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ROMER WAS RIGHT ON OPENNESS AND INFLATION: EVIDENCE FROM SUB-SAHARAN AFRICA

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Romer (1993) documents a negative relation between trade openness and inflation and offers an explanation based on time-inconsistency of monetary policy, but subsequent research casts doubt on the negative relationship and the explanation. This paper contributes to this debate by estimating the effect of openness to international trade on inflation with panel data from Sub-Saharan Africa. Employing instrumental variable techniques that correct for endogeneity bias of trade openness, the empirical evidence suggests that within-country variations in trade openness restrict inflation: a 1 percentage point increase in the ratio of trade over gross domestic product is associated with a decrease in inflation of approximately 0.08 percentage points per year. These results are robust to additional controls, different measurements of trade openness and alternative instruments. Finally, we inspect the time-inconsistency mechanism of the negative-relationship between trade openness and inflation.

JEL classification codes: C23, E31, E52, F41

Key words: trade openness, inflation, instrumental variables

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I. Introduction

Whether or not trade openness restricts inflation has been a widely debated question. In his seminal paper, for the first time, Romer (1993) observes that there is a negative correlation between trade openness and inflation. Subsequently, the negative relationship is called into question by several scholars. For example, Terra (1998) argues that the negative relation between trade openness and inflation in Romer (1993) largely depends on his data sample during the debt crisis period when most countries are heavily indebted. Temple (2002) even cautions that the direct evidence for Romer's negative correlation is not at all strong.

The above-mentioned empirical studies are based on cross-section data. One weakness of the cross-sectional regression design is the omitted variable bias. For instance, Terra (1998) shows that both the time period and the unobservable country-specific characteristics have an important influence on the relation between openness and inflation. While the effects of these characteristics of the countries and time period may be purged by including country fixed effects and year fixed effects, the cross-sectional regression design makes it infeasible to do so. The panel data methodology appears to be the most appropriate for dealing with this type of problem, because it allow us to detect effects that are either typical of certain countries or changing over time. Hence, we apply rigorous panel-data estimation techniques.

Sachsida, Carneiro and Loureiro (2003) are the first to use panel data to study the relation between openness and inflation. They find that the negative relation still holds, but they do not control for time effects and other important variables that may determine inflation. Controlling for time and country fixed effects, Alfaro (2005) finds that openness does not play a role in restricting inflation in the short run, which runs counter to Romer (1993). In this paper, we empirically examine how trade openness affects inflation. Using panel data on a sample of 46 Sub-Saharan Africa (SSA) countries during the period 1985-2012, we find that there is a negative causal relationship between trade openness and inflation.[1] Therefore, our paper contributes to the debate by reinforcing the view of Romer (1993) that trade openness restricts inflation.

Even though we can control for country-specific and year effects in panel data, the causal effect of trade openness on inflation is still not easy to identify empirically. The previous studies do not find a good way to solve the endogeneity issue, failing

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[1] Table A in the Appendix presents the list of 46 SSAs.

to rule out the omitted variable bias or the reverse causality problem and therefore cannot convincingly isolate the causal effect of trade openness on inflation. Romer (1993) already cautions that there is an endogeneity problem in the relation between openness and inflation because trade openness is itself endogenous, and makes two IV estimates using different proxies for country size to instrument openness.

To examine the causal relationship between trade openness and inflation, in this paper, we adopt an instrumental variable strategy by using the GDP growth rates from the economies of OECD + China + India (SSA's most important trade partners) as an instrument for international trade openness of SSA economies.[2] Our instrumental approach is related to Brückner and Lederman (2015) who firstly use a similar instrument. There is a reason of such an IV. Higher real GDP growth of the OECD + China + India economies can increase trade openness of SSA countries through two main channels: the supply channel (higher OECD + China + India GDP growth increases their exports of goods and services) and the demand channel (higher OECD + China + India GDP growth increases the consumption of goods and services produced by Sub-Saharan African countries).[3] The fact that Sub-Saharan African countries' GDP is only a tiny fraction of the OECD + China + India economies' GDP ensures that variations in the OECD + China + India economies' GDP growth are plausibly exogenous to within-country variations of Sub-Saharan African countries' openness to international trade. For instance, the total GDP of the 49 SSA economies accounts for around 1% of world GDP in 2012 and averages 0.85% over the period 1985-2012.

In addition, we test the validity of the OECD + China + India growth as an instrument of trade openness by using rainfall as well as the Baltic Dry Index (BDI) cost as the instruments. In the literature, rainfall is a well-accepted instrument as an exogenous shock to income in SSA economies, and so possibly to trade openness. BDI cost has proved to be a good instrument for trade in poor countries, such as SSA, since they export a lot of primary goods but their economic scale is too small to drive BDI (Lin and Sim 2013; 2014). Though rainfall and BDI cost appear to be weak instruments for trade openness in SSA, on one hand, we find that our OECD + China + India growth variable enters insignificantly in the second stage using

[2] For example, SSA's trade with the OECD + China + India economies accounts for around 75 percent of SSA's total trade with the world over the period 1985-2012. The OECD + China + India economies account for 80 percent of SSA's total imports and 70 percent of SSA's total exports.

[3] It is worth noting that when we use the import GDP ratio of SSAs as a trade openness measure, as done in the literature, real GDP growth of the OECD + China + India economies mainly increase trade openness of SSA countries through the supply channel.

rainfall and BDI cost as instruments for trade openness. On the other, the OECD + China + India growth variable has a statistically and quantitatively significant effect on inflation from the reduced-form estimates. Hence, conditional on trade openness, we find that the OECD + China + India growth variable has no direct effect on inflation. In other words, the OECD + China + India growth variable can only affect inflation through the trade openness channel and our benchmark results of trade openness on inflation using the OECD + China + India growth variable as an instrument are valid.

We apply our instrumental variable strategy and show that trade openness has statistically significant and quantitatively large negative effects on inflation. The instrumental variable estimates suggest that, on average, a one percentage point increase in the ratio of imports over GDP in SSA countries is associated with a decrease in inflation of about 0.08 percentage points. The negative causal correlation between trade openness and inflation is robust to a number of robustness checks that include additional controls, such as the independence of the central bank, the exchange-rate policy, the government budget balance, the use of different measurements of trade openness and alternative instruments. Thus, from an identification perspective, our paper contributes to the line of research on identifying the causality of trade openness on inflation. More importantly, our instruments are country specific, thus, we can apply rigorous panel data estimation techniques that account for both unobservable cross-country heterogeneity and common year shocks and identify in our empirical analysis the effect of trade openness on inflation from, exclusively, the within country variation of the data.

Romer (1993) links the negative relationship between inflation and openness to the problem of time inconsistency of monetary policy, which he shows is more moderate in more open economies. Romer's explanation relies on the specific channel of negative terms-of-trade effects that counterbalance the inflationary bias. Lane (1997) holds that for countries that are not large enough to affect the structure of international relative prices, the terms-of-trade channel is not relevant. He offers a complementary explanation of the moderating effect of openness on the time-inconsistency problem that is based on a lower domestic incentive to engineer surprise inflation, so the effect is still present in small economies that are price-takers on international markets. Lane's explanation for the time-inconsistency problem applies to our sample of SSA countries because they can be considered to be small.

In order to show why there is a negative causal relationship between trade openness and inflation, we rely on this time-inconsistency-based hypothesis to inspect the mechanism more closely. Using a monetary dependence index, we find that the more independent the central bank, the weaker the negative relation between openness and inflation, which supports the time-inconsistency explanation.

The explanation of the time-inconsistency problem can be traced back to the Kydland and Prescott (1977) and Barro and Gordon (1983) time-inconsistency models. In these models, in the absence of an independent monetary authority, the more benefit the monetary expansion brings, the higher the incentives the government has to make surprise inflation.[4] However, there are other logics for the time-inconsistency problem. For example, Ruge-Murcia (2003) offers an alternative explanation where the time-consistency problem does not have to do with a positive inflationary bias, as in Barro and Gordon (where the monetary authority aims at an unemployment level lower than the natural rate), but rather with asymmetric reactions to positive and negative shocks.

There are several reasons why we focus on Sub-Saharan African countries in this paper. The first is that the IV strategies are particularly suitable for SSA. As already mentioned before, Sub-Saharan African GDP is only a tiny fraction of OECD GDP. Thus, GDP growth of OECD countries is plausibly exogenous to variations in Sub-Saharan African countries' openness to international trade. Secondly, it is important to note the significant policy interest in factors associated with inflation in Sub-Saharan Africa. Inflation is not good for the national welfare, especially high inflation, which leads to important redistributive effects across households and usually benefits rich people but harms poor ones. For instance, Lucas (2000) show that the loss from increasing the annual inflation rate from zero to 10 percent is equivalent to a decrease in real income of around one percent.[5]

Unfortunately, the inflation in SSA is very high compared with the rest of the world average and OECD countries. In 2012, the inflation for SSA was 6.54 percent, while for the OECD countries it was only 1.53 percent, and the world average was 3.51 percent.[6] For some SSA's country, like, Sudan and Ethiopia, the inflation rate

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[4] Lohmann (1998) shows that with asymmetric information on policy decisions, time-consistency problems are exacerbated by political business cycles because incumbents have an incentive to produce monetary expansions in election years to increase their chances of winning. In the SSA region, most of the countries (over 70%) are not democracies so this explanation would not apply.

[5] Lagos and Wright (2005) show such effect of the loss from increasing the annual inflation rate from zero to 10 percent is equivalent to a decrease in real income of 1.3 percent and Chiu and Molico (2011) show such effect is around 0.6 percent.

[6] The average inflation rate over the period 1985-2012 is 6.81, 4.87, and 2.23 percent, for SSA, the world and the OECD, respectively.

in 2012 was as high as 40 and 34 percent. If trade openness can help to restrict inflation, it will be another important benefit to SSA besides income and productivity (Frankel and Romer 1999; Feyrer 2009a, 2009b, Van Biesebroeck 2005; Brückner and Lederman 2015; Lin and Sim 2013, 2014).[7]

Thirdly, due to the insular economy in SSAs, there is a significant policy interest in factors driving trade growth in Sub-Saharan Africa. See, for example, World Economic Forum (2011), IMF (2011), World Bank (2011, 2012), or the African Growth and Opportunity Act, which enabled African countries to export over 4000 products, including hundreds of apparel products, quota-free and duty-free to the US, has been the object of much economic research.[8]

The remainder of the paper is structured as follows. Section II introduces data, in particular, our instrumental variable, the growth of OECD + China + India. The empirical strategy is introduced in Section III. Section IV presents the results of our IV regression of trade openness on inflation. Section V discusses several robustness checks of our benchmark results and provides a possible mechanism based on the ideas in Romer (1993). Section VI concludes the paper.

II. Data

Our data spans from 1985 to 2012. The key variables for the subsequent econometric analyses are trade openness and inflation in Sub-Saharan Africa countries. Trade and GDP in developing and developed countries are also important variables which are later used as an IV. In addition, in the main regressions and robustness checks we also include variables related to inflation such as GDP per capita, budget balance, government debt ratio to GDP, financial openness, and exchange rate flexibility. To check the quality of our instrument, we also use other IVs in the literature such as rainfall and Baltic Dry Index. To explain our finding, we use monetary dependence index. The following paragraphs describe the relevant data, their sources and the variable definitions (see Table 1).

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[7] Van Biesebroeck (2005) demonstrates that exporting increases firms' productivity in SSA. Brückner and Lederman (2015) show that in SSA economies such effect in short-run is 0.5 percent and in long-run is about 0.8 percent. Lin and Sim (2014) show that a one percentage point expansion in trade raises the GDP per capita of the SSA countries by approximately 0.6–0.7 percentage points and Lin and Sim (2013) show such effect for LDCs, 33 of which are located in SSA, is around 0.5.

[8] Collier and Venables (2007) and Frazer and Biesebroeck (2010) both find that AGOA trade preferences had a positive and significant impact on exports from Africa to the US.

To be consistent with the literature, openness is measured as the average share of imports (including goods and services) in GDP. When we use the share of both exports and imports in GDP, the results are robust. The results are not sensitive to using only imports of goods.[9] Inflation is measured as the average annual change in the log GDP deflator, as in the literature. The openness variables come from the WDI and the UNCTAD trade database.[10] The GDP deflator is from WDI too.

We construct a bilateral-trade-weighted GDP growth rate of OECD + China + India (*OECDCI*) trading partners for each country in our SSA sample. For country

Table 1. Data variables, definitions and sources

Variables	Definition	Source
Inflation	Annual change in the log of the GDP deflator	WDI
Import	Share of imports in GDP	WDI
Export	Share of exports in GDP.	WDI
Trade	Share of exports and imports in GDP.	WDI
GDP per capita	Real GDP per capita at PPP (Purchasing Power Parity)	WDI
GDP growth	GDP annual growth rate	WDI
Bilateral trade	Imports by SSA country from OECD + China + India	UNCTAD and Feenstra et al. (2005)
Budget balance	Government budget balance as a percentage of GDP	WDI
Government debt	Government debt as a percentage of GDP	WDI
BDI cost	General indicator of shipment rates for dry bulk cargoes	The Baltic Exchange and Lin and Sim (2013)
Financial openness	A country's degree of capital account openness	Chinn and Ito (2006)
Rainfall	Log of annual rainfall	GPCP and Bruckner's paper
Exchange rate flexibility	Exchange rate flexibility index	IMF
Monetary dependence	Monetary dependence index	Aizenman, Chinn and Ito (2008)

Note: *Inflation*, *Import*, *Export*, *Trade*, *GDP growth*, *Bilateral trade*, and *Financial openness* have the same unit, where a 1 percentage point increase of these variables is counted as 0.01.

[9] See the robustness check in section V.

[10] See http://data.worldbank.org/news/world-development-indicators-2012- update and http://www.unctad.org/Templates/Page.asp?intItemID=1584&lang=1.

i and year t, the trade-weighted GDP growth rate of OECD + China + India trading partners is constructed as:

$$OECDCI_{it} = \sum_{i=1}^{n} \theta_{ij} \ GDP \ growth_{jt} \tag{1}$$

where n is the number of OECD + China + India economies, and θ_{ij} is the imports in goods by country i from j as a share of country i's GDP in 1985, which is the first year during our sample period (the service bilateral trade data is unavailable).[11] Its predetermined nature motivates the use of the period's starting-year's trade share as the interaction term in (1). The bilateral trade data are from UNCTAD and Feenstra et al. (2005). Data on the real GDP growth rate of *OECDCI* economies are from the WDI. To check the quality of the instrument, we also use rainfall and Baltic Dry Index. Our data on year-to-year variations in rainfall are from the National Aeronautics and Space Administration (NASA) Global Precipitation Climatology Project (GPCP).[12] The BDI data is drawn from the London-based Baltic Exchange office.

As to other controls, data on income (real GDP per capita), budget balance, government debt ratio to GDP, and financial openness are also from WDI. The exchange rate flexibility classification is taken from the International Monetary Fund's (IMF) *Annual Report on Exchange Arrangements and Exchange-Rate Restrictions*: the greater the value, the more flexible the exchange rate. We use the monetary dependence index from Aizenman, Chinn and Ito (2008) to test the Romer (1993) independent monetary authority hypothesis; the smaller the value, the more independent the monetary authority. For summary statistics on these variables, see Table B in the online appendix.

III. Empirical strategy

Our main estimating equation relates inflation, measured by the first difference of the log of the GDP deflator for country i in year t, as follows:

$$Inflation_{it} = C_y + \beta \ Import_{it} + \gamma Z_{it} + \mu_i + \mu_t + \delta^i Trend + \vartheta_{i,t}, \tag{2}$$

[11] Our results are robust to using openness variable only considering goods, as shown in Section III.

[12] We thank Markus Bruckner's generosity for sharing the data with us.

where $Import_{it}$, the share of imports in GDP, is the main causal variable of interest. C_y is the constant term. Z includes other controls such as GDP per capita, budget balance, government debt ratio to GDP, financial openness, and exchange rate flexibility in our main regressions and robustness checks. We let μ_i be the country fixed effects that represent time invariant permanent differences across countries, μ_t the common time effects, and $\delta^i Trend$ a country-specific linear time trend that captures additional within-country time series variation. Finally, $\vartheta_{i,t}$ is the idiosyncratic error term clustered at the country level.

The extent of how openness affects inflation is summarized by β. This cannot be consistently estimated by OLS regression as openness is likely to be endogenous in the inflation equation, in spite of controlling for country-specific characteristics such as country and year fixed effects and common time trend to solve the omitted variable bias. Firstly, decisions on whether to trade, and how much to trade, are not randomly assigned. Secondly, the regression analysis may be confounded by the reverse causal effect going from inflation to imports. For instance, high inflation leads to depreciation of domestic currency, and this will decrease imports; hence the OLS regression is susceptible to reverse-causality problems.

This paper uses the variable *OECDCI* to obtain the exogenous variation in the import openness of the SSAs. The estimating equation that relates imports to the *OECDCI* is given by:

$$Import_{it} = C_I + \alpha \ OECDCI_{\mathrm{it}} + \rho Z_{it} + \mu_i + \mu_t + \delta^i Trend + \epsilon_{i,t}, \tag{3}$$

where C_I is a constant term and $\epsilon_{i,t}$ is the idiosyncratic error term clustered at the country level. This strategy relies on the variable we labeled $OECDCI_{it}$ –the trade-weighted real GDP growth rate of *OECDCI* trading partners– which we use as an instrument for trade openness (for robustness purposes, we also present the results excluding China and India). The assumption is that changes in economic conditions of non-*OECDCI* economies have negligible effects on the GDP growth rate of *OECDCI* economies. For the group of Sub-Saharan African countries this exogeneity assumption is plausible: for all years since 1985, the GDP of the group of Sub-Saharan African countries is less than 2 percent of *OECDCI* economies' GDP (WDI 2013).

The exclusion restriction is that $OECDCI_{it}$ should only affect Sub-Saharan African countries' inflation through trade openness. With regard to this exclusion restriction, the year fixed effects are an important ingredient in our estimating framework since they pick up Sub-Saharan Africa-wide variation in inflation that is due to *OECDCI*-wide growth in GDP. The instrumental variables regressions that use $OECDCI_{it}$ as an instrumental variable therefore only use variations in *OECDCI* economies' GDP growth that is specific to each Sub-Saharan African country. That is, these are country-specific variations in GDP growth. They arise precisely because bilateral trade flows between each *OECDCI* and Sub-Saharan African country are country specific. It is important to note that we use 1985 bilateral trade flows to construct the trade weighted *OECDCI* GDP growth instrument. Using time-invariant bilateral trade flows ensures that within-country variations in Sub-Saharan African countries' inflation do not affect the *OECDCI* growth instrument.

To make the argument more solid, we test the exclusion restriction formally. As Lin and Sim (2013) have proclaimed, small economic scale and trade participation will not affect BDI, which makes BDI cost a powerful instrument for SSA trade (especially for exports).[13] In addition, the agricultural sector in SSA economies is large: roughly one-third of GDP comes from agriculture, and over two-thirds of the population is employed in agriculture, which makes rainfall a powerful instrument as a determinant of SSA income.[14]

Our main causal variable is import openness. Though these two instruments are not directly determining imports, BDI cost and rainfall may affect imports indirectly through, for example, the income channel. Thus, we rely on these two variables to test the validity of $OECDCI_{it}$ as an instrument for imports by using rainfall and BDI cost as the instrument of imports.[15] We show that in the second stage, $OECDCI_{it}$ has a statistically insignificant and quantitatively small effect on inflation after adopting BDI cost and rainfall as instruments for imports, but we find a significant effect of $OECDCI_{it}$ on inflation from the reduced-form estimates in Section IV. Hence, conditional on imports we find that $OECDCI_{it}$ has only very small effects on inflation.

After checking the validity of our instrument, equation (2) is estimated using two-stage least squares in conjunction with (3) as the first-stage regression. We also estimate the effect of $OECDCI_{it}$ on income by looking at the reduced form equation:

$$Inflation_{it} = C_G + \sigma \ OECDCI_{it} + \tau Z + \mu_i + \mu_t + \delta^i Trend + \varepsilon_{i,t}. \tag{4}$$

[13] See Lin and Sim (2013, 2014) and Lin et al. (2014) for more details about BDI cost, which is constructed by the primary products share and the BDI.

[14] Rainfall is a well-accepted instrument as an exogenous shock to income in SSA economies in the literature. See, e.g., Miguel et al. (2004), Barrios et al. (2010), Brückner (2010), Brückner and Ciccone (2011), Miguel and Satyanath (2011), Ciccone (2011), Arezki and Brückner (2012) as well as Brückner (2013).

[15] Though they are weak instruments, see section IV for details.

Equation (4) allows us to investigate directly the within-country effect that *OECDCI* has on inflation that is facilitated by the trade openness channel.

IV. Results

We begin our empirical analysis by estimating the response of within-country variations in inflation to trade openness. Openness is not significant in any specification with OLS regressions. Thus, we look into the 2SLS results to see how trade openness affects inflation using an instrumental approach. In addition, we discuss the quality of our instrumental variable $OECDCI_{it}$ when estimating the 2SLS regression.

A. IV regression results

Table 2 presents the 2SLS estimates of the causal effect of trade openness on inflation by exploiting plausibly exogenous variation of imports that is driven by $OECDCI_{it}$. Columns I reports the 2SLS results where the endogeneity test rejects the hypothesis that trade openness is exogenous.[16] We show that there is a statistically significant (at 0.01 levels) and quantitatively large negative effect of import openness on inflation, which is very different from our OLS result (see online appendix). The estimated coefficient implies that on average a one percentage point higher trade openness level is associated with around 0.08 percentage points lower inflation level. As to its economic significance, a one standard deviation change in openness from its mean value of 0.440 affects inflation by 0.08 x 0.327 = 0.02616. This impact of 2.6 percentage points is economically significant: given an average annual inflation of is 5.7% in the 46 SSA countries in the sample, inflation falls from from 8.3% to 3.1% as openness rises from one standard deviation below the mean to one standard deviation above it.

Concerning identification, the first stage results in Column II suggest that the OECD + China + India economic growth variable ($OECDCI_{it}$) is a strong, positive determinant of trade openness: a one percentage point increase in economic growth leads to about 1 percentage point increase in trade openness. Column III reports the least squares (reduced form) estimates of the within-country effect that the OECD + China + India economic growth variable ($OECDCI_{it}$) has on inflation through imports. The increase of the economic growth decreases the inflation levels in SSAs.

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[16] Before we discuss the coefficient of greatest interest to us, we briefly discuss the other determinants of inflation. The empirical model seems to work well. It delivers precisely estimated coefficients that are sensible and similar to those estimated by others. For instance, income is negatively related to inflation (Romer 1993; Alfaro 2005).

Table 2. 2SLS results of trade openness on inflation

	I	II	III	IV
	2SLS	First stage	Reduced form	System GMM
Dependent variables	*Inflation*	*Import*	*Inflation*	*Inflation*
Import	-0.081***			0.0004
	(0.019)			(0.0012)
Log(*GDP per capita*)	-0.017*	-0.099	-0.0035	-0.0033*
	(0.0091)	(0.0104)	(0.0033)	(0.0019)
Budget balance	0.013	0.185	-0.0017	-0.001
	(0.010)	(0.134)	(0.0011)	(0.0012)
OECDCI		1.066***	-0.0713***	
		(0.160)	(0.0144)	
$Inflation_{-1}$				0.0034***
				(0.001)
Angrist Pischke F test		44.67		
Endogeneity test (P)	0.000			
Hansen J statistic (p)				1.000
AR(1)				0.052
AR(2)				0.631
Country effect	yes	yes	yes	yes
Year effect	yes	yes	yes	yes
Country trend	yes	yes	yes	yes
Observations	976	976	1001	1204
R-squared	-5.40	0.018	0.056	

Note: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

For comparison purposes, we report in Column IV the system-GMM estimates. The estimate of trade openness is positive in sign and statistically insignificant and quantitatively, they are near zero as the OLS results. As already analyzed, one reason for this difference in size is reverse causality bias: if inflation has a positive effect on imports, the system-GMM estimate could have upward bias. The instrumental variable estimates that use of $OECDCI_{it}$ as an instrument for imports do not suffer from this reverse causality bias because year-to-year variations in $OECDCI_{it}$ are exogenous to economic conditions of Sub-Saharan African countries. Another reason for the quantitatively larger (in absolute value) instrumental variable estimates is measurement error. It is well known that national accounts statistics of Sub-Saharan African countries are plagued by measurement error. To the extent that this measurement error is classical, it will attenuate the least squares and system-GMM estimates towards zero but not the instrumental variable estimates.

Our absolute values of the negative estimates are much larger than previous estimates in the literature. Two observations can be made. Firstly, endogeneity issues could lead to such a bias; for example, classical measurement error would bias the estimate towards zero. Secondly, because our paper focuses on the SSA countries while the previous literature looks at both developed and developing countries, our 2SLS estimates indicate that in low-income countries there could be a larger response of inflation to the opening of trade.

B. Instrument quality

The quality of $OECDCI_{it}$ as an instrument for imports in terms of first-stage fit is reasonable. The first-stage estimates on $OECDCI_{it}$'s effect on import openness are positive and significant at the 1 percent level. Also, the joint first-stage F-statistic on $OECDCI_{it}$ in Column I of Table 2 is above the rule-of-thumb threshold of 10 suggested by Staiger and Stock (1997). What about the exclusion restriction? The assumption in the instrumental variable regression is that $OECDCI_{it}$ only affects inflation through its effect on imports. To examine empirically whether there are any significant effects of $OECDCI_{it}$ on inflation beyond trade openness, we rely on two well-accepted instruments for trade and income in SSA in the literature for this purpose. One is BDI cost for trade and income raised by Lin and Sim (2013, 2014), which has proved to be a powerful instrument for SSA trade (especially for exports). Another is rainfall used for income by, for instance, Miguel et al. (2004) and Brückner and Ciccone (2011) since agricultural sector in SSA economies is large.

Though these two instruments are not directly determining imports, BDI cost and rainfall may affect imports indirectly through, for example, income channel. Thus, we rely these two instruments to test the validity of the $OECDCI_{it}$ as an instrument for imports by using rainfall and BDI cost as the instrument for import openness. To make it more intuitive, we include $OECDCI_{it}$ directly in the second stage. Table 3 reports the results. The first stage result suggests that BDI cost reduces imports by increasing trade costs while rainfall increases imports through the income channel. Second stage result shows that, $OECDCI_{it}$'s effect on inflation beyond imports is statistically insignificant. For the reader's convenience and comparison purpose, we repeat the results from our reduced regression in Column III, where we find the effect of $OECDCI_{it}$ on inflation is statistically significant

Table 3. Test of exclusion restriction for the IV: OECDCI

	I	II	III
	2SLS	First stage	Reduced form
Dependent variables	*Inflation*	*Import*	*Inflation*
Import	-0.02**		
	(0.01)		
OECDCI	-0.068		-0.0713***
	(0.056)		(0.0144)
BDI cost		-0.111*	
		(0.060)	
Rainfall		0.086**	
		(0.037)	
Angrist Pischke F test		3.28	
Log(*GDP per capita*)	yes	yes	yes
Budget balance	yes	yes	yes
Country effect	yes	yes	yes
Year effect	yes	yes	yes
Country trend	yes	yes	yes
Observations	811	811	1001
R-squared	-0.188	0.529	0.056
First stage Angrist Pischke F test for combined instruments			
OECDCI & BDI cost		0.569	
OECDCI & Rainfall		1.444	
OECDCI & BDI cost & Rainfall		1.070	

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

at the 1 percent level. Hence, conditional on import openness we find that $OECDCI_{it}$ has no significant effects on inflation.

Since BDI cost and rainfall could be instruments of imports, readers may argue: why we do not rely on multiple instruments for identification but just on one instrument $OECDCI_{it}$? The reason is that Column II shows that the instruments are weak since the joint first-stage F-statistic for BDI cost and rainfall is 3.28, which is far below the rule-of-thumb threshold of 10 suggested by Staiger and Stock. Furthermore, in Table 3, we check the weak instruments issue by using other combinations between BDI cost, rainfall and $OECDCI_{it}$, and all the joint first-stage F-statistic are very low. Thus, we use $OECDCI_{it}$ for identification, since the first-stage F-statistic is far above 10.

We do several robustness checks. Firstly, we look at the sensitivity of the baseline estimates to the inclusion of additional explanatory variables that might be relevant in determining inflation. Our second robustness check relates to using different trade openness indicators. The third robustness check looks at the sensitivity of our benchmark results to using slightly different instrument. The baseline 2SLS results are robust to all these checks and are reported in the online appendix.

C. Mechanism: why is there a negative causal trade openness-inflation relation?

In this subsection, we try to offer supporting evidence to explain the negative relationship between trade openness and inflation. Following Romer (1993), if the openness-inflation relationship arises from the dynamic inconsistency of discretionary monetary policy, the relationship should be weaker in countries that have more independent central banks, since one would expect these countries to have had more success in overcoming the dynamic inconsistency problem. Using the central bank independence index from Aizenman, Chinn and Ito (2008), we investigate interactions between monetary dependence measures and openness.

Column I in Table 4 shows the effect of adding the measure of monetary dependence interacted with trade openness as a further control variable. The estimated impact of openness on inflation is moderately reduced by including the interaction measure of lack of monetary independence in Column I (the interaction term generates the expected negative sign but is statistically insignificant).

In Column II, after including the interactions as well as the monetary dependence index, the openness-inflation effect is over-turned, becoming positive. As expected, the monetary dependence index is strongly associated with average inflation: the less independent, the higher inflation. More importantly, the interaction term enters with the expected negative sign and is quantitatively large (the absolute value is far larger than the positive trade openness estimate). This pattern is consistent after including other controls, as we do in the robustness check in Column III and IV. Unlike Alfaro (2005), we do not see a significant effect of exchange rate flexibility and the interaction between openness and exchange rate flexibility in Column V.

Thus, the negative relationship between openness and inflation is much stronger in countries that have a less independent monetary authority (higher value of the index). To see more evidence on such pattern, we provide the results in Table 5 by splitting the sample into two groups: high central bank independenc (less the mean value) and low central bank independence (above the mean value). We can see that trade openness significantly reduces inflation when there is low independence of the monetary authority, while there is no significant effect when there is high independence. To summarize, openness plays a significant role in restricting inflation even in the short-run based on our panel data analysis. Hence, our results are consistent with the Romer (1993) explanation of this negative link through the time-inconsistency logic.

Table 4. Mechanism investigation results

	I	II	III	IV	V
Dependent variable: *Inflation*					
Import	-0.07***	0.11*	0.10*	0.122**	0.121
	(0.011)	(0.06)	(0.058)	(0.061)	(0.164)
Import × Monetary	-0.047	-0.364***	-0.358***	-0.394***	
dependence	(0.037)	(0.135)	(0.129)	(0.145)	
Import × Exchange					-0.204
rate flexibility					(0.193)
Monetary dependence		0.137***	0.140***	0.148***	
		(0.05)	(0.06)	(0.057)	
Exchange rate flexibility					0.075
					(0.072)
Log(*GDP per capita*)	yes	yes	yes	yes	yes
Budget balance	yes	yes	yes	yes	yes
Government debt			yes	yes	
Financial openness			yes	yes	
GDP growth				yes	
Exchange rate flexibility				yes	
Angrist Pischke F test	35.28	8.012	8.012	6.733	0.632
Country effect	yes	yes	yes	yes	yes
Year effect	yes	yes	yes	yes	yes
Country trend	yes	yes	yes	yes	yes
Observations	907	907	907	880	779
R-squared	-7.630	-9.811	-9.810	-10.331	-130

Note: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Mechanism investigation results: splitting the sample

	I	II
Dependent variable: *Inflation*	High central bank independence	Low central bank independence
Import	0.0036	-0.179***
	(0.0044)	(0.051)
Other controls	yes	yes
Country effect	yes	yes
Year effect	yes	yes
Country trend	yes	yes
First stage Angrist Pischke F test	9.734	14.69
Observations	349	627
R-squared	-0.024	-22.65

Note: Clustered robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

VI. Conclusion

Estimates of the effect of trade openness on inflation remain contentious. The literature has raised concerns about the validity and interpretation of cross-country evidence. In particular, since Romer (1993)'s seminal paper, it remains unclear whether a negative causal correlation between trade openness and inflation withstands the test. This paper tackled the debate with panel data and new IV strategies applied mainly to the case of Sub-Saharan Africa.

Our approaches entailed an instrumental-variable identification strategy. The strategy relied on the GDP growth of the OECD + China + India economies as an IV for trade openness in Sub-Saharan Africa. The results appear to be robust and the IVs seem to be both valid and relevant based on our IV quality test techniques. The results show that, on average, trade openness appears to have a significant negative effect on inflation in Sub-Saharan Africa. A 1 percentage point increase in the ratio of trade over gross domestic product is associated with a decrease in inflation of approximately 0.08 percentage points per year, while the OLS estimate is small and biased towards zero. These results are robust to the inclusion of additional controls such as government debt, financial openness and exchange rate flexibility and are not sensitive to the use of different measurements of trade openness and alternative instruments.

The comparison between our 2SLS results and OLS estimates and previous estimates in the literature highlights the importance of addressing the endogeneity issue. Furthermore, because our paper focuses on SSA countries, our 2SLS estimates indicate that in low income countries there could be a large response of inflation to the opening of trade. Thus, our result suggests some significant policy interest in the function of trade openness on inflation in Sub-Saharan Africa since inflation is high in SSA and it is not good for the national welfare.

Finally, we inspect the mechanism of the negative-relationship between trade openness and inflation and find that our results are consistent with Romer (1993). Romer was right on the fact that the time-inconsistency logic provides an explanation for this negative link.

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