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Energy Savings via FDI?
Empirical Evidence from Developing Countries*

Michael Hübler and Andreas Keller

Abstract:

In this paper we examine the influence of foreign direct investment inflows on energy intensities of developing countries empirically. We first show that a simple OLS estimation, as it is found in the literature, suggests energy intensity reductions from FDI inflows, which is consistent with the hypothesis of energy saving technology transfer via FDI. However, such a regression turns out to be spurious and only a starting point for further research. Therefore, we use macro level data on 60 developing countries for the period 1975-2004 including other potential determinants of energy intensities and apply panel estimation techniques and tests. The results do not confirm the hypothesis that FDI inflows reduce energy intensities of developing countries in general. Interactions of FDI with country-specific characteristics do not show significant effects, either.

Keywords: developing countries, energy intensity, FDI, technology transfer

JEL classification: F18, F21, O13, O33, Q43, Q56

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1 Introduction

While economic growth in developing countries is a desirable goal, its side effects of rising energy demand and greenhouse gas emissions are problematic in light of global warming. The controversial discussions during the Bali climate policy conference in 2007 showed that including the developing countries in a post Kyoto agreement in a fair way is a challenge, and it was emphasized that the industrialized countries need to support the developing countries by technical, financial and educational measures.

One possibility to slow down rising emissions is energy saving technology transfer to developing countries. It is thus important to detect how international technology transfer occurs, how it affects energy supply and demand and as a consequence greenhouse gas emissions. A better understanding of these issues can improve the predictions of future emissions paths in climate change models and also assist in implementing measures for greenhouse gas mitigation policies. Knowing the sources of emission reducing technological change, decision makers can systematically support these sources. Foreign direct investment (FDI) is regarded as one important channel for technology transfer in general (e.g. Keller 2004). Empirical evidence on energy saving international technology transfer could answer the question if more FDI flows to developing countries can bring about the technology transfer, which effectively helps to restrain energy use and thus greenhouse gas emissions. While it is likely that issue-linked FDI inflows – e.g. FDI under the clean development mechanism (CDM) of the Kyoto Protocol – exert an energy reducing effect, such an effect is by no means obvious when aggregate FDI inflows are analyzed. A further interesting aspect will be to identify if there exist country-specific characteristics that interact with FDI inflows and thereby enhance their energy reducing potential.

Despite the relevance of the topic, only little empirical evidence exists regarding the transfer of energy saving technologies. Some case studies and micro-econometric work using firm-level data indicate that foreign owned firms in developing countries indeed use less energy than their indigenous counterparts (e.g. Eskeland and Harrison 2003). However, comprehensive studies on an aggregate level with cross country data are missing. A 'viewpoint' by Mielnik and Goldemberg (2002) using data from 20 developing countries is a starting point for the discussion, finding a negative effect of FDI on energy intensity. However, this analysis controls for no other influences on energy demand and moreover, using unit root and cointegration tests, we show that the regression result is spurious. Hence, rather than providing general evidence, the viewpoint by Mielnik and Goldemberg opens a promising way for further research.

To resolve the shortcomings, in this paper we use a large macro level panel data set and an extended econometric model in order to investigate whether it is possible to find evidence for FDI having a general impact on energy intensity. The data set includes 60 developing countries for the years 1975 to 2004. We first carry out a detailed descriptive data analysis. We then run fixed effects regressions in first differences including control variables such as GDP per capita, domestic investment and the share of industrial value added in GDP, as well as imports and aid inflows for comparison with FDI inflows. In further specifications, we add interaction terms of FDI with country-specific characteristics like the shares of distinct energy sources in total energy supply of each country to analyze if specific country characteristics facilitate energy reductions via FDI.

In contrast to the hypothesis proposed by Mielnik and Goldemberg (2002), we find *no* robust energy reducing effect of FDI inflows in developing countries. The interactions of FDI inflows with country-specific characteristics yield no significant results, either. A possible explanation is that the energy saving technology transfer from aggregate FDI inflows is too small to yield significant effects in our macro analysis. Energy reducing effects might also be offset by a shift towards more energy intensive production via a change in the composition of an economy's output. For policy makers who seek to achieve energy reductions in developing countries, our results imply that a general support of FDI inflows is not enough; it is rather necessary to explicitly encourage that kind of foreign direct investment that brings about energy reducing technology transfer. Issue-linkage, as for example the clean development mechanism of the Kyoto protocol, might be a way to achieve this objective.

Our paper is structured as follows. Section 2 explains the theoretical background in part 2.1 and reviews related empirical evidence in the literature in part 2.2. Part 2.3 reproduces the simplified regression analysis by Mielnik and Goldemberg (2002) and shows why this approach is not sufficient. Section 3 describes our empirical analysis. In part 3.1, we explain the choice of the relevant variables and in part 3.2, a descriptive data analysis helps to identify obvious trends. In part 3.3, we specify the estimation models and in part 3.4, we present and discuss the results. Section 4 concludes.

2 The influence of FDI inflows on energy use

In this section we first present the conceptual background for the hypothesis that foreign direct investment has an energy reducing effect in the destination country. Then, we give an overview of the empirical literature examining the evidence on energy reducing technology transfer via FDI, paying special attention to the 'viewpoint' by Mielnik and Goldemberg (2002).

2.1 Theoretical background

Increasing openness to trade and rising FDI inflows affect energy use in an economy via a scale, a composition and a technique effect, which are described in the subsequent paragraphs. This decomposition of the effects of openness on the level of environmental quality has become common in the literature since the seminal work by Grossman and

Krueger (1993), who examined data on sulphur dioxide and suspended particulate matter. The intuitive framework by Grossman and Krueger was later on backed up with formal theory by Antweiler et al. (2001).[1]

FDI inflows are likely to stimulate economic growth. Since expanded economic activity is related to higher energy use, the *scale effect* resulting from FDI inflows is positive. Under the assumption of production functions homogeneous of degree one and without factor substitution, such an output increase leads to a proportional rise in energy input. This means that energy intensity, defined as energy use divided by GDP, stays constant. However, this implication would not hold in the case of economies of scale, i.e. when an expansion of output needs a proportionally lower increase in input quantities.

The *composition effect* represents a structural shift in the economic activity and can be either negative or positive. The sign depends on the specialization patterns of economies with different comparative advantages integrating into the world market. The composition effect reduces a country's energy use if the economy specializes in sectors with lower energy intensities than the previous average of the country. The opposite occurs if a country specializes in more energy intensive sectors. According to the controversial pollution haven hypothesis (developing) countries with lax environmental regulations attract pollution intensive activities raising energy use. One can also expect that in early stages of a country's economic development the sectoral change shifts economic activity from the agricultural to the (heavy) industrial sector. Since the latter is more energy intensive than the former, this implies a positive composition effect. Later in the development process, activity moves typically from the industry to the service sector or from the heavy to the lighter industry. As the latter is less energy intensive, this means a negative composition effect in this stage (Stern 2004). Furthermore, besides production movements between sectors, the composition of factor inputs can change within sectors. In particular, the shares of energy, capital and labor inputs are adjusted.

The *technique effect* covers the impact of openness on the implementation of better and less emission-intensive technologies or the adoption of ecologically beneficial management practices and has an energy reducing effect. We distinguish between a direct and an indirect technique effect. The direct effect denotes the transfer of more energy efficient cleaner technology by foreign investment or trade (in the following just named "technology transfer"). The indirect effect works via a wealth increase: If openness enhances economic growth and hence per capita income, the public's appreciation of a cleaner environment increases. This rising demand may result in the adoption of stricter environmental regulations, followed up by the introduction of cleaner technologies (in the

[1] While the earlier literature concentrated mainly on the emissions of sulphur dioxide, nowadays increasing attention is drawn to the quantity of total energy use, since this is the main driver for any emissions, in particular for greenhouse gas emissions stemming from the burning of fossil fuels. In our analysis, we examine total energy use.

following named "income induced technique effect").[2] Grossman and Krueger (1993) emphasize especially this indirect effect. In their theoretical model, Antweiler et al. (2001) treat the income induced technique effect as the *only* technique effect resulting from increasing openness.[3]

In contrast to the literature linking trade and environment, which has mainly focused on the income induced technique effect, the literature on technological change in general has recently expanded with numerous studies on *technology transfer* resulting from openness to trade and foreign direct investment (for an overview see Keller 2004). Technology transfer via FDI, which potentially reduces energy use, can occur in two ways: First, directly via more efficient foreign firms operating in the host country and second, indirectly through technological spillovers from the foreign firms to indigenous firms. Regarding the direct effect, it is commonly assumed that the technology used by foreign investors is superior to the technology that is currently in place in developing countries. Compared to a similar indigenous firm, the foreign investor uses less energy, creates fewer emissions and hence contributes to the technique effect. Regarding the indirect effect, the literature suggests three potential channels for technological spillovers: demonstration effects, which stand for imitation and reverse engineering by local firms, labor turnover, which implies the transfer of knowledge by workers who change their employer, and vertical linkages, which involve that multinationals deliberately transfer technology to their suppliers or customers (Saggi 2002). Additionally, higher exports and imports as well as foreign direct investment inflows likely lead to increased competition. Firms need to become more productive in order to stay competitive in the export market or to compete with imports and new foreign companies in the domestic market. For instance, Corcos et al. (2007) apply a theoretical model with heterogeneous firms assuming that international trade increases aggregate productivity through a selection effect: The least productive firms leave the market under increased pressure from competition. One can expect that higher productivity also implies more efficient *energy use* in production.

The literature on technology transfer and the recent criticism of the environmental Kuznets curve suggest that openness *per se* should be explicitly considered as a possible reason for the technique effect in environmental economics, instead of focusing primarily on the indirect effect of emission reductions due to rising incomes. For this reason, the technique effect resulting from technology transfer will be in the center of our analysis.

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[2] This effect together with the changing composition effect of a developing economy is related to the vast literature on the so-called environmental Kuznets curve (EKC). The EKC stands for the impact of a country's per capita income on (per capita) pollution suggesting an inverted U-shaped relationship. Although the EKC is a well-known concept and is regarded as a stylized fact in environmental economics, its existence has recently been challenged on both theoretical and empirical sides (e.g. Stern 2004, Siebert 2005). The environmental Kuznets curve has traditionally been applied to emissions of local pollutants, but recent studies also apply this concept to CO_2 emissions (e.g. Mazzanti 2006) as well as energy *intensity* (Galli 1998).

[3] In their empirical estimation of the model, Antweiler et al. (2001) provide a sensitivity test where they explicitly allow for a direct effect of FDI on SO_2 concentrations, representing a combination of composition effect and technology transfer. However, they find no substantial relationship between the extent of FDI in an economy and its pollution level.

2.2 Empirical literature on energy saving technology transfer via FDI

There is a large and growing empirical strand of literature on technology transfer and spillovers in general through FDI. The evidence is mixed, but Keller (2004) notes in his survey article that "recent micro productivity studies tend to estimate positive, and in some cases also economically large spillovers associated with FDI" (p. 771). Among other studies, Tybout (2002) finds evidence for efficiency improvements due to higher exposure to foreign competition as predicted by the new trade theory. However, he points out that it is not clear according to the related literature whether international activities cause these characteristics or vice versa. Furthermore, in all these studies on spillovers and productivity gains, the importance specifically for energy efficiency has not been identified. In the following, we focus specifically on *energy saving* technology transfer via FDI. Peterson (2007) reviews the existing evidence in the literature and remarks that although there may be a large potential for such technology transfer, there is a lack of knowledge about its empirical magnitude and its drivers, and the topic remains insufficiently researched.

The hypothesis that foreign owned companies use less energy than their indigenous counterparts in developing countries is confirmed by studies based on firm-level data. In their study of manufacturing plants in Cote d'Ivoire, Mexico and Venezuela, Eskeland and Harrison (2003) find that foreign ownership is associated with less energy use. A similar result is documented by Fisher-Vanden et al. (2004), who find a negative impact of foreign ownership on the energy intensity of Chinese companies. These examples suggest that the more efficient technology of foreign firms can indeed contribute to an energy reducing technique effect via technology transfer.

On an aggregate level, only very few studies link openness and FDI to energy saving technology transfer: Based on observations and a simplified regression analysis of 20 developing countries, Mielnik and Goldemberg (2002) conclude that FDI indeed has a reducing impact on energy intensity. However, we show in the next section that the variables they use are non-stationary and are not cointegrated, hence their finding is spurious and cannot be considered as evidence. Cole (2006) uses a variation of the model developed by Antweiler et al. (2001) to examine the impact of trade intensity (while not explicitly including FDI) on energy use in 32 developed and developing countries. His panel estimation yields that the effect of liberalization is country-specific and can be positive or negative, depending on whether the country is importing or exporting the energy intensive good (which in turn is determined by the capital to labor ratio).

2.3 Shortcomings of a simplified regression

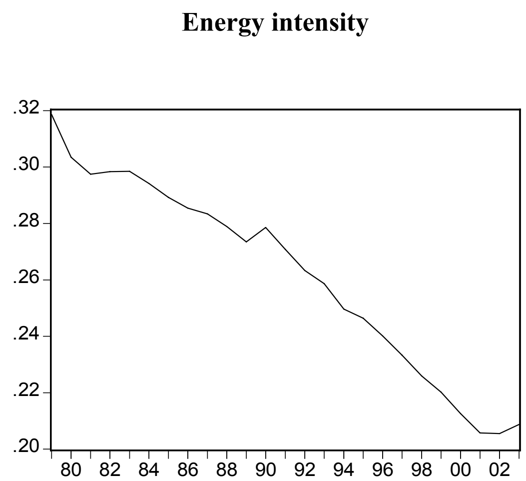
In their 'viewpoint' (Energy Policy 30, pp. 87-89), Mielnik and Goldemberg carry out a simplified regression as a starting point for further research. They interpret their result as indication that the quantity of foreign direct investment inflows has a negative influence on energy intensity. They use a sample of 20 developing countries[4] for the years 1987 to 1998, but aggregate all countries to one time series. They estimate the regression:

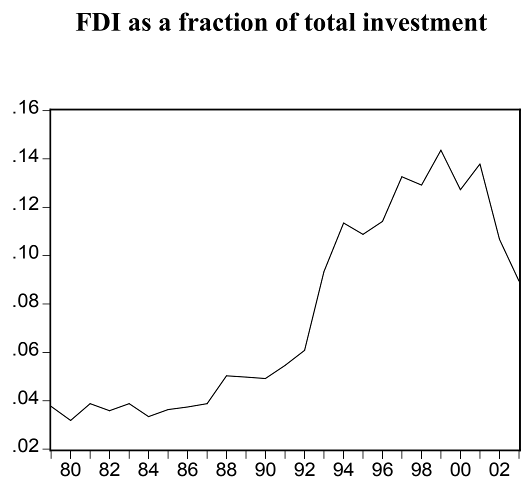
$$EI_t = \beta_0 + \beta_1 \frac{FDI_t}{I_t} + \varepsilon_t \tag{1}$$

The dependent variable EI_t is energy intensity in year t, i.e. the sum of total energy use in all 20 countries divided by their GDP which is measured in purchasing power parity. The explanatory variable FDI_t / I_t represents inflows of foreign direct investment as a fraction of total gross investment in all countries. ε_t is the error term.

First, we reproduce the regression by Mielnik and Goldemberg with the same 20 countries, but for an extended time span. Complete data on gross fixed capital formation, our variable for gross investment, is available for each of the 20 countries from 1979 to 2003. Figure 1 illustrates the trends of both variables.

Figure 1 Trends of the variables in the simplified model 1979-2003





We evaluate our dataset with the same regression model as Mielnik and Goldemberg and find a similar result, which supports the view of a strong energy reducing impact of foreign direct investment: *FDI / I* has a negative coefficient β_1 of -0.774, the constant β_0 is 0.320, and R^2 is 0.818. However, the result of this OLS estimation relies critically on the stationarity assumption of the involved variables.[5] If at least one variable is instead

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[4] The countries are in alphabetical order: Algeria, Brazil, Chile, China (PR), Colombia, Costa Rica, Egypt, India, Indonesia, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, Singapore, South Africa, Thailand, Uruguay.

[5] A time series $X=\{x_1, \ldots, x_m\}$ is called stationary if it has

1. a constant and finite mean over time: $E[x_t]=\mu$ for all t
2. a constant and finite variance over time: $Var[x_t]=\sigma^2$ for all t
3. and constant covariances over time: $Cov[x_t,x_{t+s}]=\sigma_s^2$ for all t, s.

integrated, which implies non-stationarity, standard OLS regression analysis is not appropriate and can result in a spurious regression (an apparently significant relationship although in fact, the variables are uncorrelated, Granger and Newbold 1974).

We check the variables for the stationarity property via the Augmented Dickey-Fuller (ADF) test for unit roots. According to obvious trends in the data, we test both variables against stationarity around a deterministic trend. No lagged terms of the dependent variable are needed since the residuals are not autocorrelated. For completeness, we also report the results from the test including an intercept only and from the subsequent test of first differences (appendix, Table 4). The null hypothesis of a unit root cannot be rejected in all tests of the variables in levels, but can be rejected in case of the first differences. Thus, the variables energy intensity and foreign direct investment as a fraction of total investment are both integrated of order one.

This result implies that the estimation results obtained from the classical OLS regression are likely to be misleading. However, despite the unit root property of the variables, a cointegration analysis can be applied to test whether the variables share similar stochastic trends and the residual of the regression is stationary. If this was the case, the variables would indeed be correlated. For this purpose, we employ the Johansen cointegration test. Using the variables *EI* and *FDI / I* and examining three possible model specifications, no cointegration can be found in any case (appendix, Table 5).

The results of the preceding tests show that the simplified regression by Mielnik and Goldemberg (2002) is spurious and that no relation between energy intensity and foreign direct investment can be found for this specification. A comprehensive econometric analysis needs to take the non-stationarity of the time series into account. Furthermore, there are other shortcomings in the simplified regression analysis:

Only one explanatory variable is used, namely FDI relative to total investment. If important other variables that influence energy intensity are omitted, this can lead to biased estimation results. (This applies also to the cointegration test, in which the omission of relevant variables can misleadingly yield the result of no cointegration.) Furthermore, FDI needs not necessarily be computed relative to total investment. In our further specifications we use other control variables and consider the influence of FDI and total domestic investment separately.

The aggregation of all countries eliminates heterogeneity. Large countries with high quantities of energy use and FDI inflows absolutely dominate the sample and small countries, which might have different patterns of energy intensity or FDI inflows, hardly influence the aggregated variables. We show in the description of our data that there is considerable heterogeneity in a sample of 60 countries, which we take into account by using panel data methods. Furthermore, we extend the time frame of the sample to 30 years covering 1975-2004.

Can a more detailed empirical analysis detect robust evidence for energy intensity reducing FDI? The following part describes our regression analysis using more observations, an extended model and further empirical methods.

3 Panel data analysis

This section first describes the variables used in the empirical analysis and the data. A descriptive data analysis helps to identify obvious trends. Before specifying the estimation models we carry out a number of test procedures. We then specify the estimation models based on the insights from the preceding sections, apply regression analyses and discuss the results.

3.1 Choice of variables

We use a macro approach with country-level data for 60 developing countries for the period 1975 to 2004 in order to find general conclusions about international technology transfer, which do not refer to a specific country. We are not able to include all various influences on energy intensity, since many of them are determined on the micro level and the necessary micro data is not available for many countries. One example is the detailed sectoral structure of the industry and local economic and environmental regulations. As a consequence, we include determinants used in other empirical studies (e.g. Setzer 1998) and add economically plausible variables described in the next paragraphs. The way to implicitly capture country-specific effects is to use panel data models with cross-section fixed or random effects.

When evaluating the effect of foreign direct investment on energy consumption in a country, we need to add up the scale effect, the composition effect and the technique effect, which in turn can be further broken down into an income induced effect and technology transfer. As economic growth is seen as a desirable goal itself, it may be informative to leave the scale effect aside and to examine only the partial effect from the other two influences. We therefore analyze energy intensity *EI* as the dependent variable, i.e. total primary energy supply divided by GDP (Mielnik and Goldemberg 2002, Cole 2006), where GDP is measured in purchasing power parities (for a discussion of PPP in measuring energy intensity see Birol and Okogu 1997). In the case of constant returns to scale the absolute size of an economy measured by GDP theoretically has no influence on energy intensity. In an alternative specification we use total energy supply *E* as the dependent variable and include GDP denoted by *Y* as an explanatory variable. In this case *Y* captures the scale effect explicitly.

If energy intensity decreases due to inflows of the explanatory variable foreign direct investment *FDI*, this is the result of the combined impact of the composition and technique effect. FDI can be measured relative to total domestic investment as suggested by Mielnik and Goldemberg (2002) or relative to GDP as in Agosin and Mayer (2000). Both methods yield intensity measures. In order to isolate the influence of FDI from other potential channels of technology transfer, we also include imports and aid inflows for comparison. In absolute terms these variables all depend on the size of the economy. Therefore, we transform FDI inflows, imports and aid inflows into intensities by specifying them in percentage points of GDP (Heil and Selden 2001, Cole 2006), which eliminates dependence on the size of the economy.

Furthermore, we include gross investment *I*, again measured relative to GDP. *I* represents total investment in new and possibly more energy efficient technologies. Although domestic investment is supposed to have similar effects as *foreign* investment, the technology effect is potentially higher in the case of FDI because we focus on FDI flows from industrial countries endowed with sophisticated technologies to developing countries lacking in technologies.

We also control for the average income by including GDP per capita (measured in PPP), which we denote by *YPC*, but only in the specifications that do not include GDP *Y* itself. Although the exact influence of average income on energy intensity is controversial, empirical findings confirm that an influence exists (e.g., Galli 1998 finds an inverted U-shaped curve for Asian countries).

Moreover, we consider the share of industrial value added in GDP, named *IND*, which measures the reliance of the economy on the industrial sector. This captures shifts between the industrial sector on the one hand and the agricultural and service sector on the other hand. We expect that a higher industry share raises energy intensity (in early stages of development) because industrial production needs more energy inputs than agriculture or services. Using more detailed sectoral data would of course allow a more precise treatment. It is also possible (in later stages of development), that the industry share grows and at the same time production moves from heavy, high energy to low energy sectors within the aggregate industry sector. Then the economy's energy intensity does not necessarily rise when the industry share rises. Nevertheless, such detailed data are not available for the whole data set, so that we can only use *IND* as a rough indicator for sectoral changes.

Although the price of energy is without doubt a major economic determinant of energy demand, we were not able to obtain energy prices over the sample period for most of the developing countries. Nevertheless, it is possible to include worldwide changes in energy prices indirectly via time-specific fixed effects. These effects are furthermore able to capture any other time-specific influences that affect all countries in the sample in a similar way such as technological progress.

In an extended analysis we investigate the interaction of FDI with the country-specific structures of energy supply. Thus, we need data on the shares of coal, oil, gas, hydro power, and nuclear power in total energy supply to include the most important energy sources.

3.2 Descriptive data analysis

For the empirical estimation of the effects of FDI on energy intensity, we use a dataset of 60 developing countries in the period from 1975 to 2004.[6] The countries are selected by the following method: First, to incorporate our focus on developing countries, only countries not included in Annex I of the Kyoto protocol are considered. Countries that have emerged from the former Soviet Union are excluded because data prior to their independence is missing. From the remaining selection, those countries with sufficient data availability are chosen resulting in a sample of 60 countries.

Numbers on total primary energy supply, here denoted by *E*, are taken from the International Energy Agency (2007). Data on all other variables are found in the World Development Indicators by the World Bank (2007) and, if not available there for specific countries, from the Balance of Payments Statistics and the International Financial Statistics of the International Monetary Fund (2007a, 2007b). An exact definition of the variables and units is given in Table 1.

Table 2 gives an overview of the data used for our estimation. The large differences between the minimal and maximal values of the variables in the sample indicate an obvious heterogeneity of the countries and years. For instance, per capita income *YPC* ranges from about 485 to 23,266 $ in PPP. The heterogeneity of countries is also apparent from the rising, falling and undefined time trends of energy intensity and foreign direct investment. Figures 3 and 4 in the appendix visualize that in graphs of four typical countries of the sample. It is also noteworthy that some countries exhibit negative FDI inflows in certain years. This can for instance be the case when foreign companies withdraw from the market or disinvest.

The following paragraphs describe obvious trends of important variables revealed by a closer look at the distinct time series.

As expected, GDP (in PPP), denoted by *Y*, rose during this period in all countries. A number of countries show a continuous increase, for example China, India and Pakistan.

[6] The data are available upon request. The countries are in alphabetical order: Algeria, Angola, Argentina, Bangladesh, Benin, Bolivia, Botswana, Brazil, Cameroon, Chile, China (PR), Colombia, Congo (DR), Congo (Rep), Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, Ecuador, Egypt, El Salvador, Gabon, Ghana, Guatemala, Honduras, India, Indonesia, Iran, Jamaica, Jordan, Kenya, Korea (Rep), Lebanon, Malaysia, Malta, Mexico, Morocco, Mozambique, Nicaragua, Nigeria, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Saudi Arabia, Senegal, South Africa, Sri Lanka, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Uruguay, Venezuela, Zambia, Zimbabwe.

While India's and Pakistan's GDP expanded during these 30 years by a factor of almost 5, China's GDP exploded by a factor of 13. However, there are economies with tremendous GDP fluctuations such as Nicaragua or Peru. In many countries *YPC*, income per capita, grew in a similar way as total GDP, but this is not necessarily the case. Nicaragua and Venezuela for instance show a falling trend, other countries' income per capita fluctuated around a constant level.

Table 1 Definition of variables used in the estimation

Variable	Definition	Unit
E	Total primary energy supply	ktoe
EI	Energy intensity in purchasing power parity (total primary energy supply divided by GDP in PPP)	ktoe / constant 2000 million dollars in PPP
FDI / I	Net inflows of foreign direct investment, as a share of gross fixed capital formation	in % of gross fixed capital formation
FDI	Net inflows of foreign direct investment, as a share of GDP	in % of GDP
IM	Imports, as a share of GDP	in % of GDP
AID	Official Development Assistance and Official Aid inflows, as a share of GDP	in % of GDP
I	Gross fixed capital formation, as a share of GDP	in % of GDP
Y	Total income (measured by GDP in PPP)	constant 2000 million dollars in PPP
YPC	Per capita income (measured by GDP in PPP)	constant 2000 dollars in PPP / population
IND	Share of industrial value added in GDP	in % of GDP

Table 2 Descriptive statistics of the sample including 60 developing countries in 1975-2004

Variable	*E*	*EI*	*FDI / I*	*FDI*	*IM*	*AID*	*I*	*Y*	*YPC*	*IND*
Obs.	1794	1750	1688	1745	1741	1733	1700	1756	1756	1696
Mean	42 565	0.26	8.25	1.71	34.57	4.09	21.48	176 962	4 581	33.13
Min.	276	0.04	-138.91	-12.21	2.98	-0.68	2.10	955	485	6.25
Max.	1 609 348	1.18	198.31	40.15	107.48	95.59	60.56	7 023 283	23 266	77.53
Std. dev.	128 874	0.18	14.69	2.76	18.41	6.89	6.93	486 419	3 622	11.63

Obs. = number of available observations which differs between the regressors; std. dev. = standard deviation.

Since increasing production and consumption reflected by GDP growth lead to higher energy demand, it is not surprising that total primary energy supply *E* clearly rose in all countries as well. While most countries' total energy use increased in a smooth continuous way, some countries like Peru and Uruguay show large energy fluctuations. Such energy use and GDP changes might stem from political disturbances or other economic shocks which cannot be captured in the econometric analysis and will probably create estimation errors. The development of energy *intensities EI* is ambiguous across countries. In 17 countries (including China, India and Peru) energy intensity declined. China's energy intensity, starting from a high level in 1975, decreased by approximately 75 % until 2004. On the other hand, energy intensity increased in 21 countries (Algeria, Saudi Arabia, Iran and others). 22 countries show no obvious tendency. Having a closer look at the time series of energy use E and GDP Y, it becomes obvious in a number of cases that GDP short-time fluctuations or shocks do not correspond with proportional fluctuations of energy supply. In these cases, GDP jumps up or down while energy supply is sluggish. As a consequence energy intensity defined as E / Y moves to the opposite direction of the GDP fluctuation. This is an important observation, which has to be taken into account in the specification of the estimation models. (Another question not discussed here is the role of measurement errors and measurement difficulties.)

Net FDI inflows[7] show a rising tendency in most countries, especially during the 1990s. FDI relative to GDP, here labeled *FDI*, also rose in many countries, but this trend is less obvious than the increase in absolute FDI inflows. Some countries show periods with high fluctuations or plummeting FDI shares. FDI inflows to China increased strongly from 51 million USD (0.03 % of GDP) in 1980 to 48.7 billion USD (2.8 % of GDP) in 2003. The highest ratio of FDI to GDP (in other words the highest intensity of FDI inflows) was reached in 1993 with 6.3 %. When dividing FDI inflows by total domestic investment instead of GDP, the resulting time series data are very similar.

Besides FDI, imports are another indicator for the integration of a country into the world economy and a potential channel for technology transfer. Their value had an upward sloping trend between 1975 and 2004 in all countries, while periods of decline or years of plummeting imports occurred in some countries. The imports relative to a country's GDP, denoted by *IM,* clearly rose only in 23 countries. The other countries show decreases in import intensities or fluctuations. China's import value increased from roughly 6.1 billion USD (4.6 % of GDP) in 1975 to 538.5 billion USD (31.4 % of GDP) in 2004. The reception of international aid is a further potential source of international technology transfer. In contrast to FDI and trade, there is no clear trend of aid inflows when examining the time series of the 60 countries in the sample. Referring to aid inflows relative to GDP, called *AID* in the data set, some countries show an upward trend (e.g. Ghana) and other countries have falling aid intensities (e.g. India, Tunisia). Absolute and relative aid flows to China reached their maximum in 1993 and declined in the following years.

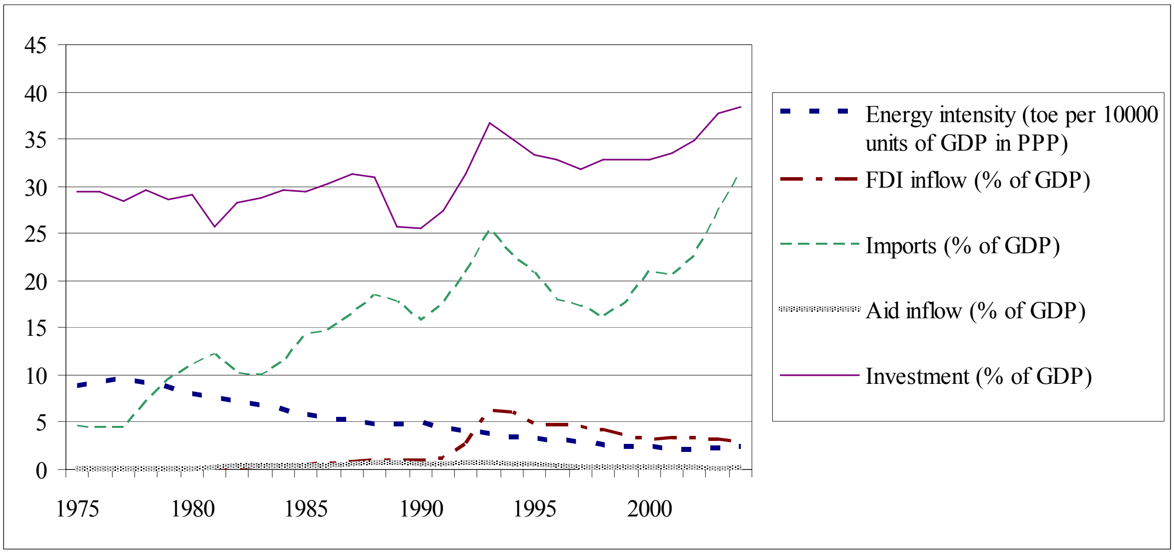
Domestic investment in absolute terms had an upward sloping tendency, and several economies had a stable continuing increase in investment during the sample period (Chile, China, India, Korea, Pakistan and others). This upward trend vanishes in many cases when looking at I, investment relative to GDP. Domestic investment in China rose from 39.2 billion USD (29.4 % of GDP) in 1975 to 658.2 billion USD (38.4 % of GDP) in 2004.

[7] In US Dollars referring to the year 2000.

A number of countries (such as Bangladesh, Honduras, India, Indonesia, Republic of Korea, Senegal and Thailand) show a clearly rising share of the industry sector *IND* over time. Other countries (like Argentina, Oman and Zambia) have falling shares. In the remaining cases *IND* fluctuates or shows upward or downward trends within the time frame of the sample. In China the industry share remained relatively stable over time, reaching its maximum of 48.2 % relative to GDP in 1978 and its minimum of 41.6 % in 1990, while the 2004 share was 46.2 % of GDP.

We conclude that there are increasing time trends of energy supply, foreign and domestic investment and imports in accordance with GDP growth. It is difficult to observe any direct relationship between energy and these variables besides this time trend. When looking at intensities, i.e. the variables divided by GDP, a different picture with considerable heterogeneity of the 60 countries arises. An econometric analysis of this panel data may reveal whether FDI has a significant influence on energy intensity. Figure 2 visualizes the facts about the Chinese economy discussed before. Obviously FDI and international trade have played an increasingly important role. However, this effect is weaker or not detectable in other developing countries.

Figure 2 Indicators of the Chinese economy, 1975-2004



3.3 The estimation models

Before setting up our estimation models, we test the variables for the presence of a stochastic trend and thus on stationarity. We apply unit root tests for panel data according to Maddala and Wu (1999) and Choi (2001) (based on Dickey-Fuller 1979 and Phillips and Perron 1988) as well as Levin, Lin and Chu (2001) and Im, Pesaran and Shin (2003). We allow for individual trends and intercepts. For most of the variables in our sample, the null hypothesis of a unit root is clearly rejected, which is in some cases a consequence of using the variables relative to GDP. Not surprisingly, we find a unit root for total primary energy supply, GDP and GDP per capita (as confirmed in other empirical studies, e.g. Perman and Stern 2003). Regarding energy intensity, the unit root hypothesis is rejected. However, the probability of error in this case is close to 5 percent, which indicates some uncertainties about the properties of this variable. When computing first differences, all variables become stationary without doubt.

As a consequence of the unit root tests' results we run our estimations in first differences. However, we use no first differences of FDI, imports, aid and domestic investment, since these variables already represent yearly changes of the respective stocks and are furthermore stationary. With this specification, each year, each unit of FDI inflow affects energy intensity, which is consistent with the notion that foreign direct investment continuously brings about technology transfer that can reduce energy intensity. By differencing the estimation model we implicitly allow for unobservable country-specific fixed effects in levels. Country-specific effects in the differenced equation represent country-specific *time trends* of energy intensity. This approach is reasonable when recalling the heterogeneously trending graphs of energy intensity. Furthermore, since we are not able to include all relevant variables in our model, applying country-specific trends is a way to capture unconsidered influences. Likewise, it is possible to include time-specific fixed effects that capture worldwide effects on energy intensity like energy prices or technological advances. We carry out *LR*-tests (likelihood ratio tests) and *F*-tests on poolability. They reject the null hypothesis that fixed effects are redundant in all cases. We then compute Hausman tests for choosing between fixed and random effects, which show that random effects are consistent only in the first specification.

In our model specification A we follow Mielnik and Goldemberg and explain energy intensity by the variable FDI_{it} / I_{it}, i.e. foreign direct investment relative to total domestic investment. Thereby, we employ relative changes in energy intensity using a semilog specification with the dependent variable $\Delta\ln(EI_{it})$.

$$\text{A}: \ \Delta \ln\left(EI_{it}\right) = \alpha + \chi_i + \theta_t + \beta_1 \frac{FDI_{it}}{I_{it}} + \varepsilon_{it} \tag{2}$$

α is the overall constant, χ_i are country-specific effects, and θ_t are period-specific effects. The ε_{it} are the error terms. According to the Hausman test we start with cross-section random effects in regression A1 (without period-specific effects, because we cannot use both cross-section and period random effects in our unbalanced panel). Since we would also like to capture time dependent effects and since the *F*-test rejects their redundancy, we turn to specification A2 with both country and time fixed effects. As in Mielnik and Goldemberg (2002), we do *not* include further control variables in this specification.

There are mainly two drawbacks of specification A. First, the estimation might suffer from an omitted variable bias if other determinants of energy intensity are partially correlated with FDI and not included in the regression and not captured by the fixed effects, either.

Therefore, we employ the control variables described in section 3.1. The two variables imports and aid are furthermore interesting for comparison with FDI, since they are other potential channels for energy reducing technology transfer. Second, using the variable FDI relative to total investment might be misleading, because the influences of FDI and domestic investment are lumped together. We therefore treat foreign direct investment and domestic investment as separate influences, both measured relative to GDP. This leads to specification B.

$$\begin{aligned} \text{B}: \ \Delta \ln\left(EI_{it}\right) &= \alpha + \chi_i + \theta_t + \beta_1 FDI_{it} + \beta_2 IM_{it} + \beta_3 AID_{it} \\ &\quad + \beta_4 I_{it} + \beta_5 \Delta \ln(YPC_{it}) + \beta_6 \Delta(IND_{it}) + \varepsilon_{it} \end{aligned} \tag{3}$$

For the exact definition of the variables see section 3.1 and Table 1. Linking this estimation model to our conceptual framework, the coefficient of *FDI* encompasses both international technology transfer and one part of the composition effect (when referring to a shift in the production pattern within the agricultural, industrial or service sector). We are not able to isolate technology transfer in our empirical model, and this has to be taken into account in the interpretation of the results. The other part of the composition effect (when referring to a shift to or away from the industrial sector as a whole) is captured by *IND*, the share of industrial value added in GDP. The income induced technique effect, which FDI may also bring about via rising incomes, is included in the impact of per capita income *YPC*. The scale effect, when neglecting positive or negative returns to scale, is implicitly included because we examine energy use relative to the size of the economy represented by GDP. It is furthermore noteworthy that, due to the estimation in first differences, the regression is not able to capture those technological spillovers, that occur only with a time lag after the FDI inflow has been recorded. This would be the case if the knowledge transferred from abroad diffused further within the country with a time delay.

Throughout specification B, we apply cross-section and time fixed effects since on the one hand, the *F*-test rejects the hypotheses of redundant cross-section as well as period fixed effects and on the other hand, the result of the Hausman test suggests that random effects are not appropriate. The pair wise correlations between the explanatory variables are all low, so that there is no multicollinearity problem (see appendix, Table 6).

Regarding our estimating equation, we notice that GDP is part of the dependent variable and several explanatory variables. This is appropriate as long as the resulting intensity variables develop independently from GDP over time. If GDP fluctuates in the short run while energy supply, FDI, imports, aid, the investment share and the industry share all adjust sluggishly, we can possibly detect a resulting correlation between energy intensity and the regressors since they are all influenced by GDP fluctuations. Especially, if energy intensity is strongly affected by short term GDP fluctuations, the effect of income, measured by GDP per capita, on energy intensity might be caused by the design of the variables. (This problem has already been mentioned in the descriptive data analysis.) In order to remedy the potential problems, we employ specification B2 where we replace the values of all explanatory variables by their one-period lagged counterparts, while B1 is the variant without time lags. This means that FDI inflows affect energy intensity in the year after the actual inflow.[8]

As a robustness check, we also apply TSLS (two stage least squares) instrumental variable estimations. We run Durbin–Wu–Hausman tests to check for endogeneity. According to the tests, GDP per capita is clearly endogenous.[9] Hence, we introduce GDP per capita lagged for one period as an instrument for current GDP per capita. We test for the presence of a weak instrument (Verbeek 2006, p. 148) running a reduced form regression. The coefficient of lagged GDP per capita is not close to zero, and the *F*-statistic for the coefficient is much higher than 10. Hence, lagged GDP per capita is not a weak instrument. We also consider including GDP per capita lagged for two periods as an additional instrument. However, the Sargan test for overidentification rejects the joint null hypothesis that the instruments are valid.

In the alternative specification C, we use total energy supply E as the dependent variable and GDP Y, which is now *not* measured in per capita terms, captures the scale effect without imposing the restriction of constant returns to scale. An advantage compared with model B is, that GDP is now not part of the dependent variable, therefore reducing distortions caused by short-term GDP fluctuations.

$$\begin{aligned} C: \ \Delta \ln(E_{it}) = {} & \alpha + \chi_i + \theta_t + \beta_1 FDI_{it} + \beta_2 IM_{it} + \beta_3 AID_{it} \\ & + \beta_4 I_{it} + \beta_5 \Delta \ln(Y_{it}) + \beta_6 \Delta(IND_{it}) + \varepsilon_{it} \end{aligned} \tag{4}$$

Nevertheless, there is still the possibility of an endogeneity bias, since the change in energy use might itself affect GDP or even FDI. Therefore, and to check if there exists a lagged influence of FDI, we again employ a specification C2 where we replace the values of all explanatory variables by their one-period lagged counterparts, while C1 is without time lags. Note that specification C2, in contrast to all other specifications, does not control for contemporary changes in real GDP so that the scale effect of FDI is implicitly included in the coefficient of FDI. Analog to specification B, we also employ GDP lagged for one period as an instrument for current GDP in specification C1 following the suggestion of the Durbin-Wu-Hausman test for endogeneity.[10] Again, there is no indication for the presence of a weak instrument (Verbeek 2006), and the Sargan test does not suggest including GDP lagged for two periods as another instrument.

[8] Note that the inflow of FDI can take place at any time during the year; if the inflow is recorded at the end of the year it is reasonable that the effect on energy intensity takes place only in the following year. A lag of one year takes possible delayed spillovers at least partially into account.

[9] According to other variants of the endogeneity test more explanatory variables could be instrumented. This, however, does not significantly alter the regression results.

[10] Again, more regressors can possibly be instrumented according to other specifications of the endogeneity test, which does not qualitatively change the results.

3.4 Regression results

The results referring to specifications A, B and C are reported in Table 3.[11] (We favor specification B2.) The results of the TSLS estimations of models B and C with GDP (per capita) instrumented by the corresponding lagged variable are not reported, since all coefficients are insignificant. Obviously, endogeneity, especially of GDP (per capita), influences the results and should not be neglected.

When computing significance levels, we always use heteroscedasticity consistent covariances, since heteroscedasticity tests (Szroeter 1978, White 1980, Cook and Weisberg 1983) clearly indicate heteroscedasticity in all cases. Testing for autocorrelation in panel data (Wooldridge 2002, Drukker 2003) on the other hand yields no clear indication for serial correlation in the residuals. Nevertheless, we use Durbin-Watson (*DW*) statistics and regressions of residuals on preceding residuals to test for autocorrelation. Since autocorrelation problems become obvious in some cases, we use heteroscedasticity and autocorrelation consistent (HAC) standard errors (Newey-West, except regression A1 where we use White heteroscedasticity corrected standard errors).

Table 3 Estimation results for specifications A, B and C

Specification Method	A1 Country-RE	A2 FE	B1 FE	B2 FE lagged regressors	C1 FE	C2 FE lagged regressors
Observations	1630	1630	1563	1507	1563	1509
Countries	60	60	60	60	60	60
Years	1976-2004	1976-2004	1976-2004	1977-2004	1976-2004	1977-2004
Depend. var.	$\Delta\ln(EI)$	$\Delta\ln(EI)$	$\Delta\ln(EI)$	$\Delta\ln(EI)$	$\Delta\ln(E)$	$\Delta\ln(E)$
CONST	0.00403	0.00391 *	-0.01232	-0.02549 **	0.00142	0.01551 *
FDI/I	-0.00031 **	-0.00027				
FDI			0.00064	0.00050	0.00072	0.00196 ***
IM			-0.00017	0.00015	-0.00010	0.00002
AID			-0.00030	-0.00118 ***	-0.00024	0.00010
I			0.00146 ***	0.00127 **	0.00153 ***	0.00068 **
$\Delta\ln(YPC)$			-0.78825 ***	0.00217		
$\Delta\ln(Y)$					0.21011 ***	0.07756 **
ΔIND			0.00005	0.00027	0.00001	0.00102 *
Adj. R^2	0.003	0.071	0.408	0.076	0.191	0.126
DW-stat.	1.944	2.014	2.059	2.135	2.046	2.111
F-stat.	5.973	2.414	12.571	2.352	4.972	3.358
Prob(*F*-stat.)	0.015	0	0	0	0	0

* Significant at the 10 % level, ** significant at the 5 % level, *** significant at the 1 % level; heteroscedasticity and autocorrelation consistent standard errors; Δ = first time differences; Country-RE = country-specific random effects; FE = country- and time-specific fixed effects.

[11] Results of the regressions not reported here as well as standard errors and statistics of the various tests are available upon request.

The usual *F*-tests for all coefficients jointly being zero reject the null hypothesis in all cases. However, the reported (adjusted) R^2 values are relatively low. One reason for the low explanatory power is that we estimate in first differences. The examination of the residuals' distributions reveals in all cases very high Jarque-Bera statistics mainly stemming from high Kurtosis values. Since this finding rejects the normal distribution assumption of the residuals, the reported significance levels should be interpreted with some caution. We could not remedy this problem by redefining the estimation model, changing the sample size or eliminating outliers.

The variable of main interest, *FDI* inflows, is significant and negative only in specification A1, which confirms the finding by Mielnik and Goldemberg (2002). In the slightly modified specification A2 with time and country-specific fixed effects, the probability that the coefficient is different from zero already falls below any common significance level, while the coefficient stays negative. In specification C2, where changes in total energy use are examined, the coefficient of the lagged FDI inflows is positive and highly significant. This finding is likely to stem from the scale effect since FDI inflows in the previous year are likely to induce increasing economic activity in the current year, which results in higher energy use. All other regressions, including the instrumental variable estimations, do not confirm any significant effect of FDI on energy intensity. Using our theoretical background, the results imply that it is not possible to identify any joint effect of technology transfer and composition effect in this macro panel.

We now compare the results for *FDI* with those for *IM* and *AID* and *I*. While imports do not show a significant effect in any regression, *AID* is highly significant and negative in specification B2. This energy intensity reduction by aid inflows would be in line with the expectations that industrialized donor countries promote energy saving technologies in developing countries. On the contrary, the investment share *I* is significantly positive in all specifications. The hypothesis that new investments bring about energy saving technical progress is therefore questioned. It may be the case that in periods of rising investment, more energy intensive processes are taking place.

Regarding the remaining control variables, income per capita growth $\Delta\ln(YPC)$ is highly significant and negative in specification B1, but not in specification B2 where it appears as a lagged variable. The strong negative correlation in B1 is likely to stem from short-term GDP-fluctuations, where energy intensity typically moves to the opposite direction than GDP. If a longer term influence existed, we would find a significant result in specification B2, but this is not the case. Furthermore, the significance of GDP per capita disappears in specification B1, when this variable is instrumented by lagged GDP per capita. In models C1 and C2, change in total income $\Delta\ln(Y)$ has a significantly positive influence on total energy supply as expected (scale effect). Again, the significance of GDP disappears in specification C1, when this variable is instrumented. Concerning the share of industrial value added in GDP, we always find a positive sign, but the coefficient is significant only in specification C2. It is likely that the sectoral change between the industry sector on the one hand and agriculture or services on the other hand is less important than sectoral changes within these aggregated sectors. Unfortunately, no such detailed data are available for the countries in our sample, so that part of the composition effect is implicitly included in the effect of FDI.

Instead of using the whole panel of developing countries we also run the regressions using data for China as an example for a one-country time series analysis. The results basically confirm those from the analysis of the whole panel, and we cannot find an energy reducing effect of FDI.

We also extend the basic model (specification B) in order to investigate the interaction of FDI with country-specific characteristics. We add interaction terms of FDI inflows with changes in per capita income, with imports and with shares of energy sources in total energy supply (particularly coal, oil, gas, nuclear power and hydro power) to assess whether a significant influence of FDI can be found in countries with specific attributes or whether the impact is related to the energy mix of a country. We run several regressions, including only one interaction term at the same time.[12] Once again, we find no evidence for an energy reducing effect of aggregate FDI and none of the interaction terms leads to significant results. Nevertheless, they show a way for further research, focusing more on the interactions of FDI with other economic indicators.

4 Conclusion

Referring to the regression by Mielnik and Goldemberg (2002), this paper examines the hypothesis that foreign direct investment inflows reduce energy intensities of developing countries. Theoretically, the impact of FDI inflows can be decomposed into a scale, a composition and a technique effect (Grossman and Krueger 1993, Antweiler et al. 2001).

In the first step we reproduce the estimation by Mielnik and Goldemberg using cross-sectional aggregations of 20 developing countries between 1979 and 2003. We find a similarly strong energy intensity reducing effect of FDI, but we identify a major shortcoming: The analyzed variables energy intensity and FDI (as a fraction of total investment) are not stationary and not cointegrated, yielding a spurious regression. In addition, no other control variables are included in the regression, although there are a number of potential influences on energy intensity. Nevertheless, we acknowledge that the estimation of the effect of FDI on energy intensity on the macro level is in general difficult. Many influences on energy intensity cannot be included, since data are only available on the micro level and not for whole economies.

[12] When adding the interaction term "FDI multiplied with the share of the energy source" we also add the share of the energy source as a separate regressor.

In the second step we investigate macro level panel data on 60 developing countries for the years 1975 to 2004. We start with a detailed descriptive data examination, which reveals rising and falling trends of energy intensities and FDI inflow intensities for different developing countries over time. We then extend the empirical model of energy intensity explained by FDI inflows proposed by Mielnik and Goldemberg step by step running regressions in first differences. We include country and time-specific effects and further explanatory variables, namely imports, aid inflows, domestic investment, income per capita and the share of industrial value added in GDP. Lagged explanatory variables are applied directly to capture time-delayed effects, and indirectly as instruments to overcome endogeneity problems. Furthermore, we control for autocorrelation and heteroscedasticity.

As a result, we do not find a robust energy reducing effect of FDI. Thus we cannot confirm the hypothesis by Mielnik and Goldemberg (2002) in general. Regarding the influence of foreign aid on energy intensity, we find a significantly negative effect in one specification. In order to take country-specific characteristics into account, we also examine the interaction of FDI inflows with changes in per capita income, imports and shares of energy sources (particularly coal, oil, gas, nuclear power and hydro power). We find no evidence for a significant joint effect of aggregate FDI together with other determinants on energy intensity (or total energy supply, respectively).

There are mainly two caveats when interpreting the results: At first, the explanatory power of our model is low. On the one hand, this is caused by the loss of information due to differencing the estimating equation; on the other hand, the energy intensity of a country is determined by many technical, infrastructural, economic and political factors that cannot all be captured in a macro model, because the necessary data are not available. To consider as many unobservable effects as possible, we use panel data models with time and country-specific effects. The second caveat is the high kurtosis of the residual distribution that biases the standard errors and consequently the significance levels. Reducing outliers from the sample and different model variants could not remedy this problem. If we restricted the study on time series of single countries, the vast heterogeneity in the sample would be reduced, and the properties of the residual distribution would be more favorable. Then, however, it would no longer be possible to derive general results.

We conclude that, although energy saving technology transfer to developing countries via FDI probably takes place, we find no empirical evidence for a general or uniform influence of FDI on energy intensity. We suppose that the effects of FDI inflows on energy use depend on country-specific characteristics in a way that certain characteristics and policies enhance energy reductions from FDI. Our regressions with interaction terms aim at identifying such influences, but do not yield significant results. Moreover, we acknowledge that FDI flows do not represent a homogenous category but rather very different kinds of investment. While some FDI might reduce energy intensity via technology transfer, other FDI might induce a shift towards more energy intensive production via a change in the sectoral composition of production. The significance of the results thus possibly suffers from the fact that we cannot disentangle technology transfer and the composition effect.

Our results imply that policies aiming at reducing energy intensities in developing countries should take country-specific characteristics into account, when actively supporting FDI inflows, and that a “one-size-fits-all” policy approach can be rather ill-designed. For example, further research can attempt to reveal the influence of the sectoral structure of the destination country on international technology transfer. Furthermore, it is sensible to make use of issue-linkage, as for instance intended by the clean development mechanism of the Kyoto Protocol, to explicitly encourage foreign direct investment that brings along energy reducing technology transfer.

A challenge for further research is to identify country-specific characteristics that enhance technology transfer via FDI. This can be accomplished by using interaction terms of FDI and country-specific variables. Departing from the panel analysis, it can be helpful to use data on specific countries in order to analyze whether FDI inflows reduce energy intensity in these specific cases. There is a broad literature on technology spillovers in general, but technology spillovers affecting energy intensity have not been investigated in depth. One can include long-run effects to examine whether spillovers from FDI decrease energy intensity with a time delay. Where sectoral data is available, the analysis can be performed in a more detailed way. One can try to distinguish explicitly the composition effect from the technology transfer. A better understanding of international technology diffusion in the context of climate change is highly important for supporting developing countries in achieving lower energy and carbon intensities than the industrialized countries did in the past.

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Appendix

Figure 3 Time trends of energy intensity 1975-2004 in four countries of the sample

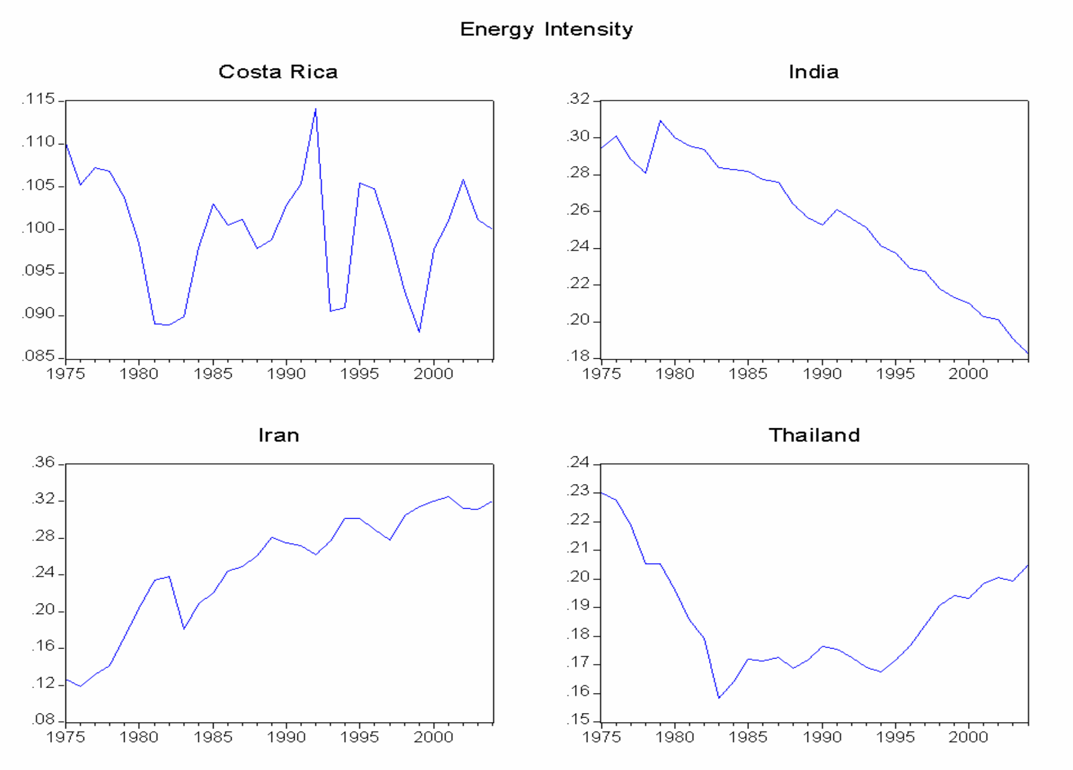

Figure 4 Time trends of FDI relative to GDP 1975-2004 in four countries of the sample

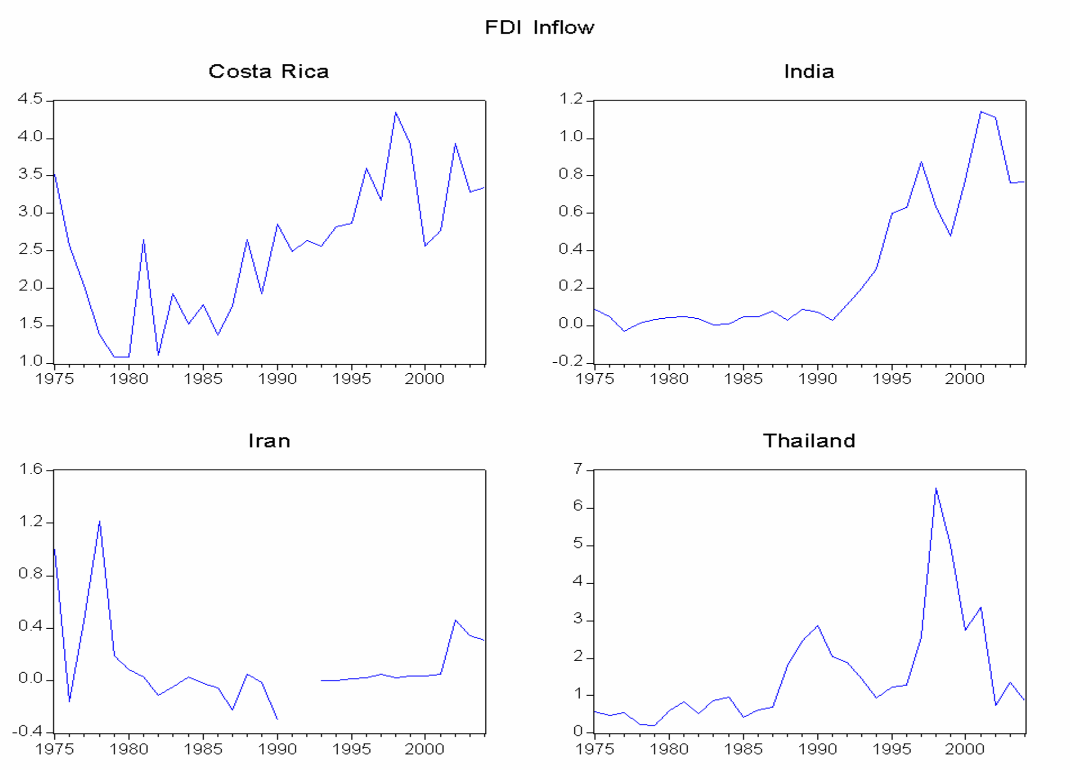

Table 4 Unit root test statistics (Augmented Dickey Fuller) for the variables in the simplified model

	Energy Intensity		
In levels		in 1st differences	
With constant and linear trend	-1.76 (-3.61)	with constant	-5.39 (-3.00)
Only with constant	-0.64 (-2.99)	no constant	-5.43 (-1.96)
	FDI as a fraction of total investment		
In levels		in 1st differences	
With constant and linear trend	-0.96 (-3.61)	with constant	-9.73 (-3.00)
Only with constant	-1.01 (-2.99)	no constant	-9.85 (-1.96)

In parentheses: 5% critical values to reject the unit root null hypothesis.

Table 5 Johansen cointegration test of the variables in the simplified 20 country model

Model Specification	Trace statistic
Intercept in CE, none in VAR	16.37 (20.26)
Intercept in CE and VAR	7.10 (15.49)
Intercept and trend in CE, intercept in VAR	20.90 (25.87)

In parentheses: 5% critical values to reject the null of no cointegration.

Table 6 Pair wise correlations of the explanatory variables

	FDI	*IM*	*AID*	*I*	$\Delta ln(YPC)$	ΔIND	$\Delta ln(Y)$
FDI	1						
IM	0.3497	1					
AID	0.0223	0.1844	1				
I	0.1354	0.3512	-0.0693	1			
$\Delta ln(YPC)$	0.1127	0.1494	-0.0184	0.2751	1		
ΔIND	0.0626	0.0504	0.0312	0.0162	0.1664	1	
$\Delta ln(Y)$	0.0880	0.1556	0.0199	0.2755	0.9837	0.1665	1