Foreign Aid and Its Effect on Per-Capita Income (Growth) in Recipient Countries: Pitfalls and Findings from a Time Series Perspective

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Abstract

In this paper we investigate the effectiveness of development aid in recipient countries. Specifically, we analyze the relationship between per-capita income and foreign aid for a maximum of 131 recipient countries over the 1960 to 2006 period. We employ annual data and 5-year averages and, contrary to the previous literature, carefully examine the time-series properties of the data. The previous literature overlooks the non-existence of a long-run relationship between aid and growth and the presence of autocorrelated error terms. To address those problems, we apply panel time-series techniques (panel unit-root tests, panel cointegration tests, and panel dynamic feasible generalized least-squares estimation [DFGLS]). Estimations with DFGLS show that aid has an insignificant or minute negative significant impact on per-capita income. This holds for countries with both above- and below-average aid-to-GDP ratios, for different levels of human development, different income levels and different regions of the world. We also find that aid has a significantly positive (although small) impact on investment, but a significant negative impact on domestic savings (crowding out) and the real exchange rate (appreciation).

JEL Classification: F35, O11, C23, C51

Keywords: Foreign aid, real per-capita income, panel time-series techniques, dynamic feasible generalized linear least squares (DFGLS)

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1. Introduction

The empirical literature on the foreign aid-growth nexus is vast to say the least. The result on the sign of the relationship is, however, still debated. Even recent surveys of the literature come to sharply opposing conclusions. While Doucouliagos and Paldam (2008 and 2009a) conclude that the aid effectiveness literature has failed to establish that aid works, McGillivray et al. (2005) stress that practically all research published since the late 1990s finds exactly that. In this paper we call the previous results into question. We deal with a fundamental issue often neglected in the literature: the possibility of a spurious relationship between foreign aid and growth based on regressions ignoring the time-series properties of the underlying data.

Accordingly, this paper is concerned with the statistical properties of the series entering the analysis. From the econometric literature it is known that spurious or nonsense regression results can occur if regressions are run between I(0) and I(1) variables, and that in such a case long-run (cointegrating) relationships do not exist (Banerjee et al., 1993 and Baffes, 1997). Given that the dependent variable (growth) is stationary [I(0)] and the explanatory variables (among them, the aid-to-GDP ratio) are non-stationary [I(1)], this might explain why previous studies on the aid-growth relationship have produced mixed results.

Only recently did studies emerge which diligently check the robustness of the results (see Rajan and Subramanian, 2008; Doucouliagos and Paldam, 2008 and 2009a) showing that there exists no systematically robust relationship between aid and growth. This holds across different time horizons, time periods, cross-sectional and panel contexts, types of aid distinguished by use, donor and recipient samples (Roodman 2007a and 2007b).

In our view, the ongoing heated debate on whether or not foreign aid is effective in promoting economic development in recipient countries is in part due to the aforementioned possibility of a spurious relationship as the underlying cause for arguably unreliable estimates (Granger and Newbold, 1974). Aid has been found to have a significant positive impact, both with and

without controlling for other factors or a significant negative impact, depending on what is controlled for (see Section 2).

The majority of the empirical aid-growth literature does not explicitly account for this spuriousness, which is a major drawback to the usefulness of the results. The benefits of an evaluation of the time-series properties of the variables are therefore obvious. Most importantly, it should be determined whether aid and economic development can possibly be cointegrated and therefore converge to a long-run equilibrium. In order to avoid the problems set by spurious regressions we propose to look at the link between per-capita income levels rather than income growth. This is justified by looking closely at the time-series properties of the variables at hand, as will be shown below.

A second danger when looking at the aid-growth relationship, which is linked to nonstationarity, is that of autocorrelation of the disturbances.[1] The problem can be dealt with by feasible generalized least squares (FGLS) estimation. A third problem related to autocorrelation is the problem of omitted-variable bias that can be tackled in various ways (e.g., by auxiliary variables or so-called concomitants (Swamy and Chang, 2002)), to obtain consistent estimators. Amazingly, neither problem has to date been adequately addressed in the existing aid-growth literature (Rajan and Subramanian, 2008). Simply averaging data over time and applying time dummies is not suitable for eliminating the autocorrelation of the error terms and cross-section dummies can only partially solve the omitted variable problem.

A fourth and major flaw in some of the existing empirical literature is the manner with which it treats the likely endogeneity of the explanatory variables. In some work all right-hand side variables are treated as exogenous, or endogeneity is dealt with by (internal or external) instruments. However, the ability to utilize lagged variables as (internal) instruments (as is standard in the GMM procedure) becomes doubtful if series and error terms show signs of persistence (autocorrelation). In this case endogeneity will not disappear by merely replacing

[1] Rajan and Subramanian (2005b) raise the issue of autocorrelation and Roodman (2007a) points to auto-correlation in several studies.

the endogenous variable by its lagged value. In other instances the (external) instruments are weak, either being insufficiently correlated with the endogenous variables or still strongly correlated with the error term (Roodman, 2007a).

In our study we will concentrate on the long-run relationship between aid and per-capita income rather than on aid and growth. We will investigate the aid-growth (aid-per-capita-income) nexus over a period of 47 years (1960-2006) and also examine the short/medium-run impact of aid. We will work with a Solow-type growth model that is compatible with our finding of growth being stationary (I(0)),[2] and we will use aggregate data, as we are interested in studying the aid-per-capita income relationship in a complex environment of institutions, motivations and organizational abilities. Given that data on the latter will not be available for the whole sample period and for all recipient countries in our sample, we are confronted with an "omitted-variables problem," which in a panel data context can be substantial. We will address this by first including country fixed effects, and then correcting, with due caution, for autocorrelation.

Our model is arguably less complex than others, in the sense that it does not offer the insertion of a new interaction term or a new category of aid upon which to focus. This allows us to concentrate on some of the neglected issues, such as the existence of a long-run relationship between aid and income, controlling for autocorrelation, omitted variables bias and endogeneity, as well as the estimation of a short-to-medium-run model in addition to the long-term focus. Since we have a long panel data set at hand, either dynamic ordinary least squares (DOLS) or DFGLS are the methods of choice for treating endogeneity (Stock and Watson, 1993). The application of the GMM procedure could also serve to be a second option to "exogenize" variables but in our case would require averaging the data over time (utilizing five-year averages to reduce the number of instruments before starting the analysis.

[2] I.e., deviations from the steady state are only temporary. The hypothesis of non-stationarity of the growth rate (longer-term growth of real per capita income) over the 1960-2006 period was rejected by the Augmented Dickey-Fuller test.

Surprisingly, these techniques have only been applied to this specific problem without taking account of autocorrelation. Moreover, if a direct long-run aid-income relationship cannot be established with some certainty, we must then estimate the indirect effects of aid in a long-run model and build a short-to-medium-term autoregressive (ARMAX) model in order to quantify the short- and medium-term impact of aid.

To anticipate the results for the long-run relationship between aid and per-capita income, we find that aid has a largely *insignificant impact on the level of real GDP per capita* in our long-run Solow-type growth model.[3] However, our results are not fully robust to the choice of the cointegration test. The inconclusive evidence is in line with the insignificant long-run aid coefficient that we obtain when applying DFGLS. Given that the other explanatory variables of the Solow-type model do all pass the cointegration tests with clear, unanimous results (implying a long-run equilibrium with real per-capita income) we conclude that aid is not part of the cointegrating (long-run) relationship.

Investigating possible long-run transmission channels (indirect links) between aid and per-capita income, we observe that the impact of aid on investment is positive, but very small. Its impact on the domestic savings-GDP ratio is negative (although again quite small), which indicates some crowding out of domestic savings. Furthermore, we find that capital inflows (aid being one component of them) lead to a slight appreciation of the real exchange rate in the long run. This finding, together with the very small positive impact on investment and a small crowding-out effect with respect to domestic savings, might result in an insignificant impact on the level of real per-capita GDP in the long run. As for reverse-causality between aid and per-capita income, we find that – on the one hand – aid Granger-causes[4] the level of real per-capita GDP in the short run (the impact is positive but extremely small) together with population growth and internal and external saving. On the other hand, per-capita income

[3] Unless otherwise mentioned, we refer to the 10%-level of significance throughout.

[4] Causality in the sense that series on the right hand side precede the series on the left hand side in time (see Granger, 1969).

does not Granger-cause aid at conventional significance levels in the short term and the relationship is therefore unidirectional going from aid to income. This finding leads us to look for a short-to-medium-term run relationship between aid and real per-capita income. Contrary to what is argued in much of the recent literature, we also find that the impact of aid on real per-capita income is linear. The non-linear model is rejected in our study.

The outline of the study is as follows. After addressing the related literature in Section 2, we motivate and derive the empirical growth model in Section 3. Section 4 presents the empirical findings. In Section 5 the results will be evaluated from an economic policy and an econometric point of view.

2. The literature

A multitude of studies has examined the effectiveness of aid in terms of increases in real per-capita GDP or growth and analyzed the effectiveness of aid in terms of reaching the Millennium Development Goals (MDGs). However, the question of whether aid increases per-capita income and enables a self-sustaining growth process in recipient countries remains open. Morrissey (2001), Hansen and Tarp (2001), Easterly (2003, 2006), Easterly, Levine and Roodman (2004), and Pattillo et al. (2007) concentrate on studying the effectiveness of aid in terms of promoting real GDP growth in recipient countries, with mixed results. Morrissey (2001), McGillivray et al. (2005), Sachs (2006), Reddy and Minoiu (2006), and Minoiu and Reddy (2007) point to a positive growth effect of development aid, even independent of the quality of economic policies prevailing in recipient countries. The (in-)famous results by Burnside and Dollar (2000) suggest that aid promotes growth only in an environment of "good policies." Following Burnside and Dollar, the bulk of recent research has focused on the significance (or the absence) of certain conditions in the recipient country. The "good policy" model, in which aid is effective only when the recipient-country government already pursues growth-promoting policies, has been very influential in shaping aid allocation

procedures of major multilateral development agencies and bilateral donors. Sen (2006) and Tarp (2006) stress that aid is beneficial if properly administered. Related research considers the effectiveness of aid to be dependent on the existence of certain features of recipient countries, such as the share of a country's area that lies in the tropics (Daalgard et al., 2004), the level of democratization (Svensson, 1999), institutional quality (Burnside and Dollar, 2004), political stability (Chauvet and Guillaumont, 2004), vulnerability to external shocks (Guillaumont and Chauvet, 2001), and absorptive capacity (Chauvet and Guillaumont, 2004). However, Easterly et al. (2004), Rajan and Subramanian (2008), and Doucouliagos and Paldam (2009b) show that these results are fragile, being sensitive to small changes in the data set or in the model specification.

Other empirical studies have even pointed to a negative long-run growth effect of aid (Svensson, 1999; Svensson, 2000; Ovaska, 2003; Easterly, 2006). Doucouliagos and Paldam (2008 and 2009a) conclude that the aid effectiveness literature has failed to establish that aid works. The insignificant long-run effect is potentially due to weak institutions, increased corruption, a dwindling willingness to raise taxes (Knack, 2004; Rajan and Subramanian, 2007) and real exchange-rate appreciation (Rajan and Subramanian, 2005b) in the recipient economies. It is argued that real exchange-rate overvaluation, which eventually harms exports and the import-substitution sectors, is brought about by the aid inflow, which affects the capital account under both flexible and fixed exchange-rate systems.

An intermediate perspective is taken in the so-called "medicine" model (Jensen and Paldam 2006) that sees some levels of aid as growth-promoting, regardless of recipient government policies. However, at higher levels of aid, the marginal effect on growth becomes negative so that aid is less effective, and perhaps even harmful (Hansen and Tarp, 2000). However, this model, too, has recently been shown to be quite fragile, and seems to depend on author ideology (Doucouliagos and Paldam (2009a).

It is sometimes argued that the motivation with which aid is given (McGillivray, 2003) and the type of aid given (Clemens et al., 2004; Reddy and Minoiu, 2006) have an impact on the effectiveness of aid. It has also been argued that some donors might be more effective in promoting growth than others, as an example, because their aid is not given for strategic or commercial reasons.[5] Results may even depend upon the specifics of how aid flows are measured.[6]

Likewise, it has been argued that aid given for different sectors of an economy might have a different impact on per-capita income (Clemens et al., 2004). For example, Dreher et al. (2008) examine sectoral aid, rather than aggregates, and investigate how aid given for education affects educational outcomes.[7]

Also, while it is clear that the short-run impact of aid on growth may differ from its long-run impact (Clemens et al., 2004) and that aid may impact positively or negatively in the short run, depending upon the project or its macroeconomic side effects (Roodman, 2007a), the estimation of the long-term impact of aid should be the focus of empirical studies even though this impact is much more difficult to analyze than the short- to-medium-term impact of aid. As in the long run variables might influence each other, a bi-directional relationship between aid and economic development is more probable over longer periods of time[8].

[5] For the United States and Japan, geopolitical and commercial interests, respectively, seem to be the most important determinants of aid (Alesina and Dollar, 2000). Berthélemy (2006) finds that "all donors are not the same" with respect to various indicators of recipient need, as well as donor interests. Multilateral institutions seem to generally pay greater attention to recipient needs than bilateral donors do (Burnside and Dollar, 2000; Alesina and Dollar, 2000). Canavire et al. (2006) find no indication that donor countries were able to push through their individual trade and political interests at the multilateral level. However, various other studies suggest that multilateral institutions are also not invulnerable to donor pressure (Weck-Hannemann and Schneider, 1981; Frey and Schneider, 1986; Fleck and Kilby, 2006; Kilby 2006, 2009; Dreher, Sturm and Vreeland, 2009, 2010; Dreher and Jensen, 2007).

[6] See, for example, the discussion in Clemens et al. (2004) concerning effective development assistance versus official development assistance.

[7] See also Michaelowa and Weber (2006) on whether aid for education raises primary enrollment rates and Mishra and Newhouse (2007) for a study on the relationship between health aid and infant mortality.

[8] Based on our data, aid and economic development Granger-cause each other in the long run. In the short run, in contrast, aid Granger-causes real per capita income, but income does not Granger-cause aid.

3. Empirical growth model

3.1 Aid and per-capita income versus aid and growth

Following Cellini (1997) we apply a lean Solow-type model, based on non-stationary [$I(1)$] variables, with a stochastic steady state. We relegate time-varying unobservable or unquantifiable country characteristics (of the above-mentioned type) into the error term ($e^{u_{i,t}}$). In contrast to Cellini's model, our model reflects an open economy that allows for external financing. It is assumed that external savings are used to (at least in part) finance domestic investment. The capital stock in the recipient country's economy (the domestic capital stock) can be either domestically financed (by domestic savings (private and public), externally financed (without a grant element; by net external savings – i.e., external savings minus foreign aid), or externally financed by official development assistance (ODA) or net aid transfers (NAT). NAT – computed by David Roodman (Roodman, 2008) – is our preferred measure of aid for the reasons given in Section 3.3 below. The domestic capital stock then consists of domestically financed physical capital (K_1), externally financed physical capital following market conditions (K_2), and externally financed physical capital involving a grant element (K_3):

$$K=K_1+K_2+K_3 \tag{1}$$

The output equation that assumes constant returns to scale then reads as follows:

$$Y_{i,t} = K_{1i,t}^{\alpha_1} \cdot K_{2i,t}^{\alpha_2} \cdot K_{3i,t}^{\alpha_3} \cdot (A_{i,t} \cdot L_{i,t})^{1-\alpha_1-\alpha_2-\alpha_3} \cdot e^{u_{i,t}} , \tag{2}$$

where $\alpha_{1,}$ $\alpha_{2,}$ α_3 are technology parameters; subscripts i and t indicate country and time, respectively; $e^{u_{i,t}}$ is the error term; L is labor, K_1, K_2, and K_3 are physical capital financed

by three different sources the returns of which are free to differ from each other since they come from different investors[9] with different demands; A indicates the technology level, which is the same across countries at date t.

K_1, K_2, and K_3 grow according to the following equations:

$$\frac{dK_{1i,t}}{dt} = sdomy_{i,t}^{K_1} Y_{i,t} - \delta K_1, \tag{3}$$

$$\frac{dK_{2i,t}}{dt} = sextny_{i,t}^{K_2} Y_{i,t} - \delta K_2, \tag{4}$$

$$\frac{dK_{3i,t}}{dt} = snaty_{i,t}^{K_3} Y_{i,t} - \delta K_3, \tag{5}$$

where $sdomy$ is the domestic savings-to-GDP ratio; $sextny$ is equal to $= sextny - snaty$, which is the external savings-to-GDP ratio minus external savings in the form of aid (NAT $(snaty)$; and δ is the depreciation rate, which is assumed to be the same for all three types of capital and to be constant across countries and over time. The rate of technological progress g, is also constant and such that

$$A_{i,t} = A_{i,0} e^{gt}. \tag{6}$$

Further, the growth of labor force is denoted by $n_{i,t}$, so that

$$L_{i,t} = L_{i,0} e^{n_{i,t}}. \tag{7}$$

A constant steady-state level can be derived for

$$\left(K_1 / AL\right)^* = k_1^* = \left(sdomy^{1-\alpha_2-\alpha_3} sextny^{\alpha_2} snaty^{\alpha_3} / (n+g+\delta)\right)^{1/(1-\alpha_1-\alpha_2-\alpha_3)}, \tag{8}$$

$$\left(K_2 / AL\right)^* = k_2^* = \left(sdomy^{\alpha_1} sextny^{1-\alpha_1-\alpha_3} snaty^{\alpha_3} / (n+g+\delta)\right)^{1/(1-\alpha_1-\alpha_2-\alpha_3)}, \tag{9}$$

[9] Domestic versus foreign investors, non-profit oriented donors of development aid.

$$\left(K_3 / AL\right)^* = k_3^* = \left(sdomy^{\alpha_1} sextny^{\alpha_2} snaty^{1-\alpha_1-\alpha_2} /(n+g+\delta)\right)^{1/(1-\alpha_1-\alpha_2-\alpha_3)}, \tag{10}$$

$$\left(Y / AL\right)^* = y^* = \left(sdomy^{\alpha_1 /1-\alpha_1-\alpha_2-\alpha_3} sextny^{\alpha_2 /1-\alpha_1-\alpha_2-\alpha_3} snaty^{\alpha_3 /1-\alpha_1-\alpha_2-\alpha_3} / (n+g+\delta)^{\alpha_1+\alpha_2+\alpha_3/1-\alpha_1-\alpha_2-\alpha_3} \right), \tag{11}$$

where the variables k and y are in efficiency units, and asterisks indicate steady-state variables.

The steady-state per-capita income y^* varies according to the following stochastic equation:

$$\ln y_{i,t}^* = (\ln A_0 + gt) + \frac{\alpha_1}{1-\alpha_1-\alpha_2-\alpha_3} \ln sdomy_{i,t} + \frac{\alpha_2}{1-\alpha_1-\alpha_2-\alpha_3} \ln sextny_{i,t} + \frac{\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3} \ln snaty_{i,t} - \frac{\alpha_1+\alpha_2+\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3} \ln(n_{i,t}+g+\delta) + u_{i,t} . \tag{12}$$

In the neighborhood of the steady-state path, per-capita income growth evolves according to the following equation:

$$\ln y_{i,t+1} - \ln y_{i,t} = g + (1-e^{-\lambda_{i,t}}).(\ln A_0 + gt) + \frac{\alpha_1}{1-\alpha_1-\alpha_2-\alpha_3} \ln sdomy_{i,t} + \frac{\alpha_2}{1-\alpha_1-\alpha_2-\alpha_3} \ln sextny_{i,t} + \frac{\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3} \ln snaty_{i,t} - \frac{\alpha_1+\alpha_2+\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3} \ln(n_{i,t}+g+\delta) - \ln y_{i,t} + u_{i,t} , \tag{13}$$

with $\lambda_{i,t} = (n_{i,t} + g + \delta) \cdot (1 - \alpha_1 - \alpha_2 - \alpha_3)$, the speed of convergence. This speed is not constant due to the variability in the population-growth rate. In theory, g and δ could also vary over time.

3.2 GDP per capita versus economic growth

Note that Equation 12 explains the *level* of real per-capita income, whereas Equation 13 describes the determinants of per-capita income *growth*. A long-run equilibrium or a long-run relationship between growth and the level of real per-capita income and its determinants requires all variables to be non-stationary (e.g., *I(1)*).

In Appendix Table A1 we find that per-capita income growth is stationary [*I(0)*] and that real per-capita income, population growth + technological progress + capital depreciation ($LPOPGPLUS$), the domestic savings-to-GDP ratio *(LSDOMY)*, the net external savings-to-GDP ratio *(LSEXTNY)*, and the net aid transfer-to-GDP measure *(LSNATY)* (all in logs) are [*I(1)*].

In visual terms, we observe that in general *growth rates of real per-capita income* show strong persistence *(they are stationary series, I(0)))*, whereas *the aid-to-GDP ratio and the level of real per-capita income, along with the other covariates*, exhibit large and persistent *movements* with strong positive trends for most developing countries since 1960 *(they are non-stationary series, I(1))*. The empirical implication of this fact is that there can be a long-run relationship between the level of per-capita output and the level of the aid-to-GDP ratio over time (Equation 12), but there cannot be a long-run relationship between the growth rate of per-capita output and the level of the aid-to-GDP ratio (Equation 13) over time (Herzer and Morrissey, 2009[10]). Cointegration between a dependent *I(0)* variable and independent *I(1)* variables must be ruled out for statistical reasons. The occurrence of spurious relationships under this setting is well known.

For statistics reasons, only Equation 12, the *aid-per-capita income relationship*, can be estimated with econometric techniques, all regression variables being I(1). Nonstationarity of the series implies that real per-capita income could *potentially* be in a long-run relationship with domestic and external savings and aid. This, however, will be more closely investigated by panel cointegration tests in Section 4.1.

Equation 12 is estimated in a simplified form leading to Equation 14:

$$LY_{i,t} = b_{0i} + b_1 LSDOMY_{i,t} + b_2 LSEXTNY_{i,t} + b_3 LSNATY_{i,t} + b_4 LPOPGPLUS_{i,t} + u_{i,t}, \qquad (14)$$

[10] Herzer and Morrissey (2009) ascertain that a long-run relationship between aid and growth is impossible to exist. They conclude, as we do, that aid and income (GDP) can be cointegrated. They test cointegration between net ODA and real GDP in the period 1971-2003 for a sample of 59 countries, whereas we test cointegration between net aid transfers (similar to net ODA) and real per capita income in the period 1960-2005 for a sample of 50 countries.

where all variables are in natural logs; subscripts i and t indicate country and time, respectively, and

$LY_{i,t}$ = per-capita income in real terms (which we shall call *per-capita income* for simplicity);

$LSDOMY_{i,t}$ = domestic savings-to-GDP ratio (which we shall call *domestic savings*);

$LSEXTNY_{i,t}$ = external savings-to-GDP ratio minus aid-to-GDP ratio (which we shall call *net external savings*);

$LSNATY_{i,t}$ = net-aid-transfers-to-GDP ratio (which we shall call *net aid transfer or aid*);

$LPOPGPLUS_{i,t}$ = population growth + 5% (includes technological progress and capital depreciation[11]; for simplicity, we shall call it *population growth*); and

$u_{i,t}$ = all unobservable and unquantifiable variables that impact on per-capita income and that vary over countries and over time.

This existence of a nonlinear impact of aid on real per capita income could not be confirmed. The coefficient on aid squared turned out to be insignificant in the long-run model in both a FGLS and a dynamic FGLS (DFGLS) estimation.

3.3 Dealing with possible endogeneity of the explanatory variables

Endogeneity constitutes a serious problem in many growth or income regressions. In our case all right-hand-side variables might be endogenous and therefore we will purge all right hand side variables from endogeneity.

In this study we are concerned particularly with potential endogeneity of our aid variable. On the one hand, donors may consciously choose to give more aid to countries with a higher per-capita income, this being an indicator of a country with "better" economic policies and

[11] Sum of the growth rate of technology and the rate of capital depreciation are assumed to be equal to 5 % (following Mankiw, Romer and Weil, 1992, p. 413).

institutions. On the other hand, donors may give more aid to poorer countries, those in need of aid and unable to develop without it. To control for above-average effectiveness of aid in wealthier countries and for below-average effectiveness of aid in poorer countries, the aid-variable must be purged from its correlation with the error term.

One possible way of dealing with endogeneity is to apply the GMM procedure. However, GMM can only be utilized if the number of observations over time is small or kept small by averaging data over time.[12] Another option is the instrumental variables technique utilizing two-stage least squares (TSLS) to eliminate endogeneity; either lagged values of the endogenous variables in question (not applicable in the presence of autocorrelation) or external instruments can be utilized, although this is extremely difficult and not always advisable (see Rajan and Subramanian, 2005a, 2008). A third option, which is used here, is the application of the DOLS and DFGLS techniques (DFGLS if an adjustment for autocorrelation must be made), which can be utilized if the time series are long enough; endogeneity is controlled for by using numerous leads and lags of the variables in differences that absorb the effect of the correlation with the error term (Stock and Watson, 1993). However, when utilizing DOLS and DFGLS, the variables must be linked to each other in the long run.[13] DFGLS has an advantage over DOLS since it controls for spuriousness in the regression due to autocorrelation.

3.4 The data

The data of *LY*, *LSDOMY*, *LSEXTNY*, and *LPOPGPLUS* are taken and compiled from the World Development Indicators 2008 CD-ROM. The series "Net Aid Transfer=NAT" is available from the Center for Global Development.[14] It has been computed by Roodman (2008) and embodies two modifications of net ODA (from the Development Assistance

[12] In our case this requires averaging the data over time.
[13] To avoid spurious regression results, we estimated the relationship between aid and real per-capita income (and not growth) in the previous section.
[14] See http://www.cgdev.org/content/publications/detail/5492 (February 20, 2009).

Committee of the Organisation for Economic Co-operation and Development [OECD]). First, it subtracts interest payments received from developing countries on outstanding aid loans, which are now treated as capital outflows, just as principal payments are. Second, NAT omits debt relief. The cancellation of old *non-aid* loans (in the form of export credits or loans with excessively high interest rates) boosted net ODA and is therefore removed in NAT. [15] We have two samples of recipient countries: a large sample of 131 recipient countries and a smaller sample of 50. The 131-country sample is utilized for the standard panel estimations (panel two-way fixed-effects, panel FGLS, panel GMM, and panel SUR), which are not especially sensitive to missing values. The 50-country sample, in contrast, strictly requires a balanced panel, with no missing values with which to consistently test the time-series properties of the series. However, the 50-country sample still covers all regions of the world, low, medium, and high income aid recipients, and countries with a low, medium, or high level of human development.

[15] See examples given by David Roodman in:
http://blogs.cgdev.org/globaldevelopment/2007/01/new_aid_data_paint_more_realis_1.php

4. The aid-per-capita income link: Empirical findings

4.1 Possible existence of a long-run equilibrium between aid and per-capita income (50-country sample)

We investigate the long-run relationship between aid and per-capita income by first testing for cointegration between aid, its covariates, and per capita income, which are all *I(1)* variables. Various cointegration tests are applied (Johansen, 1988; Kao, 1999; Pedroni, 1999, 2004). However, cointegration tests can themselves be problematic. Gregory et al. (2004) emphasize the instability of cointegration tests, specifically, that a relatively high test statistic for one test and a relatively low test statistic for another have been obtained for time series cointegration tests. This effect is particularly strong when comparing residual and system-based tests. This finding is confirmed by Hanck (2006), who compares cointegration test results by means of p values in panel data settings. In panel data cointegration tests, this problem is exacerbated by cross-sections which might cover different spans of time. In our case, Pedroni's, Kao's and the Johansen-based cointegration tests all deliver contradictory results (see Appendix Table A5, A6 and A7). Kao's and the Johansen-based cointegration test signal the existence of cointegration (even though Johansen's signals several cointegrating vectors), whereas Pedroni's cointegration test rejects the existence of a long-run relationship between per-capita income, population growth, domestic savings, net external savings, and net aid transfers. It should be pointed out that cointegration tests clearly confirmed a long-run relationship between per-capita income, population growth, domestic savings, and net external savings (excluding aid).[16]

This unfortunate mix of results should be also reflected in the coefficient estimates of the long-term relationship. Thus, if the estimates show an insignificant impact of aid on per-capita income in the long run, this can be taken as further evidence of no cointegration

[16] Hjalmarsson and Österholm (2007) propose a more robust residual-based cointegration test for near unit root variables which are usually detected in macroeconomic data settings. This test possesses very good finite sample properties.

between aid and per-capita income. Therefore, we consider the estimation of the long-run relationship as a further test of cointegration.

4.2 Estimation of the long-run aid-per-capita income relationship via DOLS/DFGLS

According to Stock and Watson (1993), both the DOLS and the DFGLS procedures generate unbiased estimates for variables that cointegrate, even with endogenous regressors. They do so by employing leads and lags of the variables in differences that absorb changes in the variables caused by changes in the disturbances if both are correlated.

$$\begin{aligned} LY_{it} &= \alpha_j + \chi_1 LPOPGPLUS_{it} + \chi_2 LSDOMY_{it} + \chi_3 LSEXTNY_{it} + \chi_4 LSNATY_{it} \\ &+ \sum_{m=-p}^{p} \delta_i \Delta LPOPGPLUS_{i-m} + \sum_{m=-p}^{p} \varepsilon_{im} \Delta LSDOMY_{it-m} \\ &+ \sum_{m=-p}^{p} \phi_{im} \Delta LSEXTNY_{it-m} + \sum_{m=-p}^{p} \varepsilon_{im} \Delta LSNATY_{it-m} + u_{it} \end{aligned} \tag{15}$$

Equation 15 can be estimated by a dynamic ordinary least squares technique (DOLS) if autocorrelation of the disturbances is absent (which is not the case in our study). To correct for autocorrelation of the disturbances, we utilize DFGLS. Just as one would apply FGLS when OLS is inefficient due to autocorrelation by pre-estimating the extent of autocorrelation of the residuals $\hat{\rho}$, one can also apply DFGLS when DOLS is inefficient due to autocorrelation (see Stock and Watson, 1993).

DFGLS requires a transformation of the original variables, as outlined in the Technical Appendix of the paper.

Table 1: The impact of aid on per-capita income: Partial and full model estimated by DFGLS

(1)	(2)	(3)	(4)	(5)
	Dependent variable: *Per-capita income*	Dependent variable: *Per-capita income*	Dependent variable: *Per- capita income*	Dependent variable: *Per-capita income*
	(partial model 1)	(partial model 2)	(partial model 3)	(full model)
Population growth	_____	_____	_____	-0.003 (-0.02)
Domestic savings	_____	0.08*** (7.38)	0.07*** (5.86)	0.07***(5.56)
Net external savings	_____	_____	0.04*** (3.89)	0.05***(4.79)
Net aid transfer	-0.02*** (-2.99)	-0.01 (-1.56)	-0.01 (-1.31)	-0.02 (-1.47)
Fixed effects	Yes	yes	yes	yes
2 leads and 2 lags	yes	yes	yes	yes
Cross sections included	57	56	50	50
R-squared adj.	0.99	0.99	0.99	0.99
Durbin-Watson stat.	**1.77**	**1.70**	**1.92**	**2.02**

Note: t values are in parentheses. All variables are in logs.

The DFGLS results show, in the bivariate model only (column 2), a negative and significant impact of the aid-to-GDP ratio on real per-capita income. If the model is augmented (see columns 3 through 5), aid's impact on per–capita income becomes insignificant. This result seems to be in line with the "mixed" results of the cointegration tests which pointed to cointegration (twice) and no cointegration (once) depending upon the cointegration test applied. Interpreting the significant coefficients of the DFGLS estimation (column 5), we can conclude that a doubling of the domestic savings-to-GDP ratio would increase per-capita income by 7% and a doubling of the net capital inflows (minus aid) -to-GDP ratio would increase per-capita income by 5% (α being 1%). In column 5 autocorrelation is perfectly controlled for, the Durbin-Watson (DW) statistic being 2.02. The DOLS estimations are

available upon request. They show autocorrelation of the error terms and a significant negative impact of aid on per capita income.

We especially checked the robustness of our results considering the net external savings-to-GDP ratio as an indicator for economic vulnerability. We consider points in time with net capital outflows as vulnerable and instable (at least in macroeconomic terms). The opposite applies to time periods with net capital inflows. Interacting aid with a dummy variable for economic vulnerability the results obtained in Table 1 stay robust. The overall impact of aid is either (close to) zero or insignificant.

4.3 The impact of aid on income in different sub-samples

Considering countries with different aid-to-GDP ratios (Table 2), we observe that a higher aid-to-GDP ratio has a slightly negative impact (-0.03) on the recipient countries with a high aid-to-GDP ratio and an insignificant impact on those developing countries that have a low aid-to-GDP ratio, having controlled for the endogeneity of aid via DFGLS. Again, correction for autocorrelation strongly reduces aid's negative impact on per capita income. DOLS results are available upon request.

Table 2: Differing impact depending upon the aid-to-GDP ratio? DFGLS estimation

	Above-average aid-to-GDP-ratio countries	**Below-average aid-to-GDP-ratio countries**
	Dependent variable: *Per capita income*	Dependent variable: *Per capita income*
Population growth	0.04 (0.23)	0.37 (1.31)
Domestic savings	0.05***(3.87)	0.16***(5.37)
Net external savings	0.04**(2.29)	0.06***(4.32)
Net aid transfer	-0.03* (-1.70)	-0.01 (-0.78)
Fixed effects	yes	yes
2 leads and 2 lags	yes	yes
Cross sections included	23	29

R-squared adj.	0.99	0.99
Durbin-Watson stat.	**2.27**	**1.99**

Note: t values are in parentheses. All variables are in logs.

To see whether the aid-per capita income link depends upon other influencing factors that are linked to a country's human development, economic development, or regional affiliation, we estimated the long-run relationship for different sub-categories of the above-mentioned characteristics.

Table 3: Different impact depending on the level of human development? DFGLS estimation

	Dependent variable: Per capita income; estimation <u>for different levels of human development</u>		
Independent variables↓	Low human-development countries (HDI below 0.500)	Medium human-development countries (HDI 0.500-0.799)	High human-development countries (HDI 0.800 and above)
Population growth	-0.53 (-1.47)	0.43* (1.69)	0.68 (0.06)
Domestic savings	0.06*** (3.53)	0.09*** (3.46)	1.91 (0.43)
Net external savings	0.02 (0.69)	0.05*** (4.08)	-1.01 (-0.30)
Net aid transfer	-0.03 (-1.11)	-0.01 (-0.45)	-0.17 (-0.21)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections included	20	25	4
R-squared adj.	0.99	0.99	0.99
Durbin-Watson stat.	**1.89**	**2.14**	**1.55**

Note: t values are in parentheses. All variables are in logs.

Table 4: Differing impact depending on the level of income: DFGLS estimation

	Dependent variable: Per capita income; estimation <u>for different levels of income</u>		
Independent variables↓	Least developed countries (LLDC)	Low-income countries (GNI per capita of $735 or less in 2002)	Middle-income countries (GNI per capita of $736-$9,075 in 2002)

Population growth	-0.23 (-0.71)	-0.30 (-1.09)	0.23 (0.70)
Domestic savings	0.05*** (3.37)	0.06*** (4.08)	0.18*** (4.62)
Net external savings	0.08*** (3.25)	0.05*** (3.37)	0.06*** (3.99)
Net aid transfer	-0.01 (-0.53)	-0.02 (-1.12)	-0.01 (-0.93)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections included	18	24	24
R-squared adj.	0.99	0.99	0.99
Durbin-Watson stat.	**2.14**	**1.73**	**2.41**

Note: t values are in parentheses. All variables are in logs.
High-income countries (GNI per capita of $9,076 or more in 2002) were not among our 58 developing countries. LLDC are defined by the United Nations. It is a socioeconomic classification considering per capita income, economic vulnerability, and human development.

Table 5: Different impact when countries are sorted by region? DFGLS estimation

	Dependent variable: Per capita income; estimation for different regions				
Independent variables↓	Caribbean countries	Latin American countries	Latin American and Caribbean countries	African countries	Asian countries
Population growth	2.87*** (2.84)	0.58 (1.17)	1.22*** (3.07)	-0.10 (-0.41)	-0.51 (-1.18)
Domestic savings	0.17*** (2.89)	0.12** (2.44)	0.12*** (3.67)	0.06*** (4.00)	0.02 (0.61)
Net external savings	0.06 (0.94)	0.06*** (2.78)	0.07*** (3.32)	0.04+** (2.45)	0.02 (1.12)
Net aid transfer	-0.04 (-1.17)	-0.03 (-0.67)	-0.05** (-2.30)	-0.01 (-0.44)	-0.03 (-1.30)
Fixed effects	yes	yes	yes	yes	yes
2 leads and 2 lags	yes	yes	yes	yes	yes
Cross sections included	5	11	16	25	6
R-squared adj.	0.99	0.99	0.99	0.99	0.99
Durbin-Watson stat.	**2.18**	**2.16**	**1.92**	**1.93**	**2.16**

Note: t values are in parentheses. All variables are in logs.

Again, when controlling for autocorrelation, the impact of aid on per capita income becomes insignificant (see Tables 3, 4, and 5; DOLS results are available upon request). These findings support the result of no cointegration (no long-run link between aid and per capita income).

In general we observe that aid has an insignificant impact on per capita income irrespective of the level of human development, the level of income, or the geographic region (except for Latin America, where we observe a significant, negative coefficient).

The mixed results with respect to cointegration (together with the finding of an insignificant impact of aid on real per capita income in the DFGLS estimations) lead us to conclude that there is no long-run relationship between aid and income.[17]

4.4 Applying standard and more refined panel data estimation techniques

This section follows the panel data approach where emphasis is often put on the within estimation, that is, an exploitation of the variation of the variables over time. Studies of this type are frequently performed to present an overview of average effects of aid to the developing world from 1960 through 2006.

For our panel of 131 countries, we utilize annual and averaged data (five-year averages, to smooth the data over time), and then estimate Equation 14 in various ways: with fixed effects, time-effects, controlling for autocorrelation, and panel GMM and SUR. In addition, we will discuss the inclusion of time effects to control for events that vary over time but are the same in all cross-sections, leading to a two-way fixed-effects estimation and the problem of finding adequate instruments.

[17] This conclusion is further reinforced by a long-run Granger causality test that points to a bi-directional link between aid and per-capita income which makes the quantification of the aid impact on income impossible. (Results are available from the authors upon request.)

Table 6: The income-aid relationship (in a sample of 131 countries)

	Dependent variable: real per capita income *(LY)*					
(1)	2-way FE estimation (annual data) (2)	2-way FE estimation (5-year averages) (3)	FE+FGLS estimation (5-year averages) (4)	GMM (5-year averages) (5)	GMM estimation (5-year averages) (6)	SUR estimation (5-year averages) (7)
	Dependent variable: *Per capita income*					
Population growth	-0.12** (-2.43)	-0.08 (-0.46)	0.17 (1.28)	0.37 (1.33)	0.28 (1.57)	0.30 (0.36)
Domestic savings	0.09*** (12.99)	0.10*** (5.17)	0.02* (1.56)	0.04* (1.92)	0.01* (1.99)	-0.18 (-1.11)
Net external savings	0.01 (1.32)	0.01 (0.70)	0.01** (2.07)	0.01 (0.53)	0.01 (1.61)	0.12 (1.10)
Net aid transfer	-0.06*** (-13.05)	-0.05*** (-4.03)	-0.02** (-2.01)	-0.02* (-1.69)	-0.02 (-1.37)	-0.13 (-1.40)
Fixed effects	yes	yes	yes	yes	yes	yes
Time effects	yes	yes	no	yes	yes	no
Instruments (IV)	no	no	no	yes	yes	no
Auto-correlation control AR term	no	no	yes 0.94*** (7.52)	no	yes (requires two steps estimation)	yes via SUR
R^2 adj.	0.99	0.99	0.86	___	___	___
DW stat.	**0.21**	**0.77**	**2.48**	___	___	___
hansen				43.874	37.452	
hansenp				0.144	0.314	
ar1				2.426	-0.719	

ar1p				0.015	0.472	
ar2				0.644	-1.301	
ar2p				0.520	0.193	
N of instruments				47	40	

Note: t values are in parentheses. All variables are in logs. The 2-way FE estimation relies on cross-section fixed effects and time effects. The FE+FGLS estimation utilizes cross-section fixed (country fixed effects) and corrects for autocorrelation of the error terms. Panel GMM (Generalized Method of Moments) is applied to the sample with 5-year averages to limit the number of moment conditions. Due to autocorrelation of the disturbances, the instruments (lagged values of the variables) become invalid.

As we can see from Table 6, the two-way fixed-effects estimation (columns 2 and 3) remains subject to autocorrelation, the Durbin-Watson statistic being 0.21 and 0.77. In column 4 the equation has been estimated via FGLS to purge the error term from autocorrelation. By doing so, the impact of domestic and external savings and of aid on per capita income has been reduced, compared to the two-way FE estimation. The FGLS results point to a minute negative impact of aid on per capita income. The Durbin-Watson statistic improves and moves more closely towards 2.00 (the DW statistic being 2.48). The application of the panel GMM estimation technique (columns 5 and 6) is only possible when we work with five-year averages[18] or 10-year averages. If we utilized annual data, we would create 4324 (47*46*4/2) moment conditions.[19] A potential benefit of GMM is that it works in dynamic models and can handle endogenous variables, if autocorrelation of the error terms is absent.[20] The results are presented in column 5, assuming that autocorrelation is absent. In the presence of autocorrelation, more complex or refined estimation methods are required (such as GMM controlling for autocorrelation or SUR). We can control for autocorrelation in a first step and then apply GMM (results are presented in column 6). Running this GMM, we obtain an insignificant impact of aid on per capita income or we can perform a SUR estimation (column 7). As to the SUR estimation, this estimation method will not be feasible if we work with

[18] Working with 5-year averages, we have already created 144 moment conditions.
[19] One can use STATA's "collapse" option in this case, but GMM is not designed for data set with a large number of observations over time.
[20] Due to lack of control for autocorrelation in the xtabond2 procedure in STATA, we do not use this procedure.

yearly data.[21] Therefore, we follow Alesina et al. (2003) and work with five-year averages, set up a system of equations, and switch cross-sections and periods when the number of cross-sections is large and the number of time periods is small. In our case, this implies that separate equations are utilized for each of the following time periods: 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2006. Following this estimation procedure, we basically estimate nine cross-section equations (with 131 countries in each equation) in the system. By switching cross sections and time periods, the estimation becomes a between estimation and autocorrelation over time is controlled for by the SUR technique. Also in the SUR estimation, the impact of aid on per capita income is insignificant.

In summation, fancy panel techniques that take endogeneity and autocorrelation into account also find an insignificant impact of aid on per capita income in the 1960 to 2006 period (see Table 6, columns 6 and 7).

4.5 Which panel technique is best?

Given our data, a further finding of application of regular panel techniques is that averaging over time does not (and cannot) eradicate autocorrelation (see the Durbin-Watson statistics in Table 6, columns 2 and 3, taking values of 0.21 and 0.77, which are far from 2.00), as it has often been suggested in the literature since autocorrelation between time intervals persists. On top of that, we give up a lot of information on the behavior of the variables over time by strongly averaging the data over time and/or working with time effects. We would therefore decide against averaging data over time and against employing time fixed effects.

A short-coming of the time-series approach, in contrast, is that it requires very long series. Institutional variables such as rule of law, protection of property rights, extent of corruption, and variables concerning the business environment are difficult to collect over the period

[21] A system of 48 equations cannot be estimated with the computer programs at hand .

under investigation, leading to these variables being omitted and relegated to the error term. As long as the omitted variables are not strongly correlated with the right–hand-side variables, we can control for their influence by taking out autocorrelation. The omitted variable problem has to be put in perspective, though. Standard panel growth or income-regression estimations, which utilize many more explanatory variables and are therefore subject to omitted variable problems to a smaller extent, usually do not control for omitted variables, thus opening the way to biased estimations.

On the whole, we give priority to the time-series-based approach followed in Sections 4.1 through 4.4, as this approach is better able to estimate the long-run relationship between aid and per capita income, controlling for autocorrelation and endogeneity simultaneously. Sample size is reduced, however. But the 50 countries that remain in the sample rely upon 47 observations per variable.

4.6 Transmission channels from aid to per capita income (the long-run view)

Even though we find a statistically insignificant impact of aid on per capita income in the overall and sub-samples over the long run, aid could still affect per capita income in an **indirect** way. In the literature regarding the transmission channels of aid to per capita income, one must be particularly concerned with aid's impact on investment, on domestic savings (public and private), and on the real exchange rate in the long run (Rajan and Subramanian, 2005a, 2005b). The indirect impact on investment is explained—assuming that at least part of the aid money is invested—by two gaps that usually exist in recipient countries: first, the savings-investment gap and, second, the foreign-exchange gap. Aid can reduce the shortage of savings (being a form of external savings with a grant element) and the shortage of foreign exchange concurrently. However, the literature also describes a possible crowding out of domestic savings by aid which may stem from either a decreasing willingness of the government in the recipient country to raise taxes to finance a certain level of expenditures or

an increasing inclination to consume. This is due to the fact that that aid transfers are considered supplemental income, given that aid funds can be quite easily appropriated by the government or private entities through careless spending bonanzas, corruption, or rent-seeking behavior, so that the average consumption-to-GDP ratio raises and the average savings-to-GDP ratio declines. A further indirect impact of aid transfers on the real economy runs through the income effect which translates into a real exchange-rate effect. Both in a flexible and a fixed exchange-rate system, transfers lead to additional income and eventually additional absorption, thus increasing the demand for both non-tradables and tradables. While the prices for non-tradables will increase, the prices for tradables will remain constant, in the small (recipient) country case. As a final result, the real exchange rate will appreciate and production factors will flow out from the tradables sector into the non-tradables sector. The resource reallocation is not desirable if productivity and externalities are higher in the tradable than in the non-tradable sector. However, if the non-tradadable sector has many backward and forward linkages (e.g., construction) and/or it creates spillovers to other sectors (e.g., telecommunication, energy) then the resource reallocation into non-tradables might even be growth-enhancing. In order to test empirically for the indirect effects of aid on per capita income, we first test for cointegration (long-run relationships) and, in case of cointegration, we then estimate the long-run indirect effects.

As to the transmission channels of aid to per capita income, we find cointegration (all cointegration tests confirm a long-run equilibrium between aid and investment, aid and domestic savings, and aid and the real exchange rate). Table 7 presents the strength of the above-mentioned transmission channels. The relationships are derived from simple multiplicative models and linearized by the log-log transformation. They are estimated by applying DFGLS, thus controlling for autocorrelation and endogeneity.

Table 7: The indirect effects of aid on per capita income

	Possible transmission channels (DFGLS estimation)		
Independent variables↓	Dependent variable: *Investment-to-GDP ratio (in logs)* *LINVY* *Investment channel*	Dependent variable: *Domestic Savings-to-GDP ratio (in logs)* *LDOMSY* *Domestic savings channel*	Dependent variable: *Real exchange rate (in logs)* *LRER* *Real exchange rate channel*
Domestic savings	0.42***(19.76)	——	——
Net external savings	0.29***(15.30)	——	-0.14 (-0.66)
Net aid transfer	0.04**(2.17)	-0.12***(-3.45)	-0.51**(-2.27)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections included	50	56	20
R-squared adj.	0.91	0.66	0.66
Durbin-Watson stat.	**1.92**	**1.83**	**2.13**

Note: t values in are parentheses. All variables are in logs.

The domestic savings-to-GDP ratio, the net external savings-to-GDP, and the net aid-transfers-to-GDP ratio all have a positive and a significant impact on recipient country's investment. The domestic savings-to-GDP ratio declines with the aid-to-GDP ratio so that there is some crowding out and the real effective exchange rate appreciates with an increase in the aid-to GDP ratio.

To summarize, we find that aid does not directly affect per capita income in the long run, while we do observe that aid has a long-run impact on per capita income via investment, domestic savings, and the real exchange rate. Thus, aid is not directly, but rather indirectly, linked to per capita income over the long run.

4.7 In search of a short-to-medium-term relationship between aid and per capita income

It is, however, important to note that failure to find a direct long-run relationship between aid and per capita income (see Section 4.5) does not imply that per capita income could not be determined by aid in the short-to-medium run. The short-run Granger causality test (results are available upon request) shows that aid determines per capita income in the short run but not the other way around. Therefore, aid can be considered a weakly exogenous variable, and instrumentation for aid is not necessary. Using instrumentation for the other variables in the model might be advisable. Concentrating on the short-to-medium-run relationship between aid and its covariates and per capita income, we estimate an ARMAX model (autoregressive moving average with exogenous input model) that explains variations in the dependent variable, not only by its lagged values, but also by additional variables, (X). Given that our observations over time are large (T=47), we do not utilize GMM[22] to instrument for potentially endogenous variables.

Searching for the specific form of the ARMAX (p,q) model, we find that the error term is a first order moving average process (MA1 with q=1); in other words, we observe first order autocorrelation and start by estimating the autoregressive process by p lags. As lags higher than p=1 are not significant at conventional levels, we then estimate an ARMAX (p=1, q=1) model[23] of the following form:

$$LY_{i,t} = \mu_i + \eta_t + \chi LY_{i,t-1} + \sum_{p=0}^{1} \alpha_p LPOPGPLUS_{i,t-p} + \sum_{p=0}^{1} \beta_p LSDOMY_{i,t-p} + \sum_{p=0}^{1} \gamma_p LSEXTNY_{i,t-p} + \sum_{p=0}^{1} \delta_p LSNATY_{i,t-p} + \varepsilon_{i,t} - \rho\varepsilon_{i,t-1} \quad (16)$$

In estimating the ARMAX model, we use two options: The first is to estimate the model by two-ways fixed effects (cross-section fixed effects and time-year dummies), instrumenting for

[22] GMM was developed for panel data that consist of many cross sections (large N) and few observations over time (small T).
[23] The lags of the ARMAX (p,1) models were not significant at conventional levels.

the lagged dependent variable. Since the other explanatory variables (including aid)[24] were weakly exogenous, we need not instrument for them. The second option is to estimate the model in a stepwise regression (suggesting appropriate instruments that are added at a later step) via FGLS, removing the moving-average process of the disturbances.[25]

We observe very similar results across the different techniques of estimation chosen. As expected, today's per capita income depends upon lagged per capita income and domestic and external savings (net of aid) increase per capita income. This year's aid decreases per capita income, and we consider real exchange-rate appreciation responsible for this empirical finding, given that capital flows react more quickly than the real economy. Furthermore, last year's aid impacts positively on per capita income as it has been either used for investment or consumption, both adding to GDP.

[24] See also the Granger causality test.

[25] This is accomplished by transforming the error term and all the variables; time-year dummies can then not be utilized. Per-capita income, lagged three and two periods, are utilized as search regressors.

Table 8: Impact of aid on per capita income in the short and medium term (ARMAX model)

Estimation methods →	**The aid-per capita income relationship (2-way fixed-effects estimation)**	**The aid-per capita income relationship (stepwise FGLS estimation)**
(1)	**(2)**	**(3)**
	Dependent variable: *Per capita income*	Dependent variable: *Per capita income (transformed)*
Per capita income (lagged)	0.97*** (146.15)	0.99*** (50.07)
Population growth	-0.02 (-0.52)	-0.01 (-0.08)
Population growth (lagged)	-0.02 (-0.77)	-0.00 (-0.04)
Domestic savings	0.01*** (4.05)	0.01*** (4.53)
Domestic savings (lagged)	0.00 (-0.19)	0.00 (-0.09)
Net external savings	0.01*** (2.15)	0.01*** (2.37)
Net external savings (lagged)	0.00 (-0.16)	0.00 (-1.23)
Net aid transfer	-0.01*** (-2.74)	-0.01*** (-2.77)
Net aid transfer (lagged)	0.01*** (3.51)	0.01*** (2.86)
Added regressors	no	*Per capita income (lagged 3 periods)*
Fixed effects	yes	no
Time year dummies	yes	no
Number of observations	1366	1182
R-squared adj.	0.97	0.99
Durbin-Watson statistic	——	1.98

Note: t values are in parentheses. All variables are in logs.

5. Conclusions

The time-series-based approach of estimating the aid-per capita income relationship allows one to obtain long-term estimates by applying either panel DFGLS or panel GMM. In both estimation techniques, the error terms can be purged from autocorrelation, and endogeneity can be controlled. A shortcoming of the time-series-based approach is that it is not as rich in terms of explanatory variables as other models because of data unavailability. Thus, the omitted-variables problem is more pressing in the time-series-based approach. However, one

can control for omitted variables, not only by fixed effects, but also by considering the impact of omitted variables that are uncorrelated with the right-hand-side variables.

In this paper, we have shown that the direct impact of aid on per capita income is statistically insignificant or negative, but very small. This finding holds not only for the long-run and for the recipient countries in general, but also for sub-groups of recipient countries which have been formed according to an above-average/below-average aid-to-GDP ratio, the level of human development, the level of income, and the region of the world. In the short and medium run, the impact of current aid is slightly negative whereas the impact of lagged aid is slightly positive, so that overall we obtain a close to zero impact of aid on per capita income. From an economic-policy view, the negative short-run impact through (presumably) real exchange-rate appreciation could be ameliorated by building up foreign exchange reserves or by other types of macroeconomic management.

Furthermore, we find over the long run that aid increases investment, whereas it causes a small crowding out of domestic savings and leads to some appreciation of the real exchange rate. In contrast to external savings (net capital inflows minus aid), which conform to market conditions (interest rate differentials and exchange rate expectations), net aid transfers (which are grants or loans with a grant element) do not increase real per capita income. The rate of return of aid-financed projects seems to be below the interest payable on those loans, whereas the rate of return of externally-financed investment projects seems to be higher than the interest payable on those loans.

Interestingly, we also observe that the impact of aid on per capita income becomes smaller when we control for autocorrelation by means of FGLS. Given that swings of error terms around the regression line can be due to both pure autocorrelation (this is very likely if time series are non-stationary) and omitted variables (this is equally likely if we have unobservable or unquantifiable country characteristics that vary over time), we eliminate both problems simultaneaously. Intuitively, by controlling for unobservable or unquantifiable country

characteristics, which very likely are related to the reasons why aid has been granted in the first place (donors motivations and donors perceptions) or how aid transfers have been managed and spent in the second place (efficiency of bureaucracy, absence of corruption, rent-seeking, and organizational, managerial, and workers' capabilities) the negative impact of aid on per capita income becomes noticeably reduced.

However, to see our primary finding (no statistically significant long-run relationship between aid and real per capita income) in perspective, it has to be kept in mind that per capita income is influenced by a multitude of factors[26], which unfortunately cannot all be possibly captured), aid playing only one part in it. In addition, given that the average amount of aid provided is quite small (on average 5% of recipient countries' GDP), it is reasonable to assume that at best, aid will only marginally contribute to per capita income. This is not to say that aid cannot have important indirect effects (on investment, for example). Development projects should therefore concentrate on delivering those effects and emphasizing infrastructure projects with multiple backward and forward linkages. Crowding out of domestic saving (the dwindling willingness of recipient countries' governments to tax) should be constrained by helping developing countries set up a functioning tax system and an efficient administration. Some donor countries have already begun sending experts and providing training in exactly that area. The real appreciation effect linked to the inflow of aid is probably something recipient countries have to live with to a certain extent, but there are promising country

[26] Not controlling for these factors leads to inconsistent parameter estimates (over- or under-estimation of parameter values). Even though cross-section analyses suffer less from finding a certain piece of information on a certain country characteristic for a certain period of time, they are unable to solve the problem of unobserved heterogeneity in general. Much better mechanisms of intervention (tackling the omitted-variables problem, dealing with endogeneity) exist when performing panel analyses which stretch over long time periods.

experiences in which real exchange-rate appreciation could be attenuated by a successful macroeconomic management of aid flows.[27] In addition, a positive aspect of a real exchange rate appreciation can be found in a strengthening of the service sectors (resources are allocated away from tradables to non-tradables), such as the provision of water, electricity, oil and gas, health services, education, and public transport.

[27] See Aiyar et al. (2008).

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Appendix

Table A1. Results of the ADF-Fisher panel unit root test

Variable tested	Fisher statistic	Probability	Variable is integrated
ΔLY (growth of per capita income)	226.91	0.00	*I(0)*
LY (per capita income [in levels])	82.73	0.99	$I(1)$
$LPOPGPLUS$ (population growth, technological change and capital-depreciation rate)	104.20	0.78	$I(1)$
$LSDOMY$ (domestic savings)	89.35	0.94	$I(1)$
$LSEXTNY$ (net external savings)	100.84	0.20	$I(1)$
$LSNATY$ (aid)	95.64	0.89	$I(1)$
$LINVY$ (investment)	110.70	0.62	$I(1)$
$LRER$ (real exchange rate)	60.00	0.33	$I(1)$

Note: The first differences of the series are stationary (results not reported). The Fisher statistic is distributed as χ^2 *with* $2\times N$ *degrees of freedom, where* N *is the number of countries in the panel. LINVY is actually the log of the investment-to-GDP ratio. LRER is the log of the real exchange rate.The test results do not depend on the type of panel root test utilized (Im-Pesaran-Sin test, Fisher-ADF test or Fisher-PP test).*

Table A2. Scatterplot of the aid-growth relationship (1960-2006) in a sample of 58 recipient countries

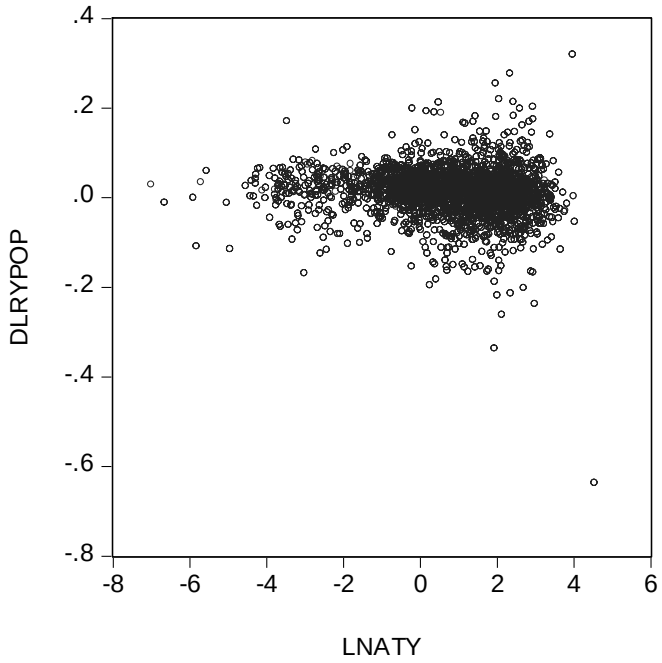

Table A3. The growth rate of real per capita income in a sample of 58 recipient countries (1960-2006)

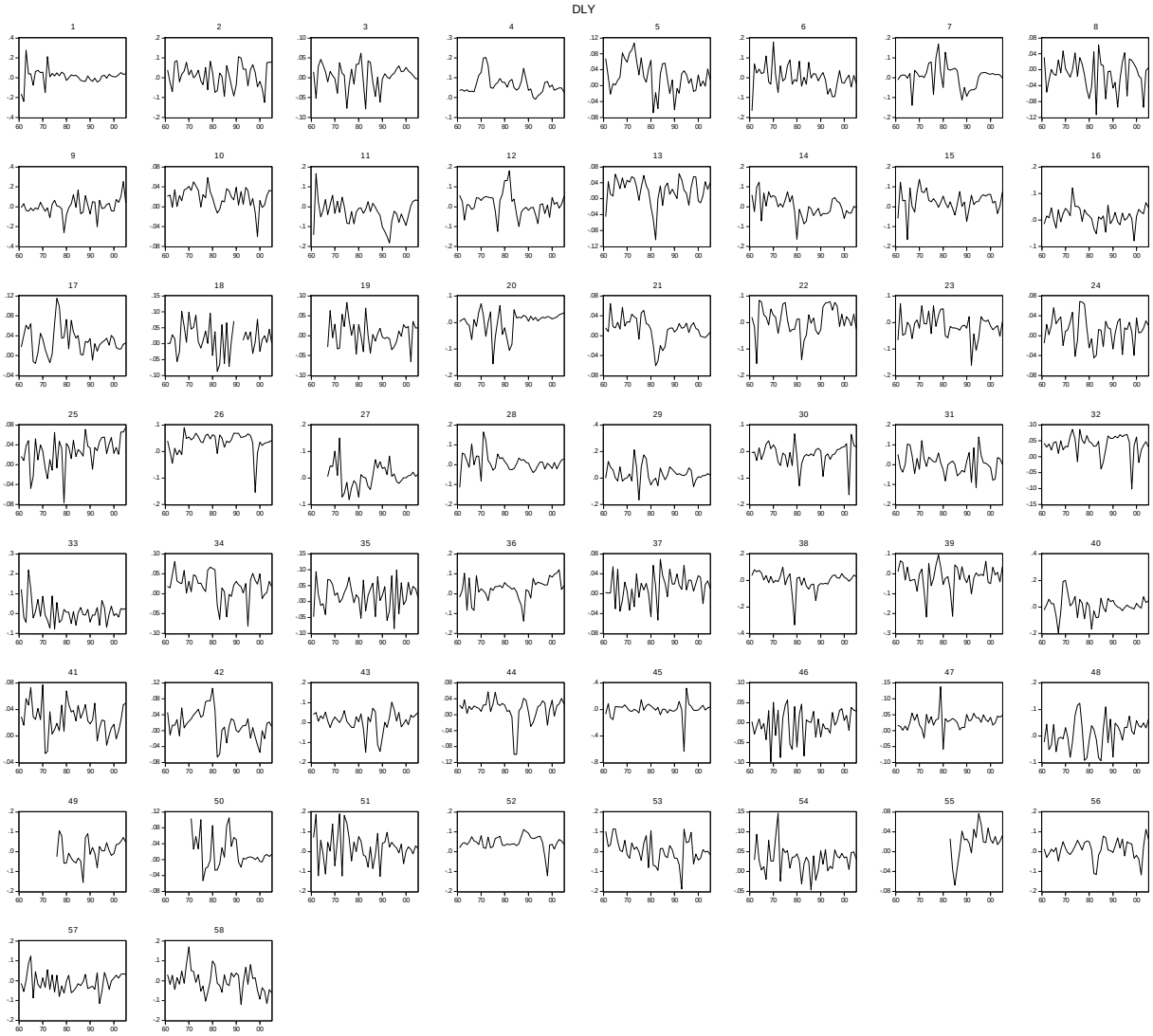

Table A4. The aid-to-GDP ratio in a sample of 58 recipient countries (1960-2006)

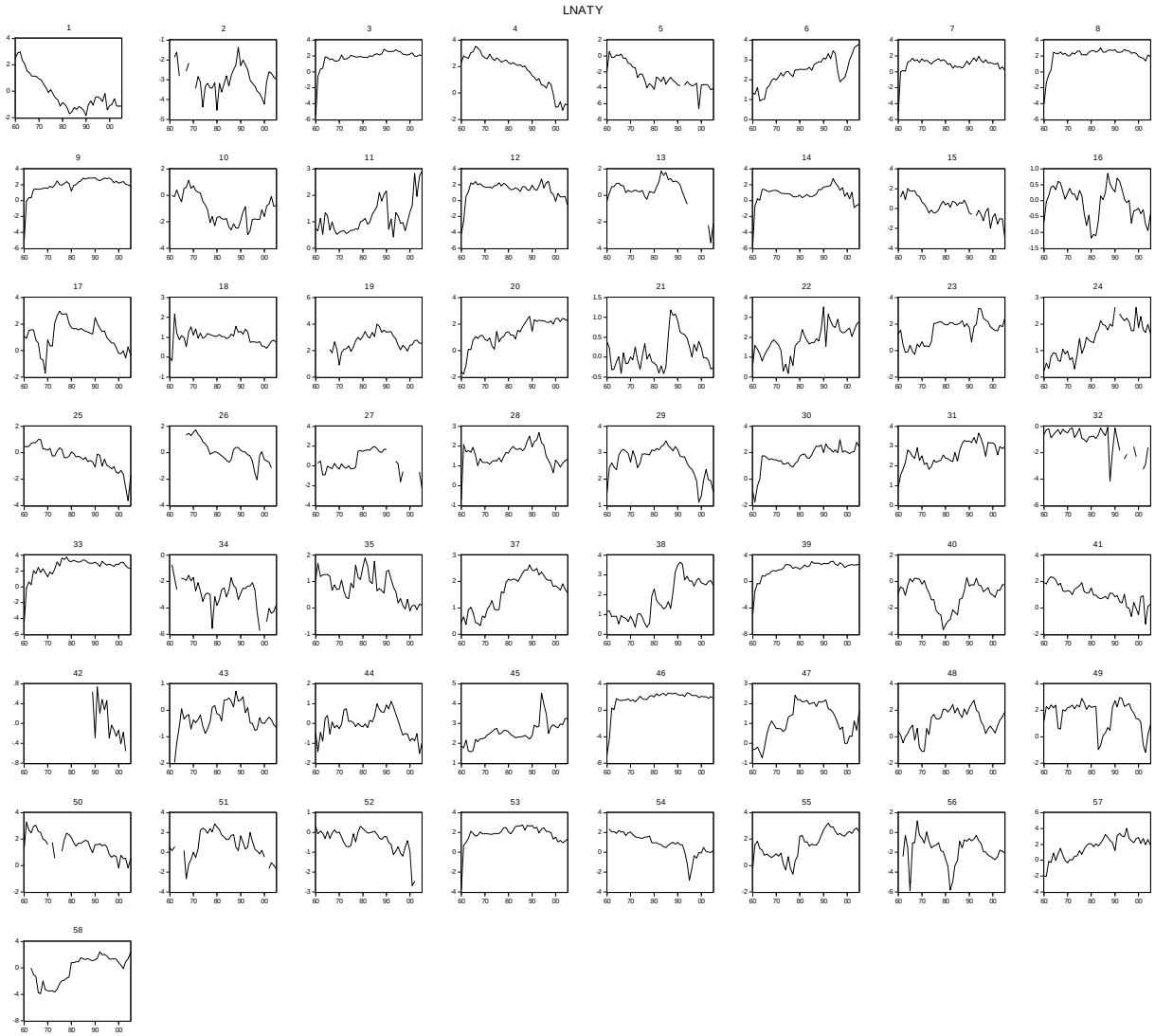

Table A5. Results of Kao's panel cointegration test

Kao residual cointegration test	**t statistic**	**p value**
DF* statistics	-2.97***	0.00

*Note H_0: The variables of interest are not cointegrated. H_1: The variables of interest are cointegrated (Kao, 1999). Kao's cointegration test is based on a fixed-effects model (our model of choice), which Pedroni does not discuss. *** indicate a rejection of the null of no cointegration at the 1% level. All test statistics are asymptotically normally distributed. The number of lags was automatically determined by the Schwartz criterion.*

Table A6. Results of Pedroni's panel cointegration test

Pedroni's residual cointegration test	**test statistic**	**p value**
Common AR coefficients		
Panel PP statistic	1.61	0.95
Panel ADF statistic	6.38	1.00
Individual AR coefficients		
Group PP statistic	3.10	1.00
Group ADF statistic	-0.23	0.41

Note: *H_0: The variables of interest are not cointegrated. H_1: The variables of interest are cointegrated . Lag-length selection was automatic based on SIC with lags from 0 to 9 (Pedroni, 1999, 2004).*

Table A7. Results of Johansen-based panel cointegration test

Johansen-based panel cointegration test	**Fisher statistic (from trace test)**	**p value**
	986.7	0.00***

Note: *H_0: The variables of interest are not cointegrated (no cointegration); H_1 : One cointegrating vector can be identified (Johansen, 1988). .*

Technical Appendix

Estimated error terms are obtained by estimating Equation 15 via DOLS in a first step. The extent of autocorrelation of the disturbances ρ is then estimated via DOLS in a second step: $u_{it} = \rho \cdot u_{it-1} + \varepsilon_{it}$ leading to $\hat{\rho}$. The third step involves the transformation of the variables (see below). Note that the transformation of the variables is driven by $\hat{\rho}$, the estimated coefficient of autocorrelation of the disturbances. This transformation leads to new variables in soft first differences (characterized by *) and a new error term u^* that is uncorrelated to the error term of the previous period:[28]

$$u*_{it} = u_{it} - \hat{\rho} \cdot u_{it-1}$$

$$LY_{it}^* = LY_{it} - \hat{\rho} \cdot LY_{it-1};$$

$$LPOPGPLUS_{it}^* = LPOPGPLUS_{it} - \hat{\rho} \cdot LPOPGPLUS_{it-1};$$

$$LSDOMY_{it}^* = LSDOMY_{it} - \hat{\rho} \cdot LSDOMY_{it-1};$$

$$LSEXTNY_{it}^* = LSEXTNY_{it} - \hat{\rho} \cdot LSEXTNY_{it-1};$$

$$LSNATY_{it}^* = LSNATY_{it} - \hat{\rho} \cdot LSNATY_{it-1};$$

and then in a fourth step, Equation 14* is estimated by DOLS:

$$\begin{aligned} LY_{it}^* = \alpha_j &+ \chi_1 LPOPGPLUS_{it}^* + \chi_2 LSDOMY_{it}^* + \chi_3 LSEXTNY_{it}^* + \chi_4 LSNATY_{it}^* \\ &+ \sum_{m=-p}^{p} \delta_i \Delta LPOPGPLUS_{i-m}^* + \sum_{m=-p}^{p} \varepsilon_{im} \Delta LSDOMY_{it-m}^* \\ &+ \sum_{m=-p}^{p} \phi_{im} \Delta LSEXTNY_{it-m}^* + \sum_{m=-p}^{p} \varepsilon_{im} \Delta LSNATY_{it-m}^* + u_{it}^* \end{aligned}$$

(15*)

[28] In our case only first-order autocorrelation was detected. However, higher orders of autocorrelation reaching back two or more periods could also be modeled.