Foreign Direct Investment and Energy Poverty in Sub-Saharan Africa: Evidence from 43 Countries

Yangzi Zhou

University of Shanghai for Science and Technology, Shanghai, 200090;

Abstract: Stable, affordable energy is vital for social welfare and economic growth in developing countries. As of 2021, Sub-Saharan Africa (SSA) had only 35.56% electricity access and 19.01% clean cooking fuels usage, reflecting severe energy poverty. This study analyzes FDI's impact on SSA energy poverty using SYS-GMM on 1990-2021 data from 43 countries. Results show FDI generally alleviates energy poverty but worsens rural electrification while improving urban access. Natural resource rents amplify FDI's positive effects, with higher rents strengthening poverty reduction. The findings suggest FDI can offset resource rents' negative impacts. The study provides policy recommendations for SSA governments to enhance affordable energy access, advancing literature on the FDI-energy poverty-resource nexus.

Keywords: FDI; Energy Poverty; Natural Resources

DOI:10.69979/3041-0843.25.01.020

1. Introduction

Energy poverty—a pressing global challenge—refers to households lacking reliable, affordable electricity and clean cooking facilities (IEA). This deprivation impedes economic growth, health, education, and gender equality, undermining Sustainable Development Goals. Limited energy access exacerbates respiratory diseases from traditional fuels and restricts education, perpetuating poverty and inequality. Recent studies explore energy poverty determinants, including remittances, financial inclusion, and public debt, yet FDI’s role remains understudied.

FDI, defined by the IMF as cross-border investment with managerial influence, spurs host-country development via job creation, technology transfer, and economic growth (Simplice & Odhiambo, 2019). This study examines FDI’s impact on energy poverty, addressing a critical research gap.Research suggests that FDI may alleviate energy poverty through multiple channels.

Natural resources play a dual role: while the "resource curse" suggests long-term growth constraints, emerging evidence highlights their potential to spur development under favorable conditions (Abdulahi, 2019). In low-income economies, resource abundance can attract FDI into energy-intensive sectors, shaping energy poverty outcomes. This study examines how FDI and natural resource rents jointly influence energy poverty in Sub-Saharan Africa.This study analyzes FDI's role in mitigating energy poverty across 43 SSA countries, where over half the population lacks electricity - costing 2% annual GDP growth (AFDB, 2019). With only 19.01% clean cooking access (2021), biomass dependence creates health and gender disparities.SSA has long grappled with severe underinvestment. The African Infrastructure Country Diagnostic (AICD) reports that the annual investment needed for the electricity sector from 2000 to 2015 exceeded the estimated actual investment of $27 billion per year by more than threefold, with only 15% allocated for maintaining existing infrastructure.

2. Literature Review

Multinational corporations increasingly invest in Africa's natural resources, leveraging superior capital and technology that often surpass local capabilities (Paul, 2021). FDI generates technological spillovers through horizontal and vertical channels, including demonstration effects , competition , and human capital development . Greenfield investments can enhance governance and policy implementation in developing countries (Antonietti, 2023).

Rising incomes drive transitions from biomass to modern fuels, with cleaner adoption increasing with expenditure levels (Sharma, 2022). Female-led households often choose cleaner options, while FDI and financial development boost clean cooking use in emerging markets(Ntegwa, 2024).

FDI inflows may intensify income inequality in developing economies through geographic and sectoral concen tration, though balanced distribution could mitigate disparities(Song, 2021). Energy poverty disproportionately affe cts ultra-poor households, where cash transfers prove effective for energy transitions (Aung, 2021). Where grid r eliability is low, diesel generators often serve as cost-effective alternatives (Sievert, 2020).

3. Data and methodology

3. 1. Data

This study employs 1990-2022 panel data from 43 SSA countries, selected based on data availability. Followi ng UNDP and IEA (2010) standards, energy poverty is measured through electricity access and clean cooking usa ge - defined as the inability to use modern fuels or access basic electric lighting. These metrics are well-establis hed in energy poverty literature (Nguea, 2022).

Based on the above definition of energy poverty, this study adopts the electricity access rate and clean coo king fuels usage rate as measures of energy poverty. For explanatory variables, this study uses net FDI inflows (new investment inflows minus disinvestment) in current US dollars. The moderating variable is measured as the percentage of GDP from natural resource rents. Control variables used in this study include GDP per capita (in current US dollars), urbanization level (the percentage of the urban population), CO2 emissions (tons per capita), industrial value-added (percentage of GDP), and population growth rate (annual percentage). All data are source d from the World Bank (WDI) database.Table 1 presents descriptive statistics for the study variables.

Table 1. Descriptive Statistics of Study Variables

variable	N	mean	sd	min	max
ELE	928	35. 56	25. 86	0. 530	100
ELERU	928	23. 63	27. 19	0. 510	100
ELEURB	928	62. 57	23. 51	3. 500	100
CF	928	19. 01	26. 59	0. 100	100
FDI	928	4. 830	16. 21	-73. 97	406. 6
SPURB	928	36. 52	14. 78	5. 420	75. 75
GDPPC	928	1460	2197	99. 76	16851
CO2	928	0. 680	1. 290	0. 0200	8. 450
IND	928	23. 94	10. 96	3. 240	72. 72
NRR	928	10. 63	9. 890	0	59. 68
POPGR	928	2. 420	1. 450	-16. 88	16. 63

3. 2. Model

In Sub-Saharan Africa, foreign investors may prefer to invest in countries or regions with high electricity acc ess rates or high usage rates of clean cooking fuels. There may be a potential reverse causality between the sta te of energy poverty and FDI, leading to endogeneity issues in the model. Moreover, omitted variables in the er ror term might also be correlated with the explanatory variables used in this study. To address potential endoge neity and omitted variable problems, this study employs a dynamic panel estimation method and constructs the following models:

$$\gamma_{it} = \beta_1\gamma_{it-1} + \beta_2 \mathrm{FDI}_{it} + \beta_3 \mathrm{Control}_{it} + \mu_{it} + \varepsilon_{it} \quad (1)$$

$$\gamma_{it} = \beta_1\gamma_{it-1} + \beta_2 \mathrm{FDI}_{it}\mathrm{NRR}_{it} + \beta_3 \mathrm{Control}_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

In the above equation (1), γ_{it} represents the dependent variable, and it denotes the country and time resp ectively. γ_{it-1} represents the first-order lagged term of the dependent variable. FDI_{it} represents the explanatory variable, i. e. , net inflows of Foreign Direct Investment. Control $_{it}$ is a set of control variables, including GDP p er capita (GDPPC), urbanization level (SPURB), carbon dioxide emissions (CO2), and industrial value-added (IND). μ_{it} represents unobserved individual fixed effects. ε_{it} denotes the error term. In equation (2), NRR_{it} represents t he total NRR, measured as a percentage of GDP.

3. 3. Estimation Strategy

This study employs the two-step System GMM method as the baseline regression strategy. The dynamic pan el estimation method is adopted, where the lagged dependent variable is included as an explanatory variable. T he lagged dependent variable in the model setup is positively correlated with the composite error term in the fi rst lag, and using OLS estimation usually results in an upward bias in the coefficient of the lagged term. Since t he System GMM estimation method can use the lagged terms of variables as instrumental variables (Blundell an d Bond, 1998), existing literature frequently employs the System GMM estimation method to address these issue s (Wang, 2023).

4. result and discussion

4. 1 Baseline Regression on the Impact of Foreign Direct Investment on Energy Poverty

Table 2 presents the baseline regression on the impact of FDI on energy poverty in Sub-Saharan Africa (SS A). L.1 represents the first lagged term of the dependent variable. The regression results indicate that the correl ation coefficient between FDI and the electricity access rate is positive and significant (at the 5% level), demonst rating statistical significance. This implies that FDI is associated with the electricity access rate in SSA, where a 1% increase in FDI can raise the electricity access rate by 0. 56%. Concurrently, the correlation coefficient betwe en FDI and the usage rate of CF is positive and highly significant (at the 1% level), also demonstrating statistical significance. This implies that FDI is associated with the usage rate of CF in SSA, where a 1% increase in FDI c an increase the usage rate of CF by 0. 02%. Overall, FDI has a positive impact on the two main indicators of e nergy poverty in SSA.

Table 2. Baseline Regression on the Impact of FDI on Energy Poverty in Sub-Saharan Africa (SSA)

	(1)	(2)	(3)	(4)	(5)	(6)
	GMM	GMM	GMM	GMM	GMM	GMM
VARIABLES	ELE	CF	ELEURB	ELERU	CFURB	CFRU
FDI	0.0123**	0.000261***	0.0140***	-0.0665***	0.000698**	0.000470***
	(0.00497)	(6.68e-05)	(0.00400)	(0.00379)	(0.000310)	(8.17e-05)
GDPPC	0.000175***	3.52e-05***	0.000477***	0.000282***	4.73e-05***	-8.90e-06***
	(6.19e-05)	(2.14e-06)	(0.000149)	(2.09e-05)	(6.94e-06)	(1.04e-06)
IND	0.0765***	-0.00161***	0.0362	0.0682***	-0.00337***	-0.000256
	(0.00865)	(0.000339)	(0.0299)	(0.0122)	(0.000945)	(0.000242)
SPURB	0.0166**	-0.00122***	0.0485***	-0.0309***	0.00297***	1.35e-05
	(0.00756)	(0.000363)	(0.0174)	(0.00950)	(0.000968)	(0.000217)
POPGR	0.0289	-0.00402	-0.305**	-0.662***	-0.0113	-0.0181***
	(0.0921)	(0.00451)	(0.132)	(0.0868)	(0.0101)	(0.00433)
CO2	-1.343***	0.0141***	-1.696***	-0.964***	-0.106***	0.0308***
	(0.203)	(0.00377)	(0.492)	(0.139)	(0.0142)	(0.00535)
Constant	-0.863*	0.0970***	2.356**	3.441***	0.0902***	0.0578***
	(0.457)	(0.0195)	(1.016)	(0.297)	(0.0307)	(0.0156)
Hansen	0.665	0.565	0.623	0.683	0.308	0.346
AR(2)	0.550	0.499	0.532	0.853	0.759	0.571
Observations	918	752	928	711	752	752
Number of Country	43	43	43	43	43	43

4. 2 Rural Urban Disparity of the Impact of Foreign Direct Investment on Energy Poverty

Table 2 examines urban-rural heterogeneity in FDI's impact on energy poverty in SSA. Using electricity acces s rates as the dependent variable, results show FDI has a positive (1% level) association with urban electrificatio n (0.36% increase per 1% FDI rise), while showing a negative (1% level) association with rural access (4.7% decr ease per 1% FDI increase). These opposing effects demonstrate FDI exacerbates urban-rural electricity disparities i n SSA. Three mechanisms explain this pattern: (1) FDI's urban concentration boosts local incomes and access (W ang et al., 2023); (2) governments prioritize urban infrastructure spending from FDI revenues; and (3) rural popul ation dispersion raises grid costs while FDI-induced migration further reduces density, undermining scale economies.

Regression results with CF usage rate as the dependent variable show that the correlation coefficient between FDI and urban CF usage rate is positive, and the correlation coefficient between FDI and rural CF usage rate is also positive and significant (urban at the 5% level, rural at the 1% level), with statistical significance. This implies that FDI is associated with CF usage rates in both rural and urban areas of Sub-Saharan Africa. Unlike electrification, FDI shows limited urban-rural disparity in clean cooking access across SSA. This stems from CF' decentralized distribution model - rural populations can adopt portable solutions (e.g., canned LNG) without relying on centralized infrastructure. Consequently, FDI-induced rural depopulation minimally impacts CF penetration.

4. 3 The Interacting Effect of NRR and Foreign Direct Investment and Energy Poverty

Table 3 demonstrates the moderating effect of NRR on FDI and energy poverty. For both electricity access and clean cooking rates, the FDI×NRR interaction term shows positive, highly significant coefficients (1% level). The inclusion of this term alters FDI's main effect coefficients in Table 3 (from positive to negative). These coefficients now reflect effects when NRR=0 rather than marginal effects under ceteris paribus conditions (Kingsley et al. 2017) – a scenario often lacking practical relevance. The positive interaction term confirms consistency with our baseline results, visualized following established methods.

Figures 1 and 2 show the marginal effects of FDI on electricity access rates and CF usage rates across different NRR levels. The Y-axis shows marginal effects, the X-axis shows NRR values, with dashed 95% confidence intervals. When NRR is low (below 13 and 14, respectively), FDI has negative effects on both outcomes. As NRR increases, these negative effects diminish. When NRR is high (above 19 and 21), FDI has positive effects that strengthen with further NRR increases.Figures 3 and 4 display the marginal effects of NRR under different FDI levels. Figure 3 shows that when FDI is low (<7), NRR negatively affects electricity access, but this effect weakens as FDI rises. At high FDI (>38), NRR has significantly positive effects that intensify with further FDI increases. Figure 4 similarly shows that at low FDI (<7), NRR negatively affects clean cooking usage, with this effect weakening as FDI rises. These results demonstrate that: (1) higher NRR proportions amplify FDI's poverty-alleviating effects, and (2) sufficient FDI inflows can mitigate NRR's potential negative impacts.

Table 3. Interacting Effect of NRR on FDI and Energy Poverty

VARIABLES	ELE	CF
	GMM	GMM
L.1	0. 633***	1. 569***
	(0. 00730)	(0. 00785)
FDI	-0. 0522***	-0. 00130**
	(0. 0171)	(0. 000536)
NRR	-0. 0535***	-0. 00349***
	(0. 0127)	(0. 000414)
FDI*NRR	0. 00339***	7. 43e-05***
	(0. 000932)	(2. 75e-05)
GDPPC	0. 000374***	3. 51e-05***
	(4. 65e-05)	(2. 38e-06)
IND	0. 0508***	0. 00124***
	(0. 00734)	(0. 000312)
SPURB	0. 0412***	-0. 00159***
	(0. 0102)	(0. 000254)
POPGR	-0. 0702	0. 00274
	(0. 0624)	(0. 00342)
CO2	-1. 661***	0. 00668
	(0. 108)	(0. 00534)
Constant	0. 350	0. 0813***
	(0. 478)	(0. 0168)
Hansen	0. 686	0. 586
AR(2)	0. 316	0. 474
Observations	918	752
Number of Country	43	43

Standard errors in parentheses
*** p<0. 01, ** p<0. 05, * p<0. 1

Figure1:

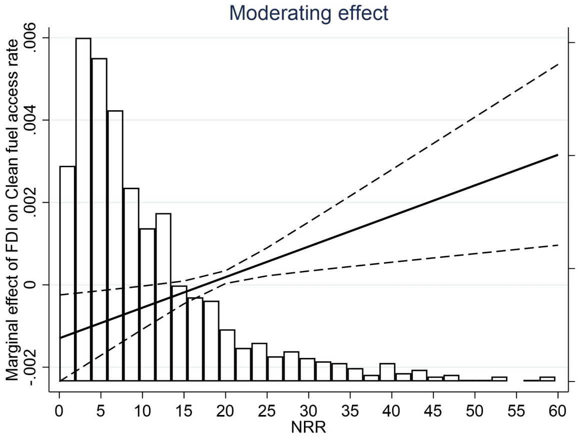


Figure2:

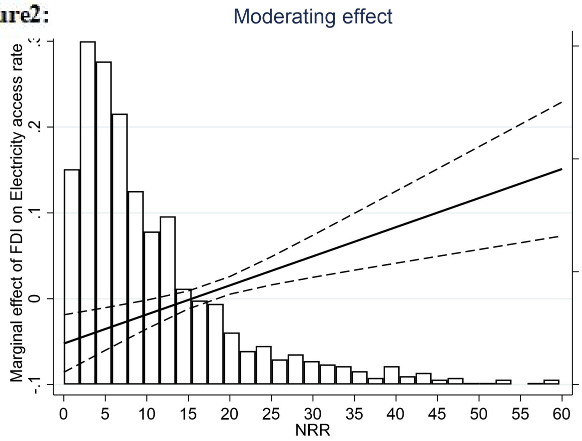


Figure3:

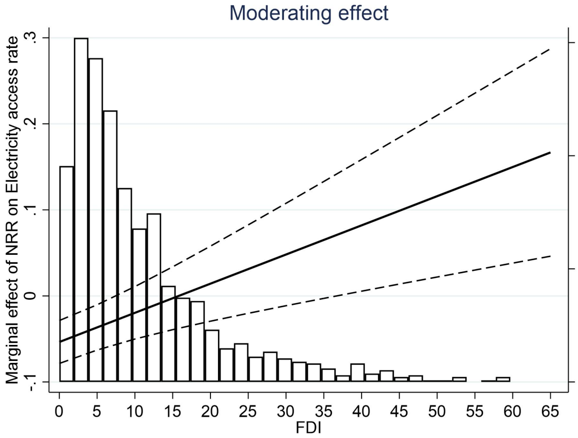
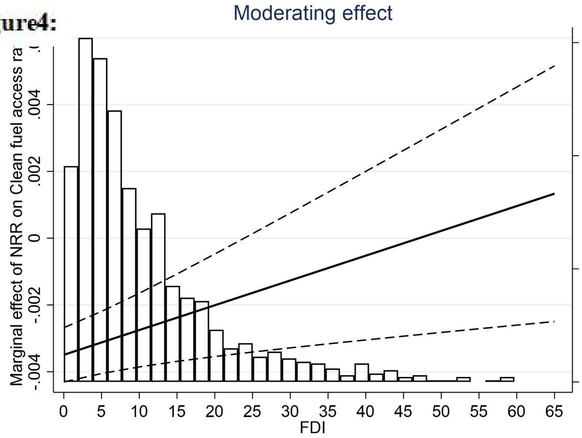


Figure4:



4.4. Robustness check

The GMM estimation strategy employed in this study effectively mitigates endogeneity issues, though it cannot entirely eliminate them. To further address potential endogeneity and omitted variable issues, we employ an estimation strategy developed by Lewbel (2012), commonly used in literature related to energy poverty, as a robustness check. This strategy identifies endogeneity using heteroskedasticity without requiring external instrumental variables (Lewbel 2012).Table 4 presents the results of the robustness check using Lewbel estimation strategy. It shows that the impact of FDI on all dependent variables aligns with the baseline regressions of this study, with significance levels exceeding 10%, indicating that the previous estimation results of this study are robust.

Table 4. Robustness Check Results Using Lewbel’ s (2012) Estimation Strategy

VARIABLES	ELE	ELERU	ELEURB	CF	CFRU	CFURB
	lewbel	lewbel	lewbel	lewbel	lewbel	lewbel
FDI	0. 169***	-0. 0909*	0. 255***	0. 128***	0. 101**	0. 573***
	(0. 0491)	(0. 0519)	(0. 0543)	(0. 0475)	(0. 0447)	(0. 130)
GDPPC	0. 00691***	0. 00842***	0. 00436***	0. 00672***	0. 000549**	0. 00282***
	(0. 000574)	(0. 000660)	(0. 000462)	(0. 000503)	(0. 000280)	(0. 000452)
IND	-0. 437***	-0. 632***	-0. 312***	0. 299***	0. 0245	0. 0147
	(0. 0600)	(0. 0623)	(0. 0786)	(0. 0456)	(0. 0548)	(0. 105)
SPURB	0. 727***	0. 171***	0. 439***	0. 0524**	-0. 101***	-0. 307***
	(0. 0400)	(0. 0519)	(0. 0555)	(0. 0244)	(0. 0381)	(0. 0957)
POPGR	-1. 321**	-1. 636***	-1. 575*	-0. 147	-6. 229***	-19. 38***
	(0. 546)	(0. 561)	(0. 828)	(0. 291)	(1. 364)	(1. 569)
CO2	-1. 378**	2. 361***	-1. 798**	3. 156***	-1. 207**	-5. 910***
	(0. 663)	(0. 662)	(0. 728)	(0. 500)	(0. 484)	(1. 044)
Constant	11. 46***	19. 67***	50. 80***	-7. 881***	23. 72***	82. 83***
	(2. 292)	(2. 501)	(3. 570)	(1. 360)	(4. 723)	(6. 106)

Observations	1,011	838	1,004	751	751	751
R-squared	0. 675	0. 674	0. 336	0. 877	0. 259	0. 388

Robust standard errors in parentheses *** p<0. 01, ** p<0. 05, * p<0. 1

5. Conculusion and policy implications

This study analyzes 43 SSA countries using SYS-GMM, finding that while FDI generally alleviates energy poverty, it exacerbates rural electricity access gaps while improving urban access. Higher natural resource rents (NRR) worsen energy poverty without FDI, but FDI-NRR interaction shows positive effects: FDI's poverty-reducing impact strengthens with higher NRR shares, while NRR's effect depends on FDI levels.Policy implications suggest: (1) targeted rural investments in off-grid solutions (solar, micro-hydro) to address infrastructure scale challenges; (2) incentives for FDI in extractive industries (tax breaks, tariff exemptions) to spur energy infrastructure development; (3) monetary policies to retain foreign profits, countering capital flight evidenced in cases like Angola's -$7.397bn FDI.

While this study focuses on natural resources' interaction with FDI, future research should examine broader resource categories (human, capital, information) in FDI-energy poverty relationships. Additionally, country/region-specific analyses could test these findings' generalizability across contexts, enabling more targeted policy solutions.

Reference

[1]Simplice A. Asongu, Nicholas M. Odhiambo,Foreign direct investment, information technology and economic growth dynamics in Sub-Saharan Africa,Telecommunications Policy,Volume 44, Issue 1,2020,101838,ISSN 0308-5961,https://doi.org/10.1016/j.telpol.2019.101838.

[2]Roberto Antonietti, Jasmine Mondolo,Inward FDI and the quality of domestic institutions: A cross-country panel VAR analysis,Economic Systems,Volume 47, Issue 3,2023,101078,ISSN 0939-3625, https://doi.org/10.1016/j.ecosys.2023.101078.

[3]Mohamued Elyas Abdulahi, Yang Shu, Muhammad Asif Khan,Resource rents, economic growth, and the role of institutional quality: A panel threshold analysis,Resources Policy,Volume 61,2019,Pages 293-303,ISSN 0301-4207, https://doi.org/10.1016/j.resourpol.2019.02.011.

[4]AfDB, The African Statistical Yearbook 2019, African Development Bank, 2019

[5]Justin Paul, María M. Feliciano-Cestero,Five decades of research on foreign direct investment by MNEs: An overview and research agenda,Journal of Business Research,Volume 124,2021,Pages 800-812,ISSN 0148-2963, https://doi.org/10.1016/j.jbusres.2020.04.017.

[6]Vikesh Sharma, Madhusmita Dash,Household energy use pattern in rural India: A path towards sustainable development,Environmental Challenges, Volume 6,2022,100404,ISSN 2667-0100,https://doi.org/10.1016/j.envc.2021.100404.

[7]Magashi Joseph Ntegwa, Lulu Silas Olan'g,Explaining the rise of economic and rural-urban inequality in clean cooking fuel use in Tanzania,Heliyon,Volume 10, Issue 1,2024,e23910,ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2023.e23910.

[8]Yuegang Song, Sudharshan Reddy Paramati, Mallesh Ummalla, Abdulrasheed Zakari, Harshavardhan Reddy Kummitha,The effect of remittances and FDI inflows on income distribution in developing economies,Economic Analysis and Policy,Volume 72,2021,Pages 255-267,ISSN 0313-5926,https://doi.org/10.1016/j.eap.2021.08.011.

[9]Aung, Ther W. et al. "Energy access and the ultra-poor: Do unconditional social cash transfers close the energy access gap in Malawi?" Energy for Sustainable Development 60 (2021): 102-112.

[10]Maximiliane Sievert, Jevgenijs Steinbuks,Willingness to pay for electricity access in extreme poverty: Evidence from sub-Saharan Africa,World Development,Volume 128,2020,104859,ISSN 0305-750X, https://doi.org/10.1016/j.worlddev.2019.104859.

[11]Qiang Wang, Jiaqi Guo, Rongrong Li, Alexey Mikhaylov, Nikita Moiseev,Does technical assistance alleviate energy poverty in sub-Saharan African countries? A new perspective on spatial spillover effects of technical assistance, Energy Strategy Reviews,Volume 45,2023,101047,ISSN 2211-467X,https://doi.org/10.1016/j.esr.2022.101047.

[12]Stéphane Mbiankeu Nguea, Ulrich Vianney Elisée Kaguendo, Issidor Noumba,Are growth effects of foreign capital significant for increasing access to electricity in Africa?,Energy Policy,Volume 168,2022,113129,ISSN 0301-4215,https://doi.org/10.1016/j.enpol.2022.113129.

[13]Kingsley, A. F., Noordewier, T. G., & Vanden Bergh, R. G. (2017). Overstating and understating interaction results in international business research. Journal of World Business, 52(2), 286–295. https://doi.org/10.1016/j.jwb.2016.12.010

[14]Lewbel, A. (2012). Using Heteroscedasticity to Identify and Estimate Mismeasured and Endogenous Regressor Models. Journal of Business & Economic Statistics, 30(1), 67–80. https://doi.org/10.1080/07350015.2012.643126