confirm the robustness of our findings with respect to possible tempo effects. Changes in the timing of birth are hence not the driving factor of the fertility rebound that is observable in highly developed countries, as even after controlling for postponement of birth, our estimation results indicate a significant convex impact of economic development on fertility.

This convex impact implies that economic development is positively correlated with fertility from a relatively high level of development on. This result suggests that economic development is the driving factor for the fertility rebound that can be observed in Ireland, Iceland, the United States, Norway and Luxembourg. In these countries, the fertility rebound was effectively observed when GDP per capita was over 34.000 US$. However, in France, Sweden, Denmark and Finland, a fertility rebound above 1.56 children per women could have been observed even though these countries had income levels below the indicated minimum. This suggests that economic development is not sufficient to explain the fertility rebound. Hence, it becomes obvious that further research is needed to find out more about the determinants that are behind the rebound of fertility in highly developed OECD countries.

6. Conclusion

The intention of our paper is to assess the extent to which economic development, measured by GDP per capita, can explain fertility rebound observed recently in many OECD countries. In this perspective, we provide analysis of fertility trends in association with economic development. We explore whether and how changes in the economic environment are related to changes in the fertility rates observed in OECD countries during the recent decades.

In a first step, we find that among the components of the HDI, GDP per capita has the most important impact on total fertility rates in OECD countries. In a second step, our descriptive analysis shows that whereas until the late 1980s in all observed countries economic advancement went hand in hand with fertility decline, that there can be observed a real fertility rebound back to replacement level in some OECD countries since the 2000s.

In a third step, we analyse to which extend variations in fertility are connected to the differences in the economic situation in OECD countries. Our empirical findings support our hypothesis of a convex impact of economic advancement on total fertility rates, implying a U-shaped pattern of fertility along the process of economic development. We find that even though there can be observed a dominating counter-cyclical relation between fertility and GDP, in highest developed countries recent economic advancement goes hand in hand with a rebound in fertility back to replacement levels.

Our estimates suggest that total fertility rates reach their low point at 1.56 children per woman. The rebound occurs at GDP per capita levels of around 34 000 US$ (in PPP). This finding is robust when controlling for the postponement of birth. Nevertheless, a closer look at the data shows that in most recent years, there are many countries with GDP per capita levels below and at the same time fertility levels above the estimated turning point. This is the case in the Netherlands, Belgium, Australia, Finland, UK, Denmark, Sweden, France and New Zealand). Among these countries, France, Sweden, Denmark and Finland are the most striking due to their relatively high total fertility rates close to the replacement level. Hence, our hypothesis that economic development is the driving factor provoking a reversal of fertility trends back to replacement levels is not in line with these countries, as for these countries our estimation models can not explain the rebound of fertility sufficiently.

What is then the driving factor behind the fertility rebound in these four countries? One possible explanation might be that in these countries, an increase in GDP per capita, which brings increased labour market opportunities for women, raises women's opportunity costs of having children less significantly than in their neighbouring countries. Given the fact that in France, Sweden, Denmark and Finland not only fertility rates but also women's labour market participation rates are relatively high, it seems that in these countries the possibilities to re-conciliate work and family life for women are more developed than in other OECD countries.

In order to adequately examine macro-determinants of fertility in OECD countries on the basis of a holistic approach, it is necessary to adequately take into account the complex interactions between economic advancement, women's education, women's labour market participation, women's income, and institutional settings like family policies. As the new OECD Family Data Base (2009) provides improved measures of fertility-determinants on the macro level for OECD countries, an in depth-analysis of the driving forces behind the fertility rebound seems to be a fruitful area for future research.

Appendix:

Appendix 1:

HDI components

- Life expectancy at birth, as an index of population health and longevity
- Knowledge and education, as measured by the adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrollment ratio (with one-third weighting)
- Standard of living, as measured by the natural logarithm of gross domestic product per capita at purchasing power parity

Data base for 30 OECD countries

variable	nb. of obs.	time period	mean	data source
				OECD Family Data Base
Fertility rate, total (births per woman)	1418	1960-2007	2,19	OECD Family Data Base
GDP per capita, PPP (constant 2005 int. US$)	1072	1960-2007	19812,53	Word Bank WDI
Life expectancy at birth, total (years)	1199	1960-2007	74,03	Word Bank WDI
Literacy rate, adult total (% of people ages 15+)	38	1975-2007	90,99	Word Bank WDI
Primary school enrolment (% gross)	632	1980-2002	48,57	UN/OECD Family Data Base
Secondary school enrolment (% gross)	617	1980-2002	49,03	UN/OECD Family Data Base
Tertiary school enrolment (% gross)	605	1980-2002	48,7	UN/OECD Family Data Base

Regression results

Endogenous variable:	**total fertility rate (*TFR*)**						
Type of regression:	Pooled OLS	Pooled OLS	Pooled OLS	Pooled OLS	Pooled OLS	Pooled OLS	Pooled OLS
Regressors:							
lnGDPpc	-0.799	-1.013***					
	(-1.54)	(-24.24)					
life expectancy	-0.245		0.0455***				
	(-1.39)		(6.45)				
literacy	-0.0240			-0.0984***			
	(-0.36)			(-8.80)			
primary education	-0.534				-0.257***		
	(-0.35)				(-6.33)		
secondary education	0.224					-0.0721***	
	(0.83)					(-9.11)	
tertiary education	-0.148*						-0.0182***
	(-3.95)						(-6.68)
constant	51.88	11.87***	-1.136*	11.13***	14.29***	5.338***	2.677***
	(0.65)	(28.98)	(-2.17)	(11.01)	(7.24)	(13.74)	(19.92)
Nb. of observations:	12	1050	1177	32	632	617	605
R-squared:	0.91	0.36	0.03	0.72	0.06	0.12	0.07

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

Appendix 2:

IV-regression in two steps (Two Stage Least Squares) with one-year lags

Step 1:

Estimation of a reduced form which regresses the endogenous regressor $\ln G\hat{D}Ppc_{i,t}$ over the instrument $\ln GDPpc_{i,t-1}$:

$$\ln G\hat{D}Ppc_{i,t} = \beta_1 + \beta_2 \ln GDPpc_{i,t-1} + \varepsilon_{i,t}$$

Calculation of $\ln G\hat{D}Ppc_{i,t}$ based on the estimated coefficients in step one.

Calculation of $\ln G\hat{D}Ppc^2{}_{i,t}$ using $\ln G\hat{D}Ppc_{i,t}$.

Step 2:

Estimation of *lnTFR* based on $\ln G\hat{D}Ppc^2{}_{i,t}$ and $\ln G\hat{D}Ppc_{i,t}$:

$$\ln TFR_{i,t} = \beta_1 + \beta_2 * \ln G\hat{D}Ppc_{i,t} + \beta_3 * \ln(G\hat{D}Ppc_{i,t})^2 + \varepsilon_{i,t}$$

Appendix 3:

Estimation results based on reduced data (*lnGDPpc* < 9.5)

Endogenous variable:	**total fertility rate (*lnTFR*)**	
Type of regression:	Pooled OLS	Pooled OLS
Regressors:		
lnGDPpc	-0.726***	4.962
	(-9.46)	(1.63)
lnGDPpc²		-0.319
		(-1.87)
constant	7.532***	-17.79
	(10.79)	(-1.31)
Nb. of observations:	218	218
R-squared:	0.29	0.30

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

Appendix 4:

Quantification of the regression results based on the coefficients of lnGDPpc_MA and lnGDPpc²_MA of the System GMM estimation without the lagged endogenous variable as regressor (table 3, column 4).

$$\ln TFR_{i,t} = 26.88 - 5.069 * \ln GDPpc_{i,t} + 0.243 * \ln(GDPpc_{i,t})^2$$

$$\frac{\delta \ln TFR}{\delta l \ln GDPpc} = -5.069 + 0{,}486 \ln GDPpc$$

$$\frac{\delta FLF}{\delta \ln GDPpc} = 0 \Leftrightarrow \ln GDPpc = 10.43$$

$$\ln TFR_{i,t} = 26.88 - 5.069 * 10.43 + 0.243 * 10.43^2 = 0.44$$

→ **Minimum at *lnGDPpc* = 10.43, *lnTFR* = 0.44**

Appendix 5:

Estimation results controlling for mothers' mean age at first birth (*MA1B)*

Endogenous variable:	**total fertility rate (*lnTFR*)**				
Type of regression:	Pooled OLS	IV (2SLS)	Fixed Effects	System GMM	System GMM
Regressors:					
lnGDPpc	-0.642	-0.299	-9.441***	-0.586***	0.182
	(-0.86)	(-0.39)	(-13.69)	(-5.99)	(1.81)
lnGDPpc²	0.0400	0.0238	**0.464*** **	**0.0374*** **	-0.00794
	(1.07)	(0.62)	(13.40)	(7.56)	(-1.56)
MA1B	-0.0510***	-0.0467***	-0.0273***	-0.0512***	0.00261***
	(-10.30)	(-9.78)	(-4.96)	(-78.22)	(3.54)
$lnTFR_{t-1}$					0.975***
					(175.68)
constant	4.268	2.358	49.12***	3.988***	-1.091*
	(1.17)	(0.63)	(14.37)	(8.27)	(-2.20)
Nb. of observations:	582	563	582	582	582
R^2	0.16	0.16	0.03		

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

Appendix 6:

Estimation results with tempo-adjusted total fertility rates and exogenous variables as MA-variables

Endogenous variable:	**adjusted total fertility rate - 3-year moving average (*adjlnTFR*)**		
Type of regression:	System GMM	System GMM	System GMM
Regressors:			
lnGDPp_MA	-2.394***	-2.571***	-1.556***
	(-13.68)	(-14.20)	(-8.35)
lnGDPpc²_MA	**0.121*** **	**0.135*** **	**0.0861*** **
	(13.59)	(14.59)	(9.08)
MAB_MA		-0.0356***	
		(-31.89)	
MA1B_MA			-0.0451***
			(-44.11)
constant	12.42***	13.85***	8.753***
	(14.50)	(15.62)	(9.63)
Nb. of observations:	430	416	391

t statistics in parentheses, * p<0.05, ** p<0.01, *** p<0.001

References:

Ahn N., Mira P., 2002, "A note on the relationship between fertility and female employment rates in developed countries." *Journal of Population Economic* 15(4): 667-682.

An C., Seung-Hoon J., 2006, "Demographic change and economic growth: An inverted-U shape relationship." *Economic Letters* 92(3): 447--454.

Arellano M., Bond S., 1991, "Some Test of Specification for Panel Data. " *Economic Letters,* 31, 337-341.

Arellano M., Bover O., 1995, "Another look at the instrumental variable estimation of error-component models." *Journal of Econometrics* 68, 29-51.

Artus P., Legros F., 1999, "*Le choix du système de retraite."* Economica.

Arrow, K.J., 1962, "The Economic Implications of Learning by Doing." *Review of Economic Studies,* vol. 29.

Beaudry P., Green D., 2000, "Population Growth, Technological Adoption and Economic Outcomes in the Information Era." Miméo NBER..

Becker, G., 1960, "*An economic analysis of fertility."* Demographic and Economic Change in Developed Countries. NBER Conference Series 11, pp. 209-231.

Becker, G., 1965, "A theory of the allocation of time." *Economic Journal* 75:493-517.

Becker G., Lewis H.G., 1973, "On the interaction between quantity and quality of children." *Journal of Political Economy* 81: S143-S162.

Blanchet, D., 1991, "Modélisation démo-économique: conséquences économiques des évolutions démographiques. " Travaux et Documents, n°130, INED, PUF.

Blundell R., Bond S., 1998, "Initial conditions and Moment Restrictions in Dynamic Panel Data Models." *Journal of Econometrics*, 87, 115-143.

Bongaarts J., Feeney G., 1998, "On the quantum and tempo of fertility", *Population and Development Review* 24, 271-291.

Boserup, E., 1965, "The Conditions of Agricultural Progress." Allen and Urwin.

Boserup, E., 1970, "*Women's Role in Economic Development."* New York: St, Martin's.

Boserup, E., 1981, "Population and Technological Change: A Study of Long-Term Trends." University of Chicago Press.

Butz W. P., Ward M.P., 1979, "The emergence of countercyclical U.S. fertility." *American Economic Review* 69(3): 318-328.

Coale A. J., Hoover E. M., 1958, "Population Growth and Economic Development in Low-Income Countries. A Case Study of India's Prospects." Princeton, NJ: Princeton University Press.

D'Addio-Dervaux, Mira d'Ercole M., 2005, *"Fertility trends and the impact of policies."* Social, Employment and Migration Working Papers, OECD, Paris.

Dickey D.A., Fuller W.A., 1979, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association*, 74, p. 427–431.

Galor O., Weil D.N., 1996, „The Gender Gap, Fertility and Growth." *American Economic Review* 86, 374-387.

Happel S., Hill J., Low S., 1984, "An economic analysis of the timing of children." *Population Studies* 38:299-311.

Hausman, J.A., 1978, “Specification tests in econometrics.” *Econometrica* 46,1251-1271.

Kennedy K., Cheng M., 2007, “Population Growth and Society.” http://www.umich.edu/~gs265/society/populationgrowth.htm

Klasen, S., 1999, “*Does Gender Inequality Reduce Growth and Development?”* World Bank Policy Research Report Working Paper Nr. 7, Washington, DC: The World Bank

Knowles S., Lorgelly P.L., Owen P.D., 2002, “Are Educational Gender Gaps a Brake on Economic Development? Some Cross-Country Empirical Evidence.” *Oxford Economic Papers* 54: 118-149.

Kohler H.-P., Billari F.C., Ortega J.A., 2002, “The emergence of lowest-low fertility in Europe during the 1990s”, *Population and Development Review* 28, 641-681.

Kögel, T., 2004, “Did the association between fertility and female employment within OECD countries really change its sign?” *Journal of Population Economics* 17: 45-65.

Krämer W., Neusser K., 1984, “The emergence of countercyclical US fertility: a note.” *American Economic Review*, 74(1): 201-202.

Levin A., Lin S.F., Chu C.S, 2002, “Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties.” *Journal of Econometrics*, 1-24.

Lindh T., Malmberg B., 1996, "*Age Structure Effects and Growth in the OECD, 1950-90: Further Evidence*", Working Paper Series 1996:12, Uppsala University, Department of Economics.

Lucas, R., 1988, “The Mechanics of Economic Development*.” Journal of Monetary Economics*, vol. 22, pp. 3-42.

Macunovich, D., 1995, “The Butz-Ward fertility model in the light of more recent data”, *Journal of Human Resources*, Spring 1995, (30)2:229-255.

Malthus, T.R., 1798, “*An essay on the principle of population*.” J. Johnson, London

McDonald, J.,1983, “The emergence of countercyclical US fertility: a reassessment of the evidence.” *Journal of Macroeconomics*, 1983, vol. 5, issue 4, pages 421-436.

Mincer, J., 1963, “*Market prices, opportunity costs and income effects.”* In: C.Christ et al., eds., Measurement in economics: studies in mathematical economics in honor of Yehuda Grunfeld (Standford University Press, Standford, CA).

Mocan, N., 1990, “Business cycles and fertility dynamics in the United States.” *Journal of Population Economics*, 3(2).

Myrskylä M., Kohler H.P., Billari F., 2009, “Advances in development reverse fertility declines.” *Nature*, 460(6), doi:10.1038/nature08230.

Phelps, E.S., 1966, “Models of Technical Progress and the Golden Rule of Research.” *Review of Economic Studies,* April 1966.

Phillips, P.C.B., Perron, P., 1988, "Testing for a Unit Root in Time Series Regression" *Biometrika*, 75, 335–346

Robinson J.A., Srinivasan T.N., 1997, *“Long Term Consequences of Population Growth: Technological Change, Natural Ressources and the Environment*.” in: Rosenzweig and Stark (eds.), Handbook of Population and Family Economics, Elsevier.

Simon, J.,1981, “*The Ultimate Resource.”* Princeton, NJ: Princeton University Press.

Simon, J., 1986, “*Theory of Population and Economic Development: Policy Questions*.” Washington, DC: National Academy Press, 1986.

Solow, R., 1956, “A Contribution to the Theory of Economic Growth.” *Quarterly Journal of Economics,* 65-94

Teitelbaum, M.S., 1977, “Relevance of Demographic Transition Theory for Developing Countries.” *Science,* 188, 420-25.

Willis, R., 1973, “A new approach to the economic theory of fertility behaviour.” *Journal of Political Economy* 81: S14-S64.

World Development Report, 1984, pp. 51-206.