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The aid-income link revisited.
How plausible and robust are the results?

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"The aid-income link revisited.

How plausible and robust are the results?"

by

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Abstract

This study provides a re-examination of the aid-income link based on a panel data set which is downloadable at the Canadian Journal of Economics 45(1), 2012 issue. Longer time series data are available for a group of 58 countries and run from 1960 to 2007. In particular, the study aims at justifying the use of time series techniques and re-investigating whether the more recent finding that aid has an insignificant impact on per capita income is plausible and robust. Plausibility is checked by looking at the transmission channels of aid and by testing the direction of causality between aid and income and robustness is checked by investigating sub-samples of the 58 countries and by refining the model. In particular, we allow for threshold effects of aid, considering that aid might become effective after certain threshold values of other growth-determining factors have been achieved. Overall, we find that the result of an insignificant impact of aid on per capita income is robust taking a long-run perspective. Not being able to establish a significant impact of aid on income in the long run does not rule out that in the short to medium run significant positive (or negative) effects of aid can appear and, therefore, a positive short-run contribution of aid is a possible result and no counter-evidence for the findings related to the long run. In addition, we do not find any evidence that would justify the use of a model with interaction terms or with thresholds.

Key words foreign aid, per capita income, time series,

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1. Introduction

The aid effectiveness literature has seen four generations of aid-income respectively aid-growth studies and altogether the results have been quite mixed. Whereas the older studies found a positive impact of aid on growth, more recent studies doubted the robustness of these results. The emphasis or precise choice of the dependent variable in those studies shifted from time to time. The first generation of aid effectiveness studies analyzed the impact of aid on capital accumulation, the second generation studied the impact on growth (both based on cross-sectional analysis), the third generation studied the impact on growth based on panel data and applied more refined techniques. Country heterogeneity was controlled for, interaction terms[1] were used and the linear impact of aid was checked. The fourth generation was even more sophisticated in that the endogeneity of aid was fully taken into account and even more rigorous research questions[2] were addressed. However, a common feature of these studies was that they all investigated the impact of aid on the *growth rate of per capita income*.

The study of Rajan and Subramanian (2008) and Nowak-Lehmann et al. (2012) fall into the fourth or respectively into a new category of aid studies and, in a nutshell, find an insignificant impact of aid on per capita income. While the fourth generation study of Rajan and Subramanian concentrates on finding proper instruments for aid and subjecting the aid-growth relationship to numerous robustness checks (looking at different components of aid, at different time periods and taking different time perspectives), the latter study makes stronger use of time series techniques, emphasizes explicitly on the long-run perspective and studies the impact of aid on per capita income and not its growth rate given the time series properties of the variables under study.

Various meta studies performed by Doucouliagos and Paldam (2009, 2010, 2013) support our results and the results found by Rajan and Subramanian (2008). Fuelled by a critique of Lof, Mekesha and Tarp (2013, 2014) it is one objective of the paper to

[1] The third generation of growth models intensively used interaction terms and studied whether aid in conjunction with geography, economic policy, institutional quality, political stability and the like had an impact on economic growth.

[2] The researchers studied e.g. whether different types of aid would have a different impact on growth, whether the impact of aid differed between time periods (the 1960s, the 1970s etc.) or over different time horizons (10-year, 20-year, 30-year, 40-year horizon).

check anew the plausibility and the robustness of results of the study by Nowak-Lehmann et al. (2012).

The paper is structured as follows: Section 2 presents our parsimonious empirical open economy model as well as its main findings and provides a justification for the use of time series techniques. Section 3 checks the plausibility of the results by taking a close look at the macroeconomic transmission channels of aid and by uncovering the direction of causality in the aid-income relationship by means of a Vector Error Correction Model (VECM)[3].. Section 4 tests the general robustness of our parsimonious Solow model by looking at an augmented model that allows for indirect (combined effects of aid) by applying Panel Smooth Transition (PSTR) models and Section 5 finally concludes.

2. Applying a Solow-type model

2.1 The open economy Solow-type model and a time-series based estimation technique (DFGLS)

Following Cellini (1997), we apply a 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 aforementioned 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 (domestic capital stock) can be either domestically financed (by both private and/or public domestic savings), 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, calculated by Roodman (2008), is our preferred measure of aid as it substracts interest payments on debt and debt forgiveness. The domestic capital stock then consists of domestically financed physical capital (*Kdomy*), externally financed physical capital following market conditions (*Kextny*), and externally financed physical capital involving a grant element (*Knaty*):

[3] VECMs are the basis for long-run and short-run Granger causality tests.

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

$$Y_{i,t} = Kdomy_{i,t}^{\alpha_1} \cdot Kextny_{i,t}^{\alpha_2} \cdot Knaty_{i,t}^{\alpha_3} \cdot (A_{i,t} \cdot L_{i,t})^{1-\alpha_1-\alpha_2-\alpha_3} \cdot e^{u_{i,t}} , \quad (1)$$

where $\alpha_1,\ \alpha_2,\ \alpha_3$ are technology parameters; subscripts i and t indicate country and time respectively; $e^{u_{i,t}}$ is the error term; L is labor; $Kdomy,\ Kextny$, and $Knaty$ are (imperfectly substitutable) physical capital financed by three different sources, with their returns free to differ from each other since they come from different investors[4] with varying motivations and demands; A indicates the technology level, which is the same across countries at date t.

$Kdomy,\ Kextny$ and $Knaty$ grow according to the following equations:

$$\frac{dKdomy_{i,t}}{dt} = sdomy_{i,t} Y_{i,t} - \delta Kdomy_{i,t} , \quad (2)$$

$$\frac{dKextny_{i,t}}{dt} = sextny_{i,t} Y_{i,t} - \delta Kextny_{i,t} , \quad (3)$$

$$\frac{dKnaty_{i,t}}{dt} = snaty_{i,t} Y_{i,t} - \delta Knaty_{i,t} , \quad (4)$$

where $sdomy$ is the domestic savings-to-GDP ratio; $sextny$ is the external savings-to-GDP ratio minus the aid-to-GDP ratio (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 constant across countries and over time. The rate of technological progress g is also constant, such that:

$$A_{i,t} = A_{i,0} e^{gt} . \quad (5)$$

Furthermore, the growth of the labor force is denoted by $n_{i,t}$, such that:

$$L_{i,t} = L_{i,0} e^{n_{i,t}} . \quad (6)$$

A constant steady-state level can be derived for:

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

$$\left(Kdomy/AL\right)^{*}=kdomy^{*}=\left(sdomy^{1-\alpha_2-\alpha_3}\,sextny^{\alpha_2}\,snaty^{\alpha_3}\ /(n+g+\delta)\right)^{1/(1-\alpha_1-\alpha_2-\alpha_3)}, \qquad (7)$$

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

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

$$\left(Y/AL\right)^{*}=y^{*}=\left(\begin{array}{l} sdomy^{\alpha_1\ /1-\alpha_1-\alpha_2-\alpha_3}\,sextny^{\alpha_2/1-\alpha_1-\alpha_2-\alpha_3}\,snaty^{\alpha_3/1-\alpha_1-\alpha_2-\alpha_3}\ / \\ (n+g+\delta)^{\alpha_1+\alpha_2+\alpha_3/1-\alpha_1-\alpha_2-\alpha_3} \end{array}\right), \qquad (10)$$

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

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

$$\begin{array}{l} \ln y^{*}_{i,t}=(\ln A_0+gt)+\dfrac{\alpha_1}{1-\alpha_1-\alpha_2-\alpha_3}\ln sdomy_{i,t}+\dfrac{\alpha_2}{1-\alpha_1-\alpha_2-\alpha_3}\ln sextny_{i,t}+ \\ \dfrac{\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3}\ln snaty_{i,t}-\dfrac{\alpha_1+\alpha_2+\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3}\ln(n_{i,t}+g+\delta)+u_{i,t} \end{array}. \qquad (11)$$

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

$$\begin{array}{l} \ln y_{i,t+1}-\ln y_{i,t}=g+(1-e^{-\lambda_{i,t}})\cdot(\ln A_0+gt)+\dfrac{\alpha_1}{1-\alpha_1-\alpha_2-\alpha_3}\ln sdomy_{i,t} \\ +\dfrac{\alpha_2}{1-\alpha_1-\alpha_2-\alpha_3}\ln sextny_{i,t}+\dfrac{\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3}\ln snaty_{i,t} \\ -\dfrac{\alpha_1+\alpha_2+\alpha_3}{1-\alpha_1-\alpha_2-\alpha_3}\ln(n_{i,t}+g+\delta)-\ln y_{i,t}+u_{i,t} \end{array}, \qquad (12)$$

with $\lambda_{i,t}=(n_{i,t}+g+\delta)\cdot(1-\alpha_1-\alpha_2-\alpha_3)$ representing 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.

Given the time series properties of our series we estimate equation (11) respectively (13) and not equation (12)

$$\ln y_{i,t} = \mu_i + \beta_1 \ln sdomy_{i,t} + \beta_2 \ln sextny_{i,t} + \beta_4 \ln snaty_{i,t} + \beta_5 \ln(n_{i,t} + g + \delta) + u_{i,t} \tag{13}$$

Adding 2 leads and lags of all the explanatory variables in first differences to control for endogeneity puts the model into its Dynamic Ordinary Least Squares (DOLS) specification. The DOLS estimator is superconsistent, asymptotically unbiased and normally distributed, even in the presence of endogenous regressors (Herzer et al., 2014)

$$\ln y_{i,t} = \mu_i + \beta_1 \ln sdomy_{i,t} + \beta_2 \ln sextny_{i,t} + \beta_3 \ln snaty_{i,t} + \beta_4 \ln(n_{i,t} + g + \delta) + \sum_{p=-2}^{p=+2} b_{1p} \Delta \ln sdomy_{i,t-p} + \sum_{p=-2}^{p=+2} b_{2p} \Delta \ln sextny_{i,t-p} + \sum_{p=-2}^{p=+2} b_{3p} \Delta \ln snaty_{i,t-p} + \sum_{p=-2}^{p=+2} b_{4p} \Delta \ln(n + g + \delta)_{i,t-p} + u_{i,t}$$

(14)

Equation (14) can be purged from autocorrelation by the Feasible Generalizes Least Squares (FGLS) technique. Thus, we eliminate autocorrelation of the error terms which are linked through

$$u_{i,t} = \rho u_{i,t-1} + \varepsilon_{i,t} \tag{15}$$

with ρ being the autocorrelation coefficient. To this aim, we first run a DOLS estimation (equation (14)) and save the residuals ($\hat{u}_{i,t}$ and $\hat{u}_{i,t-1}$); second, we run a regression on $\hat{u}_{i,t}$ (equation (15)) and estimate $\hat{\rho}$; and third, we transform all variables of equation (14) according to $\ln y^*_{i,t} = \ln y_{i,t} - \hat{\rho} \ln y_{i,t-1}$;.....; $u^*_{i,t} = u_{i,t} - \rho u_{i,t-1}$. We do so for all variables (also the ones in first differences). This leads to the DFGLS estimation which is given by

$$\ln y_{i,t}^{*} = \mu_i + \beta_1 \ln sdomy_{i,t}^{*} + \beta_2 \ln sextny_{i,t}^{*} + \beta_3 \ln snaty_{i,t}^{*} +$$
$$\beta_4 \ln(n_{i,t} + g + \delta)^{*} + \sum_{p=-2}^{p=+2} b_{1p} \Delta \ln sdomy_{i,t-p}^{*} + \sum_{p=-2}^{p=+2} b_{2p} \Delta \ln sextny_{i,t-p}^{*} +$$
$$\sum_{p=-2}^{p=+2} b_{3p} \Delta \ln snaty_{i,t-p}^{*} + \sum_{p=-2}^{p=+2} b_{4p} \Delta \ln(n + g + \delta)_{i,t-p}^{*} + u_{i,t}^{*}$$

(16)

DFGLS is our preferred estimation technique as the DFGLS estimator has all the desirable properties of the DOLS estimator and is also efficient.

2.2 The main reasons for using time series techniques

Time series techniques are a handy tool for pre-checking the statistical relationship between two or more variables but have also received a fair amount of critique[5] (Lof et al., 2013, 2014). By applying time series techniques we are in particular able to follow the relationship between aid and income over time and to check whether and how aid and income are related over time. Below we offer a number of reasons that support the usefulness of time series techniques to estimate the aid-income relationship:

First, given the time series properties of aid and income (aid, the other control variables and per capita income are non-stationary) we have to make sure that these variables do not form a spurious relationship.[6] To this end, we perform unit root tests on the series (even though not perfect as there are missing values[7]; see Appendix A, Table A1) to evaluate the trending behavior of the series in question. Thereafter we apply a test of cointegration to check the non-spuriousness of the relationship (see Appendix A, Table A2-A4). Overall, we find the series to be non-stationary (trending upwards and downwards) and to be cointegrated, i.e. they stand in a systematic

[5] One critique was the presence of missing values which hampers working with leads and lags, another related critique was the creation of missing values by the log transformation of the series (in particular net external savings).
[6] To be clear, using other estimation techniques (panel fixed effects, 2ways panel fixed effects, pooled OLS, GMM, SUR, Maximum Likelihood or any other technique), *we ought to rule out as well that we are running spurious regressions*.
[7] In particular, missing values affect the control variable "log of net capital inflows" as negative values do occur when recipient countries' lending exceeds their borrowing abroad. Aid and per capita have only 3 % missing values.

(non-spurious) relationship[8]! Thus, we claim that by running the regression between $\ln y_{i,t}$ and $\ln snaty_{i,t}$ (and some further control variables) we can rule out estimating a spurious relationship in the period of 1960 to 2007. By analogy, the analysis of the time series properties allows us to reject the idea of running a regression between the *growth rate of per capita income* (dependent variable: $\ln y_{i,t} - \ln y_{i,t-1}$) [9] and aid (and other control variables) as growth of per capita income is stationary and aid and other controls are non-stationary variables[10].

Second, cointegration of the series implies a systematic long-run relationship, but remains silent about the direction of the relationship between aid and per capita income. To clarify the direction of causality we apply Granger causality tests within a Vector Error Correction (VEC) framework and test whether aid impacts on income OR whether income influences aid (reverse causality).

Third, inclusion of the variables in first differences with its leads and lags allows us to control for *endogeneity*. This is equivalent to an internal instrument approach which has been called Dynamic Ordinary Least Squares (DOLS) by Stock and Watson (1993) or Leads and Lags approach by Wooldridge (2009).

Fourth, time series techniques allow us to *control for autocorrelation of the error terms*. As it is well-known, autocorrelation renders the estimators inefficient. Control of autocorrelation is achieved by the standard two stage Feasible Generalized Least Squares technique (FGLS) and this technique is integrated into the leads and lags approach thus leading to DFGLS estimates.

To sum up, we use time series techniques (such as DFGLS) not because these techniques are fancy but rather because these techniques enable us to run non-spurious regressions , to determine the direction of the relationship, to control for endogeneity of all regressors and to eliminate autocorrelation.

[8] Based on the data we have (the sample is of course reduced due to missing values)
[9] Growth of per capita income was usually chosen as the relevant dependent variable and we show this to be a questionable approach.
[10] Aid might be related with growth for a few years but not over the whole time period (1960-2007).

Table 1 Results for all countries

	Dependent variable: per capita income (DFGLS estimation)		
	Full model **All countries** (1)	Full model **Above-average aid recipients** aid/GDP> 5.5% (2)	Full model **Below-average aid recipients** Aid/GDP< 5.5% (3)
Population growth	-0.003 (-0.02)	0.04 (0.26)	0.37 (1.43)
Domestic savings	0.07*** (4.69)	0.05*** (3.52)	0.16*** (5.32)
Net external savings	0.05*** (4.42)	0.04** (2.01)	0.06*** (5.01)
Net aid transfer (aid-to-GDP)	-0.01 (-1.23)	-0.03 (-1.48)	-0.01 (-0.62)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections	50	23	27
Periods	41	41	41
Observations	755	343	412
R-squared adj.	0.99	0.99	0.99
Durbin-Watson stat.	2.02	2.27	1.99

Note: All variables are in logs; Full model with 4 independent variables; t-values in parentheses: White robust standard errors; Control for autocorrelation via FGLS.

Table 2 Results for regions of the world

	Dependent variable: per capita income (DFGLS estimation)		
	Full model **Africa** (1)	Full model **Asia** (2)	Full model **Latin America & Caribbean** (3)
Population growth	-0.10 (-0.45)	-0.51 (-1.31)	1.21** (2.50)
Domestic savings	0.06*** (4.24)	0.02 (0.65)	0.12*** (3.83)
Net external savings	0.04** (2.32)	0.02 (1.46)	0.07*** (3.50)
Net aid transfer (aid-to-GDP)	-0.01 (-0.45)	-0.03 (-1.24)	-0.05** (-2.03)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections	25	6	16
Periods	41	41	41
Observations	356	136	186

R-squared adj.	0.99	0.99	0.99
Durbin-Watson stat.	1.93	2.16	1.92

Note: All variables are in logs; Full model with 4 independent variables; t-values in parentheses: White robust standard errors; Control for autocorrelation via FGLS.

Table 3 Results according to human development and income

	Dependent variable: per capita income (DFGLS estimation)		
	Full model **LDCs** (1)	Full model **Low income countries** (2)	Full model **Middle income countries** (3)
Population growth	-0.23 (-0.69)	-0.30 (-1.09)	0.23 (0.78)
Domestic savings	0.05*** (2.94)	0.06*** (3.61)	0.18*** (5.53)
Net external savings	0.08*** (2.61)	0.05*** (2.57)	0.06*** (4.31)
Net aid transfer (aid-to-GDP)	-0.01 (-0.50)	-0.02 (-1.06)	-0.01 (-0.68)
Fixed effects	yes	yes	yes
2 leads and 2 lags	yes	yes	yes
Cross sections	18	24	24
Periods	41	41	41
Observations	295	397	321
R-squared adj.	0.99	0.99	0.99
Durbin-Watson stat.	2.14	1.73	2.41

Note: All variables are in logs; Full model with 4 independent variables; t-values in parentheses: White robust standard errors; Control for autocorrelation via FGLS.

The main results are given in Tables 1-3. We find that domestic and external savings always have a positive and significant impact on per capita income which makes the increase of domestic and external savings a policy imperative. The impact of population growth is mostly insignificant and so is the impact of aid (net aid transfers as a percentage of GDP).

2.3 The plausibility of results: An economic perspective

As critiques doubt the correctness and robustness of the finding that aid had an insignificant influence with respect to per capita income during the period of 1960 to 2007, we offer some robustness[11] and plausibility checks in the following paragraphs (Tables 4-6) and Appendix B1&B2 (Tables 1* and 1**).

Table 4 Macroeconomic transmission channels of aid

	Possible transmission channels (DFGLS estimation)		
	Investment channel *Dependent variable: Investment-to-GDP ratio* (1)	**Domestic savings channel** *Dependent variable: Domestic Savings-to-GDP ratio* (2)	**Real exchange rate channel** *Dependent variable: Real exchange rate* (3)
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
Periods included	41	41	28
R-squared adj.	0.91	0.66	0.66
Durbin-Watson stat.	1.92	1.83	2.13

t values are in parentheses. *** (*): significant at the one (five) percent level. All variables are in logs.

In Table 4 we ask whether and how we can explain the insignificant impact of development aid by investigating the macroeconomic transmission channels of aid. Again the DFGLS technique that controls for endogeneity of all explanatory variables

[11] More robustness checks that deal especially with the missing values problem can be found in Herzer et a. (2014).

and autocorrelation of the error terms has been used. We look at three transmission channels: the investment channel (investment-to-GDP; col.1), the domestic saving channel (domestic savings-to-GDP; col. 2) and the real exchange rate channel (col. 3). Table 4 shows that aid has a small but positive and significant impact on investment which is good news for aid effectiveness but both a negative and significant impact on domestic savings (both household and government savings) and the real exchange rate, i.e. aid crowds out domestic savings and leads to an appreciation of the real exchange rate, the latter being detrimental for the production of tradables. The latter two effects counteract the positive effect on investment and thus are able to explain the insignificant impact of aid on per capita income from an economic perspective and make the result look plausible.

3. Long-run Granger causality and robustness checks with a vector error correction model

In this section we will search for a statistical/econometric explanation for the insignificant impact of aid by checking the direction of causality between aid and per capita income.

Having established cointegration we can be assured that per capita income and aid stand in a long-run relationship but the direction of this relationship has not yet been uncovered (see Appendix A, Tables A2-A4). In principle, the relationship between aid and per capita income can be unidirectional, i.e. either running from aid to per capita income or the other way around, or the relationship can be bidirectional.

The direction of the relationship can be determined by means of a panel Vector error correction model (VECM) which also serves as a tool for checking the direction of causation. As aid_{it} [12] and $income_{it}$ [13] are cointegrated, the bivariate panel VECM is given by equation (17):

$$\Delta y_{it} = \mu_i + \alpha\beta' y_{it-1} + \sum_{j=1}^{p-1} B_j \Delta y_{it-j} + \varepsilon_{it} \tag{17}$$

[12] The logarithm of the aid-to-GDP ratio.
[13] The logarithm of per capita income.

where Δy_{it} is the vector of log first differences $(\Delta income_{it}, \Delta aid_{it})'$, α = $(\alpha_1, \alpha_2)'$ is the vector of adjustment (or loading) coefficients, B_j is a matrix of short-run coefficients, and $\beta = (1, -\beta_{aid})'$ is the cointegrating vector for $y_{it} = (income_{it}, aid_{it})'$ normalized on $income_{it}$. This normalization suggests the long-run relationship $income_{it} = \beta_{aid} aid_{it} + \varepsilon_{it}$.

The term $\beta' y_{it-1} = ec_{it-1}$ is the (lagged) error correction term, or cointegrating residual. It represents the error in, or deviation from, the equilibrium, and the adjustment coefficients (α_1 and α_2) capture how $income_{it}$ and aid_{it} respond to deviations from the equilibrium. The Granger Representation Theorem (Engle and Granger, 1987) states that, if a vector y_{it} is cointegrated, at least one of the adjustment coefficients must be non-zero in the VEC representation (17).

Table 5a. *Weak exogeneity tests / long-run causality tests*

Dependent var.	aid_{it}	$income_{it}$
Right-hand side variable	$income_{it}$	aid_{it}
(Adjustment coefficient)	(α_1)	(α_2)
Chi-sq	7.35	1.76
p-values	(0.03)	(0.41)

Note: H_0: $\alpha_{1,2} = 0$. The variables do not Granger cause each other (long-run perspective). The number of lags was set to 2, based on the Akaike, Schwarz information criterion and the Hannan-Quinn criterion.

Table 5b. *Weak exogeneity tests / short-run causality tests*

Dependent var.	Δaid_{it}	$\Delta income_{it}$
Right-hand side variable	$\Delta income_{it}$ (B_1)	Δaid_{it} (B_2)
Chi-sq	5.48	14.32
p-values	(0.06)	(0.001)

Note: H_0: $B_{1,2} = 0$. The variables do not Granger cause each other (short-run perspective). The number of lags was set to 2, based on the Akaike, Schwarz information criterion and the Hannan-Quinn criterion.

Table 5a depicts the results related to long-run Granger causality. We see that *income* determines *aid* in the long run (α_1 is significantly different from zero) whereas *aid* does not Granger cause *income (*α_2 is not significantly different from zero). Thus, *cointegration is unidirectional and aid does not Granger cause changes in income in the long term* which explains why aid has been ineffective in promoting per capita income in our period of study.

Short-run causality is shown in Table 5b. With B_1 and B_2 being significantly different from zero, we conclude that Granger short-run causality runs in both directions. Hence, in the short run *aid* and *income* influence each other.To sum up, we find a *long-run causal relationship in one direction, running from income to aid* but not from aid to income (see Table 5a) and a *bidirectional relationship in the short run* (see Table 5b).

All in all, the results of the long-run Granger causality test showing that aid turns out to be an inadequate/insignificant predictor of per capita income add statistical plausibility to our central finding that aid had an insignificant impact on per capita in the period of 1960 to 2007

We also use the VECM to check the robustness of the regression coefficients which were obtained through DFGLS. Hence, we estimate the 1960-2007 period, using 55-57 cross-sections and including country fixed effects to control for country heterogeneity. We estimate both a multivariate VECM (col. 1) and a bivariate VECM (col. 2).

By applying a vector error correction model we obtain positive but *insignificant results for the long-run impact of aid*[14] (see Table 6). This finding is in line with the results presented in Tables 1-3 and the Granger causality findings in Table 5a. The *short-run coefficients of aid* (in the first two lines of the explanatory variables) are positive and insignificant for the first lag and significant for the second lag; together they have a positive and significant short-run impact on changes of per capita income. However, it has to be emphasized that endogeneity is not properly controlled for in the VECM estimation and therefore the DFGLS estimators remain our preferred estimators.

[14] The VECM allows us to differentiate between short-run and long-run effects, but in contrast to the DFGLS estimation it does not control for endogeneity.

Table 6 Vector error correction models confirm the insignificance of the aid coefficient using the aid-to-GDP ratio

	Multivariate model VECM (1) Dependent variable: *Per-capita income*	Bivariate model VECM (2) Dependent variable: *Per-capita income*
$\Delta netaidtr(-1)$ *Short run*	0.0025 (0.15)	0.0017 (0.37)
$\Delta netaidtr(-2)$ *Short run*	0.0042*** (0.001)	0.0038*** (0.010)
Net aid transfer Long run	0.04 (0.22)	0.04 (0.31)
Further controls in cluded, number	yes, 2	no
Fixed effects	yes	yes
2 lags	yes	yes
Cross sections included	56	57
Periods included	44	44
Number of observations	1964	2314
R-squared adj.	0.17	0.13
Durbin-Watson stat.	1.92	1.98

p values are in parentheses. *** (**; *): significant at the one (five; ten) percent level. All variables are in logs. Coefficients of population growth and domestic savings are not reported in col.1.

4. Does the impact of aid depend on other variables and certain threshold values? A further robustness check

So far we could not find a significant *direct* impact of aid on per capita income (running from aid to per capita income), but it might still be the case that aid impacts in conjunction with other variables on income. Hence, we will refine our model in line with the third generation of growth models.

In a first step we will test on interaction effects[15], in specific, aid interacted with 'key' macroeconomic variables and aid interacted with institutional variables. Only if the interaction terms are significant we will proceed to the second step. In this latter step we will try to determine certain threshold values above which aid might have an impact on income by estimating a non-linear model with one threshold and two regimes.

We test for the relevance of the investment-to-GDP ratio, the saving-to-GDP ratio and variables, such as external conflict, internal conflict, ethnic tensions, government stability, bureaucratic quality, democratic accountability, corruption, law and order and a composite index of institutional quality considering them as factors that could enhance the effectiveness of development aid. Significance of the interaction terms is a prerequisite for qualifying as a transition variable. According to Appendix B2, Tables 2* and 2** only two variables *are possibly able to carve out or reinforce the impact of aid on income*, namely *democratic accountability* and *bureaucratic quality*. Results for the other variables are available upon request.

Applying a smooth transition model

The above tests on the relevance of simple and higher order interaction terms have demonstrated that only *democratic accountability* and *bureaucratic quality* qualify as transition variables.

Hence, *we will apply a smooth transition model to these two variables*, studying their continuous impact and looking for a threshold value above which aid might be effective. By utilizing smooth transition models, we do allow for heterogeneity in the regression coefficients that can vary both across countries and over time. The relevant coefficients are defined as continuous functions (transition functions) of an observable variable (transition variable) and fluctuate between a limited number of regimes (in our case two regimes). As the transition variable q_{it} is country-specific and time-varying, the regression coefficients for each of the countries in the panel do change over time.

[15] According to the literature (Hansen, 2000; González et al. , 2005) the relevance of interaction effects is tested by interacting aid with the so-called transition variables 'q' and its second and third moments.

Following González et al. (2005) who apply the smooth transition model to panel data (PSTR) we can formulate the following equation for cases with two extreme regimes (regime1: aid has no impact *below* the threshold: β_0; aid has additional impact *above* the threshold: $\beta_0 + \beta_1$)

$$\ln y_{it} = \mu_i + \beta_0^{'} x_{it} + \beta_1^{'} x_{it} trf(q_{it};\lambda;c) + u_{it} \tag{18}$$

Using a logistic specification for the transition function

$$trf(q_{it};\gamma;c) = \left(1 + \exp(-\gamma \prod_{j=1}^{J} (q_{it} - c_j)\right)^{-1} \tag{19}$$

with $\gamma > 0$ and $c_1 \leq c_2 \leq ..... \leq c_J$

With only two regimes (below and above threshold value c) equation (7) turns into

$$\ln y_{it} = \mu_i + \beta_0^{'} x_{it} + \beta_1^{'} x_{it} \left(1 + \exp(-\gamma (q_{it} - c)\right)^{-1} + u_{it} \tag{20}$$

which is estimated via Limited Information Maximum Likelihood (LIML) on the demeaned variables to account for country fixed effects and to simulate a within LIML estimation.

Table 7 The impact of aid when a covariate (transition variable) changes

	Dependent variable: $\ln y_{it}$ LIML estimation, within transformation of variables	
Transition variable	**(1) Democratic accountability**	**(2) Bureaucratic quality**
Direct impact of aid	-0.005 (-0.001)	0.001 (0.00)
Indirect impact of aid Coefficient of composite term	-0.013 (-0.00)	0.002 (0.00)
Slope of transition function	-0.017 (0.00)	0.004 (0.00)
Threshold value	0.020 (0.00)	0.12 (0.00)
Threshold value transformed	1.02	1.13
Included obs	1663	1467

Note: All variables are demeaned to account for country heterogeneity. Endogenous variables are instrumented. T-values in parentheses.

Table 7 consistently shows that the direct impact of aid is insignificant which adds further evidence to the results obtained earlier. The indirect impact of aid for which we assume that aid works better when the democratic accountability or bureaucratic quality are higher, is also insignificant. The insignificant impact implies that neither democratic accountability nor bureaucratic quality add anything to the impact of aid. Why? First, we observe that the slope of the transition function is very flat, meaning that the transition variable does not really trigger any additional impact of aid and no further impact of aid is generated by improving the institutional quality. Second, we must note that the threshold value of the transition variable is extremely low (being about 1). Remember that the transition variable can take on values ranging from 0 to 10 and the average value for democratic accountability is about 3.05 and the average value for bureaucratic quality is about 1.60. Higher values mean better quality/less problems. The threshold value computed suggests that basically all countries in the sample comply with this value (the value being so low) and that given the above-threshold institutional quality does not play a role.

5. Conclusions

Applying DFGLS, a fixed effects panel time series technique, which allows to control for time-invariant country heterogeneity, endogeneity and autocorrelation, we find aid to have an insignificant impact on per capita income. This result does neither depend upon the estimation technique (VECM, GMM, SUR,) nor on the parsimonious specification of our model that shows no omitted variable problem but allows only for a direct impact of aid. Running models augmented with interaction effects and threshold models (panel smooth transition models) the results remain unchanged. Thus, we can conclude that aid did not have a significant positive impact on per capita income in the period of 1960-2007. This was not the effect we were hoping for, but this effect is supported by the data and the time period under investigation.[16]

[16] As to the African region, Goldbach (2013) found an insignificant impact of aid (aid-to-GDP; aid per capita; early aid; multilateral aid; aid interacted with policy, governance, democracy, ethnolinguistic fractionalization) using GMM (controlling for country heterogeneity and endogeneity). The impact of aid turned positive and significant *when no fixed effects were used and when endogeneity was insufficiently controlled for*.

This finding does neither rule out the possibility that aid might have a positive impact in the short run nor that aid could become more effective in the future by changing the voice of recipient countries, the administration of aid and/or the structural allocation of aid. Nor does it rule out that particular portions of aid have had a positive impact (while others had an insignificant or negative effect). All of these issues deserve further analysis in future work.

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Appendix A

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

Variable tested	Fisher statistic	Probability	Degree of integration
Growth of per-capita income	226.91	0.00	I(0)
Per-capita income [in levels]	82.73	0.99	I(1)
Population growth, technological change, and capital-depreciation rate	104.20	0.78	I(1)
Domestic savings	89.35	0.94	I(1)
Net external savings	100.84	0.20	I(1)
Aid	95.64	0.89	I(1)
Investment	110.70	0.62	I(1)
real exchange rate	60.00	0.33	I(1)

The Fisher statistic proposed by Madalla and Wu (1999) is based on the p-values of the individual ADF tests. It is distributed as χ^2 with $2\times N$ degrees of freedom, where N is the number of countries in the panel. All variables are in logs. Investment is the log of the investment-to-GDP ratio. 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). The first differences of the rest of the series are stationary (results not reported).

Table A2 Results of Kao's panel cointegration test

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

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 determined by the Schwartz criterion.

Table A3 Results of Pedroni's panel cointegration test

Pedroni's residual-based 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

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

Table A4 Results of the Johansen-Fisher panel cointegration test

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

The Fisher statistic proposed by Madalla and Wu (1999) is based on the p-values of the individual country trace statistics for different cointegration ranks. The Fisher statistic is distributed as χ2 with 2×N degrees of freedom. H_0: The variables of interest are not cointegrated (no cointegration); H_1: One cointegrating vector can be identified (Johansen, 1988).

Appendix B

B1. Checking the robustness of results by using different estimation techniques

Using 5-year averages to smooth series and to mitigate the missing values problem

Taking 5-year averages smoothes series over time and mitigates or even eradicates the missing values problem and can thus be used as a robustness check.

Being sure that the relationship is non-spurious and by tackling the endogeneity and the autocorrelation problem, Table 1*[17] contains alternative estimation techniques that are not based on pure time series techniques, namely GMM (Generalized Method of Moments) and Seemingly Unrelated Regressions (SUR) estimations. Table 1 displays either an insignificant (Table 1, col. 2 and 3) or a negative and significant relationship (Table 1, col. 1) between aid and per capita income.

Table 1* The income-aid relationship (in a sample of 131 countries) using 5-year averages and standard (not time series based) panel data techniques

	Dependent variable: real per capita income		
	GMM estimation (5-year averages) (1)	GMM estimation (5-year averages) (2)	SUR estimation (5-year averages) (3)
Population growth	0.37	0.28	0.30
	(1.33)	(1.57)	(0.36)
Domestic savings	0.04*	0.01*	-0.18
	(1.92)	(1.99)	(-1.11)

[17] Table 1, col. 1-3 corresponds to Table 6, col. 4-6 (NDHKM, 2012; Canadian Journal of Economics, 45(1): 288-313).

Net extern. savings	0.01	0.01	0.12
	(0.53)	(1.61)	(1.10)
Net aid transfer	-0.02*	-0.02	-0.13
(aid-to-GDP)	(-1.69)	(-1.37)	(-1.40)
Fixed effects	yes	yes	yes
Time effects	yes	yes	no
Instrum. (IV)	yes	yes	no
Autocorr. control	no	yes via a two step procedure	yes via SUR
AR(1)-coefficient		0.88***	
		(3.98)	
Periods included	8	7	7
Number of observations	400	350	350
R^2 adj.	___	___	___
DW stat.	___	___	___
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	

t values are in parentheses. *** (**; *): significant at the one (five; ten) percent level. All variables are in logs. Panel GMM (Generalized Method of Moments) is applied to the sample with 5-year averages. Taking averages alleviates or even eliminates the missing value problem (also due to the log transformation) and allows to limit the number of moment conditions. Due to autocorrelation of the disturbances, the instruments (lagged values of the variables) can become invalid (col.1.). The instruments in col. 2 are OK at a 80% confidence level. ar1 (ar2) stands for a test on first order (second order) autocorrelation. ar1p and ar2p represent the corresponding p-values of the test.

B2. Pre-testing the relevance of interaction terms

Table 2*Testing the interaction between aid and democratic accountability

Dependent Variable: LRYPOP
Method: Panel Least Squares
Date: 04/15/14 Time: 15:07
Sample (adjusted): 1961 2006
Periods included: 46
Cross-sections included: 47
Total panel (unbalanced) observations: 1988
White cross-section standard errors & covariance (d.f. corrected)
Convergence achieved after 6 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.372419	0.215892	43.41263	0.0000
LNATY	-0.008991	0.006034	-1.490233	0.1363
LNATY*LDEMOACC	-0.036649	0.020694	-1.771038	0.0767
LNATY*LDEMOACC^2	0.058349	0.030389	1.920108	0.0550
LNATY*LDEMOACC^3	-0.021709	0.012161	-1.785110	0.0744
AR(1)	0.981362	0.004708	208.4250	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.999898	Mean dependent var	8.670904
Adjusted R-squared	0.999895	S.D. dependent var	4.627276
S.E. of regression	0.047403	Akaike info criterion	-3.234439
Sum squared resid	4.350344	Schwarz criterion	-3.088093
Log likelihood	3267.032	Hannan-Quinn criter.	-3.180687
F-statistic	371206.8	Durbin-Watson stat	1.630234
Prob(F-statistic)	0.000000		

Inverted AR Roots .98

Table 2** Testing the interaction between aid and bureaucratic quality

Dependent Variable: LRYPOP
Method: Panel Least Squares
Date: 04/15/14 Time: 15:01
Sample (adjusted): 1961 2006
Periods included: 46
Cross-sections included: 46
Total panel (unbalanced) observations: 1729
White cross-section standard errors & covariance (d.f. corrected)
Convergence achieved after 7 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.600784	0.231238	41.51910	0.0000
LNATY	-0.010037	0.003680	-2.727108	0.0065
LNATY*LBQ	-0.205846	0.066358	-3.102068	0.0020
LNATY*LBQ^2	0.508272	0.153394	3.313496	0.0009
LNATY*LBQ^3	-0.290228	0.084955	-3.416245	0.0007
AR(1)	0.980803	0.005311	184.6822	0.0000

Effects Specification

Cross-section fixed (dummy variables)			
R-squared	0.999887	Mean dependent var	8.869462
Adjusted R-squared	0.999883	S.D. dependent var	4.453617
S.E. of regression	0.048139	Akaike info criterion	-3.200408
Sum squared resid	3.888485	Schwarz criterion	-3.039494
Log likelihood	2817.753	Hannan-Quinn criter.	-3.140888
F-statistic	295775.2	Durbin-Watson stat	1.682599
Prob(F-statistic)	0.000000		
Inverted AR Roots	.98		