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Technology Adoption and the Middle-Income Trap: Lessons from the Middle East and East Asia

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Abstract

This paper documents the existence of a "middle-income trap" for the Middle East and North Africa region and contrasts the evidence with that of the East Asia and Pacific region. The results are two-folds. First, non-parametric regressions show that the average rate of economic growth in the Middle East and North Africa has not only been significantly lower than that in the East Asia and Pacific region, but it has also tended to drop at an earlier level of income. Second, econometric results point to Middle East and North Africa having experienced a relatively slow pace of technology adoption in general-purpose technologies and that a slower adoption pace of technology is associated with significant lower economic growth. The paper concludes that barriers to the adoption of general-purpose technologies related to the lack of contestability in key sectors constitute an important channel of transmission for the middle-income trap.

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Technology Adoption and the Middle-Income Trap: Lessons from the Middle East and East Asia

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1. Introduction

The term "middle-income trap" refers to the possibility that economies could get stuck at a certain level of income. The debate on the trap has thus far focused mostly on the East Asia and Pacific region (EAP).[4] While economies in Middle East and North Africa region (MENA) have stalled, they have largely been overlooked in the debate over the middle-income trap. Indeed, MENA has been characterized by pervasively low growth. In the 1980s and 1990s, GDP growth per worker in the region was less than 1 percent per year, with continuous decline in total factor productivity (Yousef, 2004). In recent decades, growth in MENA has remained relatively low (see Figure 1).[5] In the present paper, we document the existence of a middle-income trap for MENA and contrast the evidence with that of EAP.

To do so, we adopt a non-parametric analysis of growth dynamics that helps flexibly capture sharp changes in growth. Results from non-parametric regressions show that growth in GDP per capita and total factor productivity (TFP) in MENA quickly decline as income levels rise. In contrast, growth in GDP per capita and TFP in EAP is not only higher on average along the income ladder but also decline at much higher levels of income. Importantly, we document that the slow pace of technology adoption of general-purpose technologies (GPT) is associated with lower levels of economic growth. We then examine the adoption of both older GPT and their applications such as electricity, and newer ones, such as broadband and internet. For all technologies, when controlling for the level of income, MENA falls behind EAP in terms of the adoption pace. Barriers to the adoption of general-purpose technologies thus constitute an important channel of transmission for the middle-income trap.

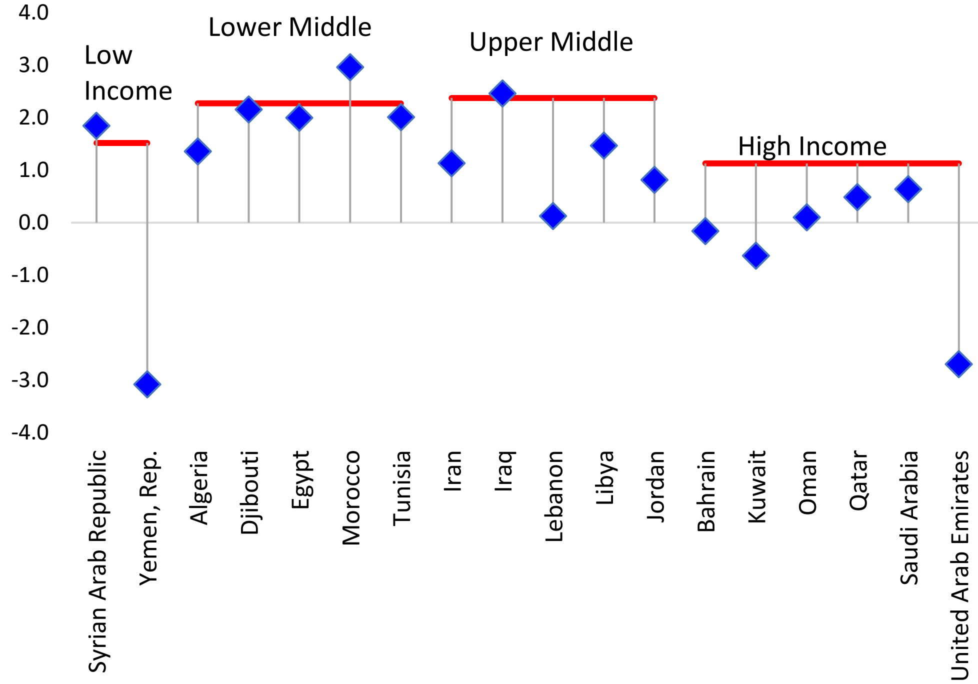
This paper is most directly related to the strand of literature testing for the existence of a middle-income trap. For example, Aiyar et al. (2013) uncover that middle-income countries are more likely to experience growth slowdowns. Also, Eichengreen et al. (2013) determines that level of income within the $10,000-$11,000 and $15,000-$16,0000 ranges. The jury is however still out on the empirical validity of

[4] The term "middle income trap" was first coined by Gill, Kharas and others (2007). Policymakers and commentators have used the term abundantly in the media to characterize the risk of facing a ceiling on the level of economic growth for countries such as Malaysia, Vietnam and China. Also, researchers have investigated the risk associated with the trap in Asia and as well as the needed reforms to escape it (Ohno and Le, 2015 for Vietnam; Fragen et al, 2013 for Malaysia; Eichengreen et al, 2012 and Glaw and Wagner, 2017 for China).

[5] Figure 1 shows that for the period from 2000 to 2021, MENA countries, with the exceptions of Djibouti and Morocco, are expected to experience lower growth in GDP per capita than the median of other countries in the same income group. The years from 2019 to 2021 are projections.

the middle-income trap.[6] The contribution of this paper is to provide evidence that MENA is subject to much lower levels of growth along the income ladder compared to EAP.

Figure 1: MENA Growth performance has been subpar (2000-2019)



Source: Authors' calculation, based on data from International Monetary Fund, World Economic Outlook.
Note: The blue diamonds are country average growth in GDP per capita. The red lines capture the median growth in GDP per capita in non-MENA countries in the same income group.

This paper is also related to the literature on the link between innovation and economic growth. In Schumpeterian growth theory, faster growth is associated with higher rates of firm creation and destruction driven by R&D and innovation (Aghion and Howitt, 1992). In this environment, incumbent firms' innovation and productivity growth would be stimulated by competition and entry, particularly in firms near the technology frontier (Aghion et al, 2014).[7] There is strong empirical evidence that competition and productivity growth display an inverted-U shaped relationship: starting at an initially low level of competition, higher competition stimulates innovation and growth; however, starting from a higher initial

[6] Bulman et al. (2017) find that the fraction of countries "trapped" at the middle-income level is not larger than the fraction of countries "trapped" at the low-income level. Similarly, Han and Wei (2017) find that the probability of escaping from the middle-income level is not smaller than the probability of escaping from the low-income level.
[7] See Aghion et al. (2014) for a recent review.

level of competition, higher competition may hurt innovation and productivity growth.[8] This paper documents MENA's slow pace of adoption in GPT which can help explain the pervasively low economic growth and TFP. This paper also provides evidence that technology adoption is slower when concentration is higher in key (upstream) sectors of the economy.

The remainder of the paper is organized as follows. Section II documents the evidence of a middle-income trap for MENA. Section III explores the link between technology adoption and economic growth. Section IV presents evidence of the relatively slow pace of technology adoption of GPT in MENA. Section V concludes.

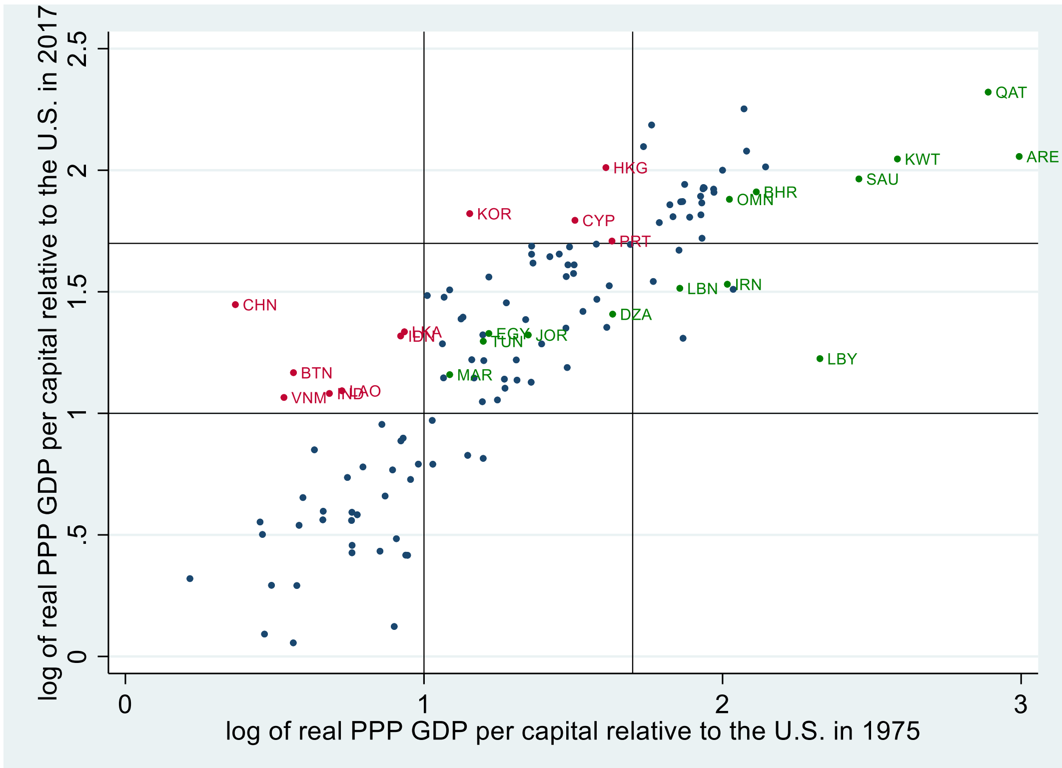
2. Empirical Evidence for the Middle East's Middle-Income Trap

MENA countries are less likely to escape the middle-income trap than other countries around the globe. Figure 2 illustrates that by comparing levels of income reached in 1975 to the ones in 2017. We follow Bulman et al. (2017) in grouping countries into three relative income groups, namely low-income, middle-income and high-income depending on their GDP per capita relative to that of the United States in the same year.[9] Countries in the middle-left quadrant escaped the low-income group in 1975 and shifted to the middle-income group in 2017. Countries in the top-middle quadrant escaped the middle-income group and shifted to the high-income group. Countries in the center quadrant have been trapped in the middle-income group for more than four decades. Among MENA countries, aside from the six countries that have remained high-income, five have been trapped in the middle-income group (Algeria, Egypt, Jordan, Morocco, and Tunisia), three fell from the high-income to middle-income group (the Islamic Republic of Iran, Lebanon, and Libya), while none have become "escapees". The Republic of Korea; Hong Kong SAR, China; Cyprus and Portugal have become escapees.

8 See for instance Aghion et al. (2005).

9 A country is defined as low-income if its per capita GDP is lower than or equal to 10 percent of that of the United States; middle-income if between 10 percent and 50 percent of U.S. GDP, and high-income if above 50 percent.

Figure 2: Illustrating the Middle-Income Trap



Sources: International Monetary Fund, World Economic Outlook database, and authors' calculations.
Note: Data labels use International Organization for Standardization (ISO) country codes. Regions follows World Bank country groups.

To document more systematically the evidence of a middle-income trap for MENA relative to EAP, we use the non-parametric local-linear regression technique that give the mean and standard errors of the estimated growth rate of each region at each level of income:[10]

$$\Delta\log(y)_{it,t+10} - \Delta\log(y)_{USt,t+10} = f\left(\frac{y_{it}}{y_{USt}}, fe_t\right) + \varepsilon_t$$

[10] The STATA command is *npregress kernel y x1 x2*, where y is the dependent variable, and x1 and x2 are the explanatory variables. See Fan and Gijbels (1996) for a reference on local-linear regressions.

where $\Delta\log(y)_{it,t+10}$ and $\Delta\log(y)_{USt,t+10}$ are overlapping annualized decadal growth in GDP per capita (or TFP) of country i and of the U.S. between time t and time $t+10$, $\frac{y_{it}}{y_{USt}}$ is the country's relative income per capita relative to the U.S. at time t. We use GDP per capita derived from output-side real GDP at chained PPPs and total factor productivity (TFP), both from Penn World Table 9.0. The regressions also include overlapping decade fixed-effect, fe_t, to control for common global shocks.

Note that we are agnostic about the form of the function $f\left(\frac{y_{it}}{y_{USt}}, fe_t\right)$. Unlike linear regression, a nonparametric regression is agnostic about the functional form between the outcome and the explanatory variables and is therefore not subject to misspecification error. In our context, a non-parametric regression could capture sharp changes in growth rates as relative income rises, a key advantage for us to identify an income trap.

For each region, the non-parametric regressions (with 100 bootstrap replications) help provide the average predicted values and confidence intervals of annualized decadal growth in GDP per capita at different levels of relative income. Average predicted relative growth in GDP per capita relative to the U.S. (and its 95% confidence interval) for MENA and EAP are visually shown in Panel A of Figure 3, while those of absolute growth in GDP per capita are shown in Panel B[11]. Their numerical values are reported in Appendix Table A1. The results for other regions are also reported in Appendix Figure A2, although not discussed in the text.

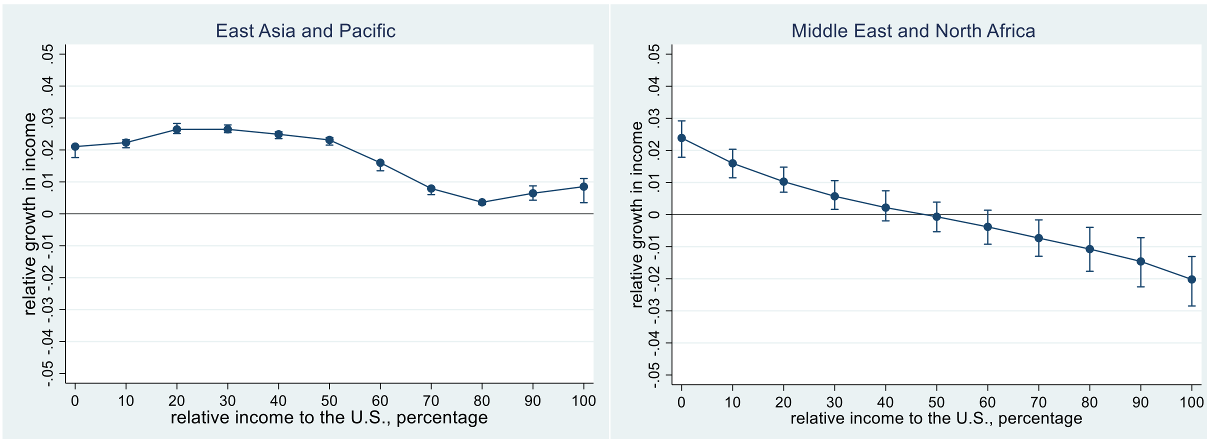
For EAP countries, both average relative and absolute growth in GDP do not significantly decline until the countries reach 60 percent of U.S. GDP per capita. At 50 percent or below, EAP economies maintain a stable growth rate at 4 to 4.5 percent (Panel B), or 2 to 2.5 percent higher than the U.S. (Panel A) indicating that these countries are catching up. In contrast, the growth performance of MENA countries is much weaker. Although starting at the same level of growth as EAP, around 4 percent, growth for MENA quickly and steadily declines. At 20 percent of U.S. GDP, the average growth rate for MENA is about 3 percent (Panel B), only 1 percent higher than that of the U.S. (Panel A) as opposed to almost 3 percent gap as in EAP. At 40 percent of U.S. income, MENA relative growth in GDP per capita becomes insignificantly different to that of the U.S., and starting from 60 percent of U.S. income, MENA growth is lower than that of the United States. The steady decline in per capita GDP in MENA along the income ladder indicates

[11] Note that we restrict the estimation at below 100 percent of U.S. income because we focus on the middle-income level. In addition, at above 100 percent of U.S. income, there are fewer observations making the estimations imprecise.

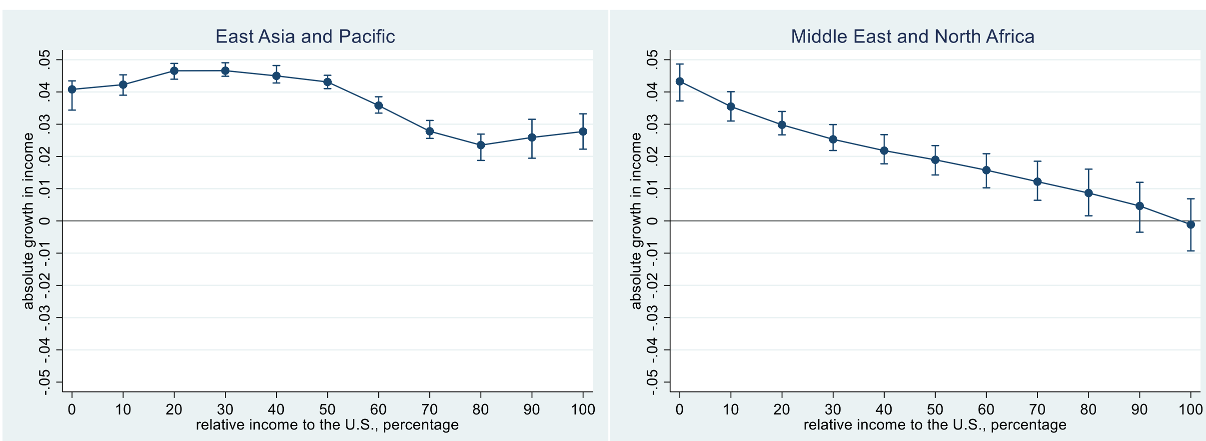
stronger evidence of the middle-income trap for MENA than for EAP—the region most prominently associated with the debate about the middle-income trap.

Figure 3: Growth in PPP GDP per capita

Panel A: Relative to the U.S.



Panel B: Actual growth (not relative to the U.S.)

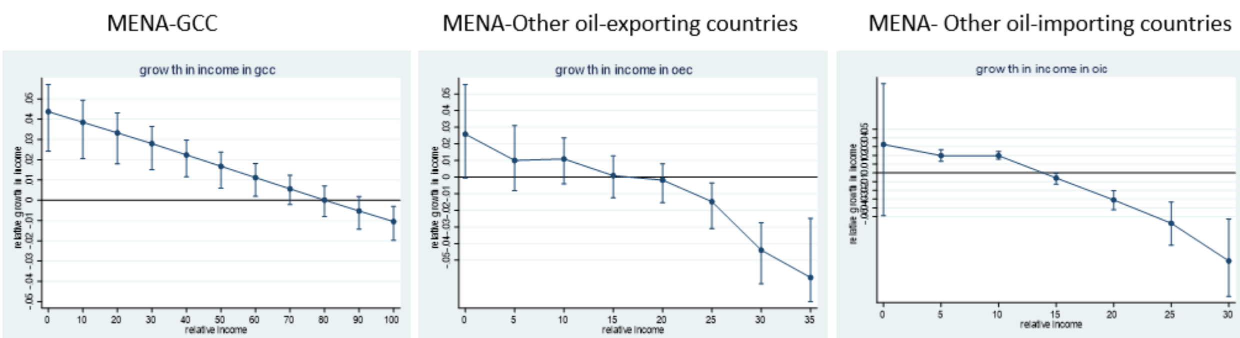


Note: MENA includes Algeria, Bahrain, Djibouti, the Arab Republic of Egypt, the Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, Tunisia, United Arab Emirates, and the Republic of Yemen; EAP includes Australia, Brunei Darussalam, Cambodia, China, Fiji, Hong Kong SAR-China, Indonesia, Japan, the Republic of Korea, Lao PDR, Macao SAR-China, Malaysia, Mongolia, Myanmar, New Zealand, Philippines, Singapore, Thailand, and Vietnam.

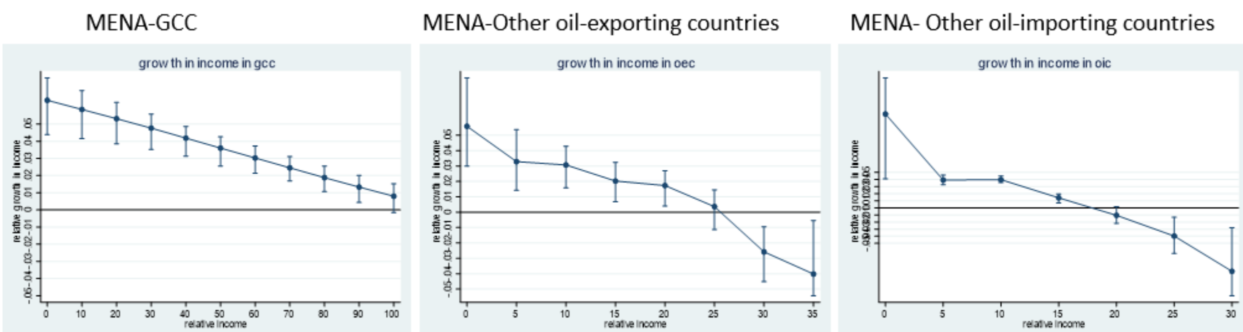
A similar pattern emerges when we explore the evolution of TFP growth. Figure A1 in the Appendix shows the results of non-parametric regressions for relative and absolute TFP growth for EAP and MENA. In both relative TFP growth (Panel A) and absolute TFP growth (Panel B), MENA under-performs compared to EAP along the income ladder. MENA's absolute TFP growth is downward-sloping and quickly falls below zero when the countries reach 20 percent of U.S. GDP per capita. EAP's absolute TFP growth, on the other hand, is stable at 1 percent level. In relative terms, MENA's TFP growth is almost always below that of the United States.

Figure 4: Growth in PPP GDP per capita – MENA sub-regions

Panel A: Relative growth to the U.S.



Panel B: Absolute growth.



Note: Gulf Cooperation Council (GCC) consists of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. Other oil exporting countries include Algeria, the Islamic Republic of Iran, Iraq, the Syrian Arab Republic and the Republic of Yemen. Other oil importing countries include Djibouti, the Arab Republic of Egypt, Jordan, Lebanon, Morocco, and Tunisia.

The pattern of the middle-income trap is robust across three sub-regions in MENA.[12] All the sub-regions have experienced a decline in GDP per capita at early levels of income (Figure 4), consistent with the regional overall pattern shown in Figure 3.[13] GCC countries perform best in terms of growth. Growth in GDP per capita in the GCC does not drop to below zero when the countries are still below the U.S.

[12] Countries in the Gulf Cooperation Council (GCC) are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. Other oil exporting countries are Algeria, the Islamic Republic of Iran, Iraq, the Syrian Arab Republic, and the Republic of Yemen. Other oil importing countries are Djibouti, the Arab Republic of Egypt, Jordan, Lebanon, Morocco, and Tunisia.

[13] Unfortunately, the TFP data for MENA do not allow us to run non-parametric regressions at the sub-region level.

level of per capita income.[14] In contrast, growth in per capita income of other oil exporting countries and oil importing countries quickly drops as their income rises. Specifically, growth falls below zero at about 30 percent of the U.S. per capita income for other oil exporting countries and at about 20 percent of the U.S. per capita income for other oil importing countries.

3. Empirical Evidence for the Slow Pace of Technology Adoption in MENA

There are several explanations for relatively slow growth in MENA. The literature has identified technology adoption as one important cause for economic growth (see Parente and Prescott, 1994 and Temple, 1999). This paper explores the relevance of that explanation for MENA.

In this section, we focus on poor technology adoption. Specifically, we show that MENA's technology adoption in general purpose industries (GPT) has been poor. We do so within a framework of cross-country panel regressions, specifically contrasting technology adoption between MENA and EAP. The specification is as follows:

$$\frac{tech_{it}^{x}}{tech_{US,t}^{x}} = \beta_0 + \beta_1 \frac{y_{it-1}}{y_{US,t-1}} + \beta_2 MENA + \beta_3 EAP + \beta_4 MENA \times \frac{y_{it-1}}{y_{US,t-1}} + \beta_5 EAP \times \frac{y_{it-1}}{y_{US,t-1}} + fe_t + \varepsilon_{it}$$

where $tech_{it}^{x}$ captures technology adoption of technology x in county i at time t; hence $\frac{tech_{it}^{x}}{tech_{US,t}^{x}}$ captures technology adoption relative to the U.S. Technology adoption depends on the country's development level, proxied by lagged per capita income relative to the U.S. $(\frac{y_{it-1}}{y_{US,t-1}})$, time fixed effects fe_t, region fixed effects, and the interaction of the region fixed effects and per capita income relative to the United States. The EAP and MENA fixed effects capture region-specific difference in technology adoption *relative to the rest of the world*. The interactions capture the speed of technology adoption in MENA and EAP, relative to other countries with the same level of income, *as income rises.*

Technology adoption is proxied by (1) bandwidth per internet user (bits per second), (2) number of self-contained computers designed for use by one person, (3) internet users in percentage of population, (4) number of ATMs per million capita (5) number of payments by credit and debit cards per million capita, (6) tractors used in agriculture per million capita, and (7) gross output of electric energy per million capita.

[14] The focus of our paper being on middle-income, we do not examine the performance of the GCC when their per capita income is higher than that of the United States.

Data are mainly from the CHAT database (Comin and Hobjin, 2010), except that bandwidth and internet users in percentage of population are from World Telecommunication Database (ITU).

For MENA, the pace of technology adoption for all technologies as income rises is slower *compared to other countries with the same income*. The results are shown in Table 1 and illustrated graphically in Figure 5. The coefficients associated with the interaction between the MENA regional dummy and relative income are all negative and statistically significant, which translates into downward-sloping lines for MENA (in red) in Figure 5. For EAP, the coefficients associated with the interaction between the EAP regional dummy and relative income are also negative and significant, but the magnitudes are much smaller than those for MENA. That implies the speed of technology adoption as income rises in EAP is larger than that in MENA. This is shown by the gaps between the blue lines (EAP) and the red lines (MENA) in Figure 5.

It is noteworthy that both MENA and EAP have positive and significant coefficients for the region fixed effects (translating into positive intercepts of the blue and red lines in Figure 6). That suggests that at (very) low levels of income, EAP and MENA countries have a faster pace of technology adoption relative to the rest of the world. However, when income rises, that initial advantage quickly fades away because of the lower speed of adoption. Results are robust to using all regional dummies (see Appendix Table A3).

A synthetic measure of technology adoption is Technology Readiness obtained from the World Economic Forum. Technology readiness captures availability of latest technologies, firm-level technology absorption, FDI and technology transfers, and other indicators of technology adoption.[15] The findings are similar to the ones presented earlier for specific technologies. MENA's technology readiness is indeed lower as income rises compared to other countries with the same income.

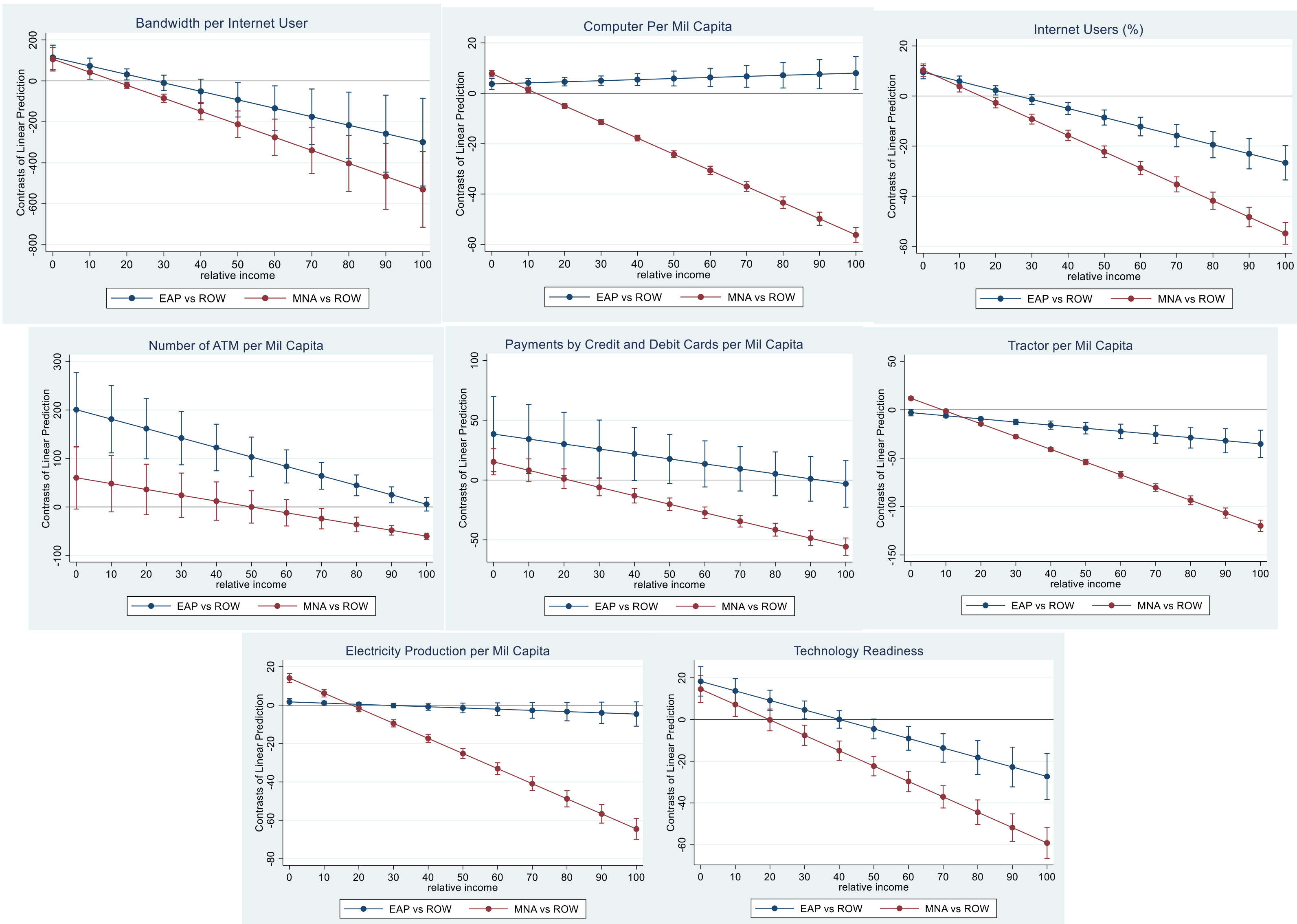
[15] Data for Technology Readiness are from Global Competitiveness Index. The index captures: availability of latest technologies, firm-level technology absorption, FDI and technology transfer, individuals using internet, fixed broadband internet subscriptions, international internet bandwidth, and mobile broadband subscriptions. In the following we use the terms "technology adoption" and "technology readiness" interchangeably.

Table 1: Technology adoption in MENA and EAP

	(1) Bandwidth per Internet User	(2) Computer Per Mil Capita	(3) Internet Users (%)	(4) Number of ATM per Mil Capita	(5) Payments by Credit and Debit Cards per Mil Capita	(6) Tractor per Mil Capita	(7) Electricity Production per Mil Capita	(8) Technology Readiness
Relative income to the US	6.556***	0.718***	0.835***	0.621***	0.649***	1.307***	0.848***	1.071***
	(1.227)	(0.0181)	(0.0214)	(0.0539)	(0.0569)	(0.0339)	(0.0317)	(0.0419)
EAP	114.2***	3.716***	9.481***	200.6***	38.39**	-2.956*	1.678*	18.29***
	(30.67)	(1.108)	(1.336)	(39.10)	(15.99)	(1.676)	(0.871)	(3.597)
MNA	105.8***	7.814***	10.33***	60.16*	15.19***	11.83***	14.08***	14.54***
	(29.45)	(0.653)	(1.266)	(32.83)	(5.540)	(0.851)	(1.193)	(3.280)
EAP * Relative Income	-4.134***	0.0430	-0.361***	-1.951***	-0.416**	-0.323***	-0.0633	-0.456***
	(1.359)	(0.0395)	(0.0431)	(0.377)	(0.166)	(0.0859)	(0.0396)	(0.0807)
MNA * Relative Income	-6.360***	-0.640***	-0.651***	-1.205***	-0.709***	-1.317***	-0.786***	-0.737***
	(1.228)	(0.0185)	(0.0274)	(0.320)	(0.0775)	(0.0340)	(0.0338)	(0.0520)
Constant	-74.77*	14.97*	-20.84***	4.214	-27.73**	-25.35***	-0.178	-106.8***
	(42.66)	(8.378)	(1.892)	(9.867)	(13.66)	(5.750)	(10.90)	(2.251)
Observations	2967	1281	4170	368	372	4115	3151	1366
R-Squared	0.165	0.796	0.674	0.432	0.262	0.536	0.579	0.693

Note: (1) Bandwidth per internet user (bits per second), (2) number of self-contained computers designed for use by one person, (3) internet users in percentage of population, (4) numbers of ATM per million capita (5) payments by credit and debit cards per million capita, (6) tractors used in agriculture per million capita, (7) Gross output of electric energy per million capita. Time-fixed effects are included in all regressions. See the list of countries included in these regressions presented in Appendix Table A2.

Figure 5: Technology adoption in MENA and EAP



Generally, there could be several reasons behind to the lack of technology adoption. The literature has identified many factors that could affect a country's technology adoption, such as human capital (Wozniak, 1987; Benhabib and Spiegel, 2005; Che and Zhang, 2018), trade and FDI (see Keller, 2004 for a review), and competition (Aghion et al, 2005; Seim and Viard, 2011).

With a cross-country regression framework, we show that the lack of competition could be one of the reasons behind MENA's lack of technology adoption. Our measure for market competition is market concentration. The argument is that, *comparing within the same industry*, countries or regions with higher market concentration tend to have weaker competition (see Berger and Hannan, 1989 and Bikker and Haaf, 2002 in the banking industry, and Sung, 2014 for the telecom industry). Market concentration is widely used to proxy for market competition. The calculation of market concentration indices such as Herfindahl-Hirschman Index (HHI) has been a starting point for assessing the state of market competition (see for example, U.S. Department of Justice and the Federal Trade Commission, 2010). Obviously, market concentration is just one indicator and does not contain all relevant information about competition. However, given our data limitation in cross-country regressions, it is our best choice.

In general purpose industries (GPT) such as telecom and finance, there is a high level of market concentration in MENA. Table 2 and the associated graphical illustration in Figure 6 show that market concentration for Mobile Operators and Banking in MENA increases significantly faster as income rises than other countries with the same income (see the red lines in Figure 6)[16]. To account for possible non-linearities we include a quadratic term. Figure 6 shows that for mobile operators, while market concentration is smaller in MENA when income is low, it quickly increases with a steep positive slope, while the slope for EAP is negative. For banking, asset concentration for both EAP and MENA is rising faster than the rest of the world, but MENA is above EAP in levels of asset concentration. This evidence is consistent with a popular notion that MENA does not fare well in market competition. For example, according to the World Bank's Doing Business data, MENA countries are generally ranked very low in starting a business (e.g. Saudi Arabia is ranked 141, Egypt 109, Algeria 150, Iraq 155).[17] Results are robust to using regional dummies for all regions of the world (see Appendix Table A4).

[16] For Mobile Operators, market concentration is calculated as annual average of quarterly HHI, based on market share of mobile operators provided by GSMA. For Banking, market concentration is calculated as assets of three largest banks as a share of assets of all commercial banks, data source is World Bank Database on Financial Development and Structure which was first constructed by Beck et al (2000).
[17] As Arezki et al. (2018) argue, "MENA governments seeking to protect incumbents, especially in sectors like banking and telecommunications, impose excessive and outdated regulations that deter new actors from entering the

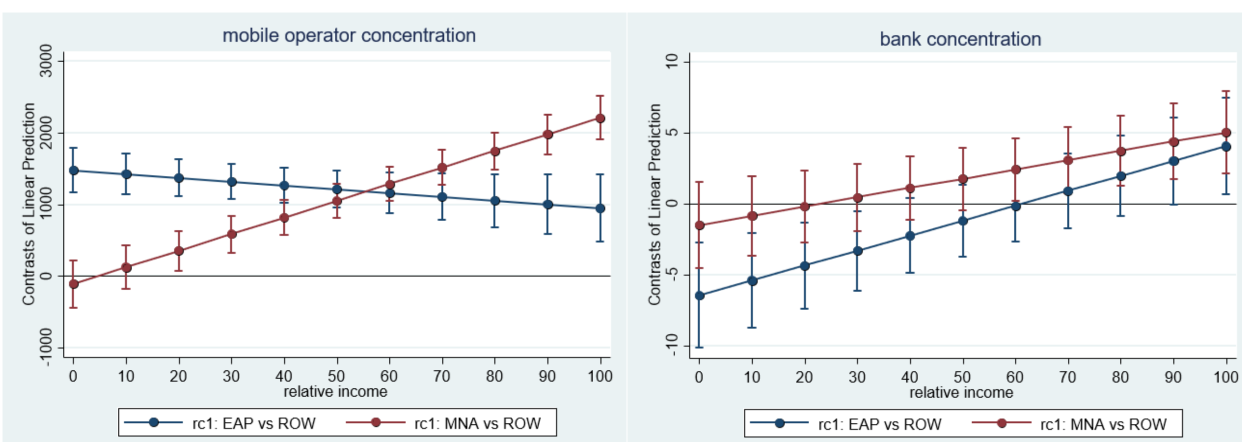
Table 2: Market Concentration in Telecom and Finance

	(1) Mobile Operators Concentration	(2) Bank Concentration
Relative Income to the US	-13.72***	-0.0472***
	(1.394)	(0.0146)
EAP	1477.3***	-6.485***
	(161.0)	(1.894)
MNA	-112.6	-1.523
	(168.7)	(1.559)
EAP * Relative Income	-5.327*	0.105***
	(3.123)	(0.0255)
MNA * Relative Income	23.21***	0.0655***
	(2.166)	(0.0205)
Constant	6791.0***	72.84***
	(207.0)	(2.118)
Observations	3321	2983
r2	0.194	0.0246

* p<0.10 ** p<0.05 *** p<0.01

Note: Time-fixed effects are included in all regressions.

Figure 6: Visual illustration for Table 2



market. This short-circuits competition, undermines the diffusion of general-purpose technology, and blocks the type of adaptation and evolution that underpins a vibrant private sector".

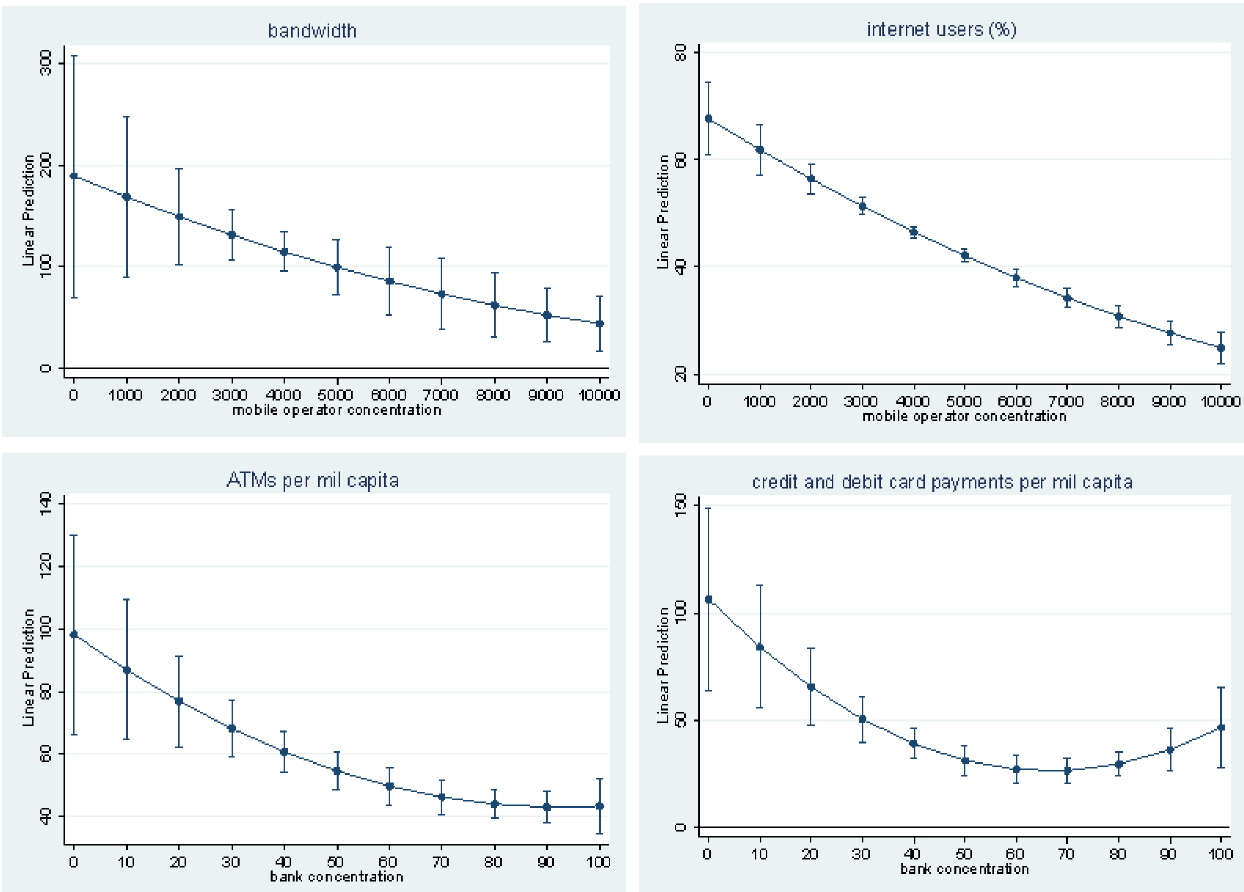
A large literature has helped document both theoretically and empirically that weak competition is arguably harmful for innovation and productivity growth (see Aghion and Hewitt, 1992 and Aghion et al, 2014). Results from cross-country regressions presented in Table 3 show that given the same level of relative income, mobile and banking concentrations are negatively correlated with technology adoption in the corresponding sector. In other words, a higher level of concentration is associated with lower penetration of the technology. Figure 7 provides a graphical illustration of the results in Table 3. The lines for bandwidth, internet users and ATMs are downward-sloping. For credit and debit card payments, the line slopes upward when bank concentration is very high. However, the confidence band becomes large.

To summarize, this section shows that market concentration in GPT such as banking and telecom in MENA becomes higher than other comparators as income rises. This translates to lower adoption of the GPT technologies in MENA.

Table 3: Concentration in mobile and banking operators and technology adoption

	bandwidth per internet user	internet users (%)	Number of ATMs per mil capita	Payments by credit and debit cards per mil capita
relative income (t-1)	3.505***	0.616***	0.478***	0.490***
	(0.690)	(0.0253)	(0.0722)	(0.0691)
mobile concentration	-0.0213	-0.00595***		
	(0.0224)	(0.00121)		
mobile concentration^2	0.000000682	0.000000167*		
	(0.00000167)	(9.10e-08)		
bank concentration			-1.198**	-2.410***
			(0.547)	(0.781)
bank concentration^2			0.00649	0.0181***
			(0.00425)	(0.00657)
Constant	66.30	31.01***	73.31***	73.07***
	(79.92)	(4.211)	(19.88)	(24.41)
Observations	2464	2658	178	182
year fixed effects	y	y	y	y
r2	0.108	0.621	0.385	0.344

Figure 7: Visualization for Table 3



4. Technology Adoption and Economic Growth

In this section, we show that poor technology adoption can cause low growth and quantify the gap in growth performance between MENA and EAP attributable to the gap in the pace of technology adoption. To do so, we regress decadal growth on the initial level of income, a measure of technology adoption that is Technology Readiness obtained from the World Economic Forum and the interaction between the latter two terms. Technology readiness captures availability of latest technologies, firm-level technology absorption, FDI and technology transfers, and other indicators of technology adoption. The interaction allows to explore the importance of the technology adoption in driving growth at different levels of income.

Results presented in Table 4 show that higher technology adoption is associated with higher economic growth and that the effect of technology also differ depending on the initial level of income. Indeed, the coefficient of the interaction term is significantly positive in all three columns, indicating that given the same initial income level, a high ranking of technology readiness is associated with higher economic growth. According to column (3), for a country whose initial GDP per capita is 50 percent of that of the US, increasing average technology readiness ranking by 10, would increase annual growth of GDP per capita in the next decade by 0.8 percent.

Table 4. Technology Adoption Readiness and Growth

	(1)	(2)	(3)
	Relative decadal growth		
Relative income	-0.0130***	-0.0135***	0.0302***
	(0.00186)	(0.00168)	(0.00328)
Average technology readiness (-)	0.000243***	0.000243***	
	(0.0000146)	(0.0000133)	
Relative income # Average technology readiness (-)	0.000335***	0.000259***	0.00169***
	(0.0000459)	(0.0000415)	(0.0000846)
Observations	6319	6319	6319
Country fixed effect	no	no	yes
Year fixed effect	no	yes	yes
R-square	0.115	0.286	0.451

Notes: Coefficient estimates from ordinary least squares regressions at the country-year level. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. The dependent variable is the relative annualized overlapping decadal growth of real GDP per capita, compared to the growth in the US. Relative income is the relative real GDP per capita from the initial year of the decade (US's real GDP per capita at the same year equals 1). Average technology readiness in the regression represents the average ranking for technology readiness. A higher number means a better ranking and higher technology readiness. The main variable of interest in all columns are the technology readiness, interacted with relative income from the initial year. The coefficient estimates associated with the constant are not reported to save space. Column (1) has no fixed effects, while column (2) is added with year fixed effects. In column (3), we added country fixed effect to replace the linear term of average technology readiness, in order to capture country-specific characteristics in addition to technology readiness. See Appendix Table A5 for the list of countries.

To address concerns about endogeneity associated with technology adopted, we instrumented Technology Readiness with variable capturing variables capturing the attitude toward innovation and risks presented in Hofstede et al (2010).[18] Attitudes toward innovation vary considerably across countries. These attitudes play a critical role in driving decision of governments, firms, individuals toward adoption of technology and innovation. Figure 9 provides illustrative evidence of the powerful relationship between attitude traits and technology readiness. The correlations validate that the most relevant psychological traits are power distance (the way in which power is distributed), avoidance of uncertainty, and individualism (see Figure 9). Other dimensions that might affect are tough versus tender, (short-term) normative versus

[18] Data are from Hofstede Insights: https://hi.hofstede-insights.com/national-culture

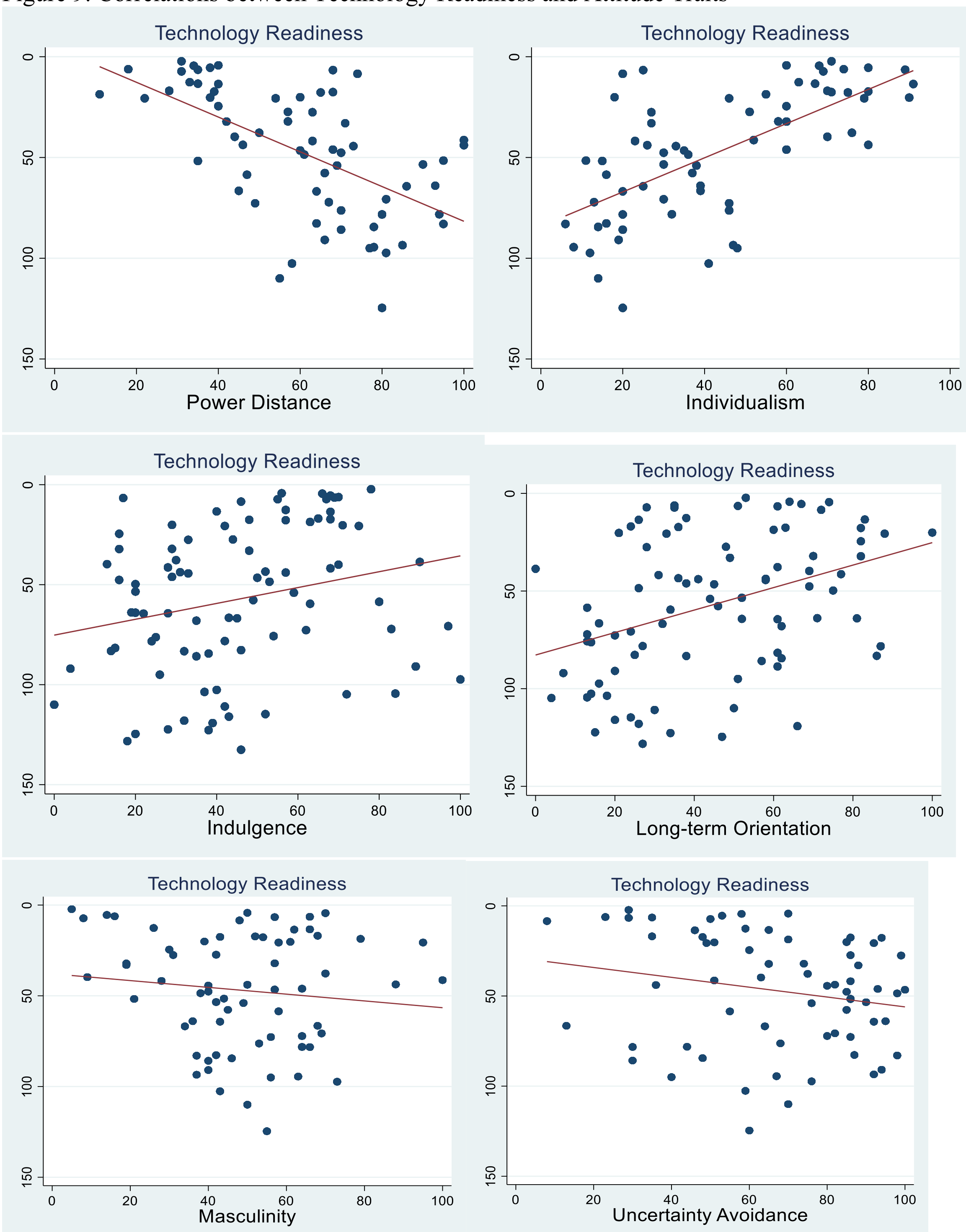
(long-term) pragmatic, and indulgence versus restraint. We use all six dimensions to instrument technology readiness in the first table, and the results are presented in Table 5.

Table 5. Growth and technology, OLS and IV regressions

	Relative decadal growth					
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV
Relative income	-0.0525***	-0.0555***	-0.0558***	-0.0544***	-0.0654***	-0.0862***
	(0.00297)	(0.00366)	(0.00266)	(0.00323)	(0.00656)	(0.00721)
Average technology readiness (-)	0.000383***	0.000413***	0.000407***	0.000389***		
	(0.0000262)	(0.0000347)	(0.0000234)	(0.0000305)		
Relative income x Average technology readiness (-)	0.000691***	0.000582***	0.000662***	0.000524***	0.00275***	0.00202***
	(0.0000756)	(0.0000874)	(0.0000672)	(0.0000770)	(0.000174)	(0.000205)
Observations	2794	2794	2794	2794	2794	2794
Year fixed effect	no	no	yes	yes	yes	yes
Country fixed effect	no	no	no	no	yes	yes
R-square	0.201	0.200	0.382	0.380	0.555	0.552
First-stage F-stat		249.5		255.1		1009.8
First-stage Sargan-stat		70.56		95.94		107.0

Notes: Coefficient estimates from ordinary least squares regressions at the country-year level. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. The dependent variable is the relative annualized decadal growth of real GDP per capita, compared to the growth in the US. Relative income is the relative real GDP per capita from the initial year of the decade (US's real GDP per capita at the same year equals 1). Average technology readiness in the regression represents the average ranking for technology readiness. A higher number means a better ranking, and higher technology readiness. This variable is instrumented in column (2) (4) (6), by 6-dimensions of country specific attitudes. First stage F-stat and Sargan test for over-identification are both reported. Regressions in all columns have the same sample to ease comparison. The coefficient estimates on constant are not reported to save space. Column (1) and (2) has no fixed effects, while column (3) and (4) is added with year fixed effects. In column (5) and (6), we added country fixed effect to replace the linear term of average technology readiness, in order to capture country specific characteristics in addition to technology readiness. The main variable of interest in all columns are the technology readiness, interacted with relative income from the initial year. This coefficient has been significant through all columns. Countries involved this regression are listed below. The relationship between technology readiness and 6 dimensions of attitude are graphed in Figure 5. First stage regressions of column (4) is provided in Appendix Table A6. We have also conducted regressions in Table 2 with quadratic term of relative income and confirmed the relationship between decadal growth and initial income to be negative in the segment of interest.

Figure 9. Correlations between Technology Readiness and Attitude Traits



Source: World Economic Forum, The Global Competitiveness Index dataset 2007-2017; and Hofstede Insights.

Note: Technology readiness in y-axis represents the average ranking for technology readiness. A smaller number means a better ranking, and higher technology readiness. The y-axis is reversed.

The results from the instrumental regressions using attitude traits as instruments for technology readiness confirm that there is a causal relationship between technology adoption and economic growth. Indeed, Table 5 shows that the individual coefficients associated with technology readiness and interactions with the level of initial income are statically significant and with the expected signs. Due to the lack of complete 6-dimensions of attitude for some countries, regressions in Table 5 are conducted again with only two dimensions, namely long-term orientation and indulgence. The coefficients of the interaction term remain significantly positive, indicating a causal relationship between technology on economic growth (Appendix Table A7). To streamline the instrumentation, we use the first component of the 6-dimensions of the attitude using a principal component analysis in the IV regressions presented in Table 5. The regression table is provided in Appendix Table A8. The first stage regression is provided in Appendix Table A9, and the weights in the first principle component is reported in Appendix Table A10. The results confirm the causal relationship between technology adoption and economic growth.

We now turn to quantifying how much of the gap in growth performance in MENA is attributable to slow technology adoption. To do so, we conduct a thought experiment whereby MENA would have experienced EAP level of technology readiness given MENA's relative income. We first calculate for each MENA country its counter-factual level of technology readiness given its relative income in 2017 as if it were a typical EAP country (using the coefficients obtained in Column (8) of Table 1). After obtaining the counter-factual EAP-equivalent level of technology readiness, we use it to calculate the new GDP growth for each MENA country (using the coefficients obtained in Column (6) of Table 5) and then take the GDP-weighted average regional growth. We find that the growth gains for MENA would be 4% per year. This is driven by high-income MENA countries (i.e., the Gulf Cooperation Council countries), as their technology readiness levels are remarkably low given their relative income to the US. Once we include only development MENA in the sample (i.e., Algeria, Egypt, Iraq, Jordan, Lebanon, Libya, Morocco, Tunisia and Yemen), the GDP growth gains would be 0.61% per year.

Similarly, we estimate the hypothetical GDP growth gains if MENA were to be a typical country in the rest of the world (excluding EAP). We follow a similar approach and find that the growth gains for MENA would be 5.8% per year and the growth gains for developing MENA would be 0.34% per year.

5. Conclusion

This paper documented the existence of a "middle-income trap" for the Middle East and North Africa region (MENA). It argued that MENA economic woes offer new insights into the debate on the trap, which has thus far focused on the East Asia and Pacific region (EAP). The results are two-folds. First, non-parametric regressions show that the average rate of economic growth in MENA has not only been significantly lower than EAP but has also tended to drop at an earlier level of income. Second, a slower pace of technology adoption is associated with slower levels of economic growth and MENA has experienced a relatively slow pace of technology adoption in general purpose technologies (GPT).

These results suggest that barriers to GPT adoption constitute an important channel of transmission for the middle-income trap. Indeed, the pervasive lack of market contestability in MENA markets and the resulting slow pace of technology adoption including in key sectors can help explain why more generally economies tend to get stuck. To the extent that governments play a key role in the regulation of entry including in key "upstream" sectors, the literature focus on firm level dynamics only shed lights on "downstream" matters. Instead, the lack of availability of frontier GPT can seclude firms into low productivity activities, limiting trade and economic growth. Further research on the interplay between the causes and consequences of lack of (government induced) GPT adoption would help understand the nature and consequences of upstream factors impeding productivity gains and growth.

From a policy perspective, one proposal put forward by Arezki et al (2018) to break with "business as usual" in the MENA region is for the authorities to embrace a "moonshot approach" to the adoption of information technology and communications. MENA countries could emulate President John F. Kennedy's 1961 decision to unleash an extraordinary collective national effort that achieved its seemingly impossible goal: a manned lunar landing in mid-1969. A MENA moonshot would involve a collective regional commitment to achieve parity with advanced economies in information and communications technology by 2021. MENA countries would seek to equal or better OECD countries in terms of their level of access to the internet, capacity to transmit data (bandwidth) and the number of financial transactions carried out electronically. This would unleash the potential of the young and educated population—who have been subject to abnormally high levels of unemployment—and spur growth. [19]

[19] World Bank (2019) shows that MENA has the highest youth unemployment rates in the world and these rates are highest among the educated.

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Table A1: Coefficients for the non-parametric regressions: Relative growth versus relative income

EAP

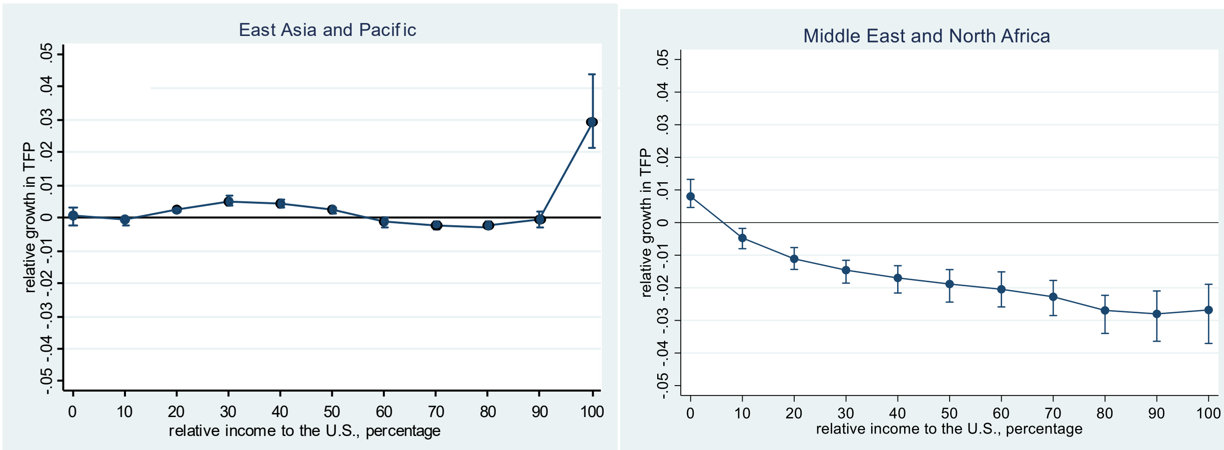
relative income	Average Predicted Growth	Std.Err	z	P>|z|	Percentile [95% Conf. Interval]	
0	0.021	0.001	14.4	0	0.018	0.021
10	0.022	0.001	19.76	0	0.021	0.023
20	0.026	0.002	16.71	0	0.025	0.028
30	0.026	0.001	28.82	0	0.025	0.028
40	0.025	0.001	25.62	0	0.024	0.026
50	0.023	0.001	22.65	0	0.022	0.024
60	0.016	0.001	14.9	0	0.013	0.016
70	0.008	0.001	11.25	0	0.006	0.008
80	0.004	0	8.88	0	0.003	0.004
90	0.006	0.002	3.89	0	0.004	0.009
100	0.009	0.003	2.96	0.003	0.003	0.011

MENA

relative income	Average Predicted Growth	Std.Err	z	P>|z|	Percentile [95% Conf. Interval]	
0	0.024	0.003	8.123	0	0.018	0.029
10	0.016	0.002	6.683	0	0.011	0.02
20	0.01	0.002	4.693	0	0.007	0.015
30	0.006	0.002	2.509	0.012	0.002	0.011
40	0.002	0.002	0.869	0.385	-0.002	0.007
50	-0.001	0.003	-0.242	0.809	-0.005	0.004
60	-0.004	0.003	-1.241	0.215	-0.009	0.001
70	-0.007	0.003	-2.117	0.034	-0.013	-0.002
80	-0.011	0.004	-2.775	0.006	-0.018	-0.004
90	-0.015	0.004	-3.497	0	-0.023	-0.007
100	-0.02	0.004	-4.784	0	-0.028	-0.013

Figure A1: Growth in TFP

Panel A: Relative TFP Growth (to the U.S.)



Panel B: Absolute TFP growth

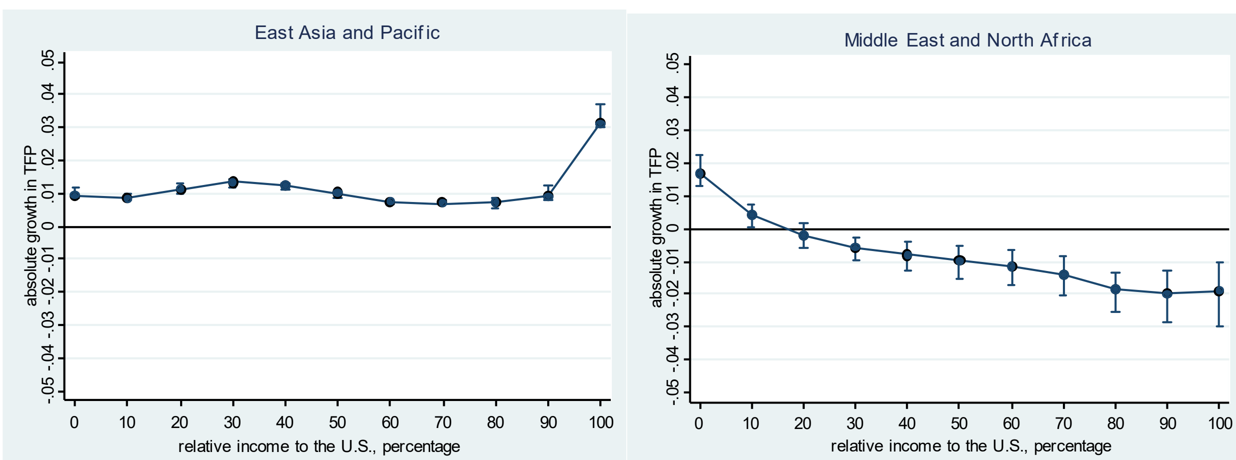
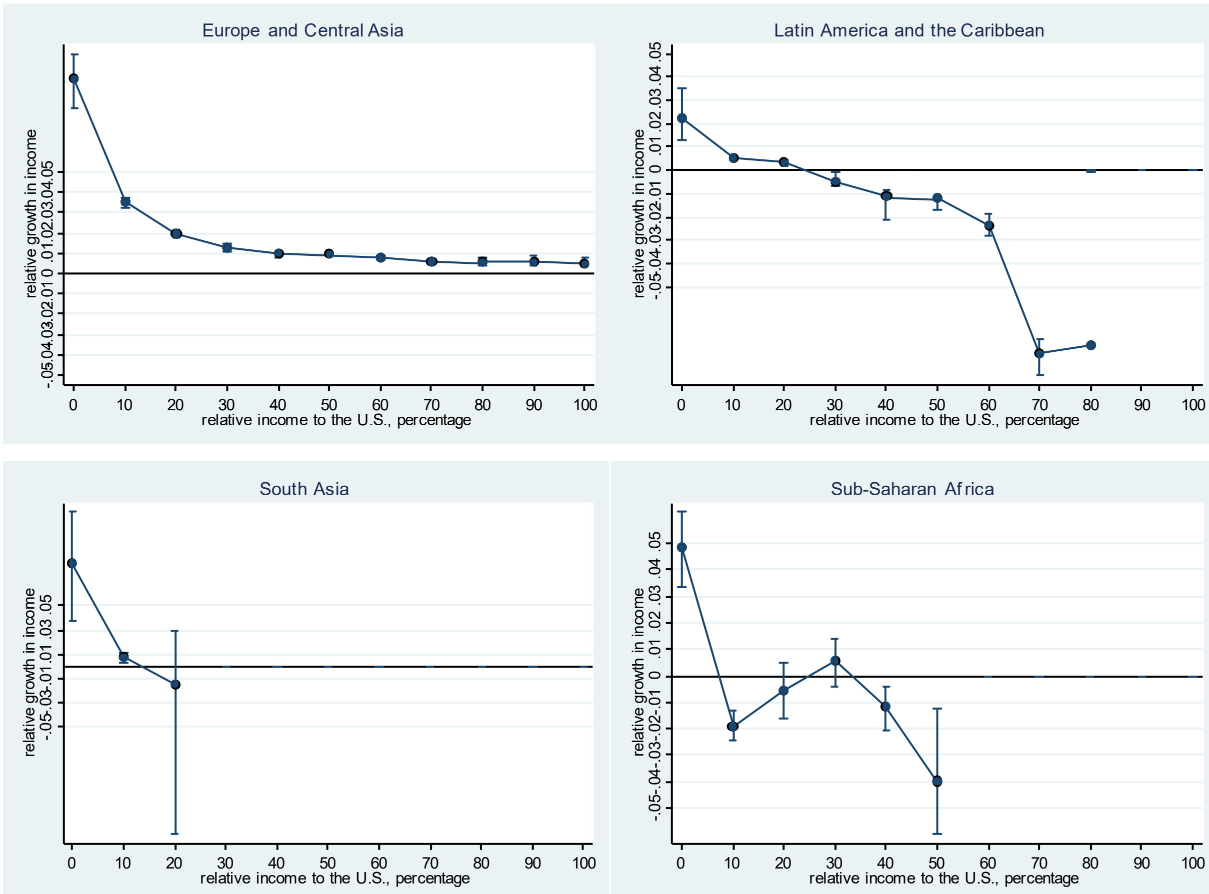


Figure A2: Relative GDP growth for other regions



Note: All regions are defined following World Bank country groups[20].

[20] See http://databank.worldbank.org/data/download/site-content/CLASS.xls for the current classification.

Table A2: List of countries

United States	Guatemala	Vietnam	Sudan
United Kingdom	Haiti	Algeria	Swaziland
Austria	Honduras	Angola	Tanzania
Belgium	Mexico	Botswana	Togo
Denmark	Nicaragua	Burundi	Tunisia
France	Panama	Cameroon	Uganda
Germany	Paraguay	Central African Republic	Burkina Faso
Italy	Peru	Chad	Zambia
Netherlands	Uruguay	Congo, Democratic Republic of the	Armenia
Norway	Belize	Benin	Azerbaijan
Sweden	Suriname	Equatorial Guinea	Belarus
Switzerland	Iran	Ethiopia	Albania
Canada	Jordan	Gabon	Georgia
Japan	Kuwait	Ghana	Kazakhstan
Finland	Lebanon	Guinea-Bissau	Bulgaria
Greece	Oman	Guinea	Moldova
Iceland	Saudi Arabia	Kenya	Russia
Ireland	Syria	Lesotho	Tajikistan
Portugal	United Arab Emirates	Liberia	China
Spain	Egypt	Madagascar	Turkmenistan
Turkey	Yemen	Malawi	Ukraine
Australia	Bangladesh	Mali	Uzbekistan
New Zealand	Cambodia	Mauritania	Czech Republic
South Africa	Sri Lanka	Mauritius	Slovak Republic
Argentina	India	Morocco	Estonia
Bolivia	Indonesia	Mozambique	Latvia
Brazil	Korea	Niger	Hungary
Chile	Malaysia	Nigeria	Lithuania
Colombia	Nepal	Zimbabwe	Mongolia
Costa Rica	Pakistan	Rwanda	Croatia
Dominican Republic	Philippines	Senegal	Slovenia
Ecuador	Singapore	Sierra Leone	Poland
El Salvador	Thailand	Namibia	Romania

Note: The table presents countries included in Table 1.

Table A3: Estimating Technology Adoption with Regional Dummies

	(1) Bandwidth per internet user	(2) Computer per mil capita	(3) Internet users (%)	(4) Number of ATM per mil capita	(5) Payments by credit and debit cards per mil capita	(6) Tractor per mil capita	(7) Electricity production per mil capita
Relative income	-3.618***	2.220***	0.387	-1.072***	0.547**	-1.847***	-2.979***
	(0.818)	(0.215)	(0.279)	(0.231)	(0.266)	(0.143)	(0.174)
EAP	-435.4***	118.4***	-48.61*	8.481	-24.39	-295.0***	-405.9***
	(80.72)	(20.76)	(25.21)	(44.27)	(29.85)	(13.63)	(17.35)
ECA	-792.3***	113.2***	-44.66*	-191.1***	-57.90**	-249.8***	-406.8***
	(123.2)	(20.78)	(25.21)	(21.64)	(25.45)	(14.02)	(17.70)
LAC	-374.4***	120.0***	-51.10**			-293.7***	-403.0***
	(85.68)	(20.76)	(25.20)			(13.58)	(17.37)
MNA	-444.1***	122.6***	-47.76*	-132.7***	-46.98*	-279.9***	-394.4***
	(80.24)	(20.74)	(25.20)	(37.24)	(25.79)	(13.58)	(17.40)
SAR	-452.5***	121.6***	-62.83**			-287.4***	-401.7***
	(80.33)	(20.79)	(25.23)			(13.69)	(17.39)
SSA	-449.5***	121.2***	-60.60**			-288.0***	-401.1***
	(80.14)	(20.77)	(25.18)			(13.57)	(17.38)
EAP x Relative income	6.038***	-1.454***	0.0865	-0.259	-0.311	2.837***	3.753***
	(1.002)	(0.218)	(0.282)	(0.437)	(0.309)	(0.162)	(0.175)
ECA x Relative income	14.05***	-1.510***	0.296	1.628***	-0.0432	2.733***	3.778***
	(2.290)	(0.217)	(0.281)	(0.234)	(0.268)	(0.155)	(0.186)
LAC x Relative income	3.616***	-1.840***	0.243			2.638***	3.316***
	(0.974)	(0.218)	(0.282)			(0.149)	(0.175)
MNA x Relative income	3.812***	-2.142***	-0.204	0.494	-0.614**	1.836***	3.041***
	(0.819)	(0.215)	(0.280)	(0.376)	(0.272)	(0.143)	(0.174)
SAR x Relative income	4.654***	-2.064***	0.474			2.356***	3.208***
	(0.932)	(0.287)	(0.304)			(0.306)	(0.220)
SSA x Relative income	4.117***	-2.026***	-0.0954			2.105***	3.187***
	(0.855)	(0.220)	(0.286)			(0.146)	(0.177)
Observations	2967	1281	4170	368	372	4115	3151
R-square	0.219	0.839	0.709	0.545	0.476	0.611	0.671

Note: This table reports all regional dummies with North America as the default region. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Time-fixed effects are included in all regressions. Coefficients of constants are not reported to save space.

Table A4: Market Concentration in Telecom and Finance

	(1) Mobile operators Concentration	(2) Bank concentration
Relative income	-33.65	-1.831***
	(20.52)	(0.223)
EAP	1328.9	-147.9***
	(1834.6)	(21.49)
ECA	-1088.4	-146.1***
	(1830.8)	(21.45)
LAC	-272.5	-144.6***
	(1837.4)	(21.48)
MNA	-211.6	-144.3***
	(1835.7)	(21.46)
SAR	-1835.0	-164.0***
	(1852.6)	(21.76)
SSA	13.51	-135.7***
	(1830.6)	(21.43)
EAP x Relative income	14.63	1.890***
	(20.71)	(0.224)
ECA x Relative income	29.33	1.870***
	(20.59)	(0.224)
LAC x Relative income	34.90	1.757***
	(21.75)	(0.231)
MNA x Relative income	43.11**	1.852***
	(20.59)	(0.223)
SAR x Relative income	119.8***	3.063***
	(28.16)	(0.450)
SSA x Relative income	53.61**	1.929***
	(21.08)	(0.235)
Observations	3303	2962
R-square	0.248	0.111

Note: This table reports all regional dummies with North America as the default region. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Time-fixed effects are included in all regressions. Coefficients of constants are not reported to save space.

Table A5. List of countries

Albania	Denmark	Latvia	Qatar
Algeria	Dominican Republic	Lesotho	Romania
Argentina	Ecuador	Lithuania	Russia
Armenia	Egypt	Luxembourg	Saudi Arabia
Australia	El Salvador	Macedonia, FYR	Senegal
Austria	Estonia	Madagascar	Serbia
Azerbaijan	Ethiopia	Malaysia	Singapore
Bahrain	Finland	Mali	Slovak Republic
Bangladesh	France	Mauritania	Slovenia
Barbados	Gambia, The	Mauritius	South Africa
Belgium	Georgia	Mexico	Spain
Benin	Germany	Mongolia	Sri Lanka
Bolivia	Greece	Montenegro, Rep. of	Sweden
Bosnia and Herzegovina	Guatemala	Morocco	Switzerland
Botswana	Honduras	Mozambique	Syria
Brazil	Hong Kong SAR	Namibia	Tajikistan
Bulgaria	Hungary	Nepal	Tanzania
Burkina Faso	Iceland	Netherlands	Thailand
Burundi	India	New Zealand	Trinidad and Tobago
Cambodia	Indonesia	Nicaragua	Tunisia
Cameroon	Ireland	Nigeria	Turkey
Canada	Italy	Norway	Uganda
Chad	Jamaica	Oman	Ukraine
Chile	Japan	Pakistan	United Arab Emirates
China	Jordan	Panama	United Kingdom
Colombia	Kazakhstan	Paraguay	United States
Costa Rica	Kenya	Peru	Uruguay
Croatia	Korea	Philippines	Venezuela
Cyprus	Kuwait	Poland	Vietnam
Czech Republic	Kyrgyz Republic	Portugal	Zambia
			Zimbabwe

Note: The table presents countries included in Table 4.

Table A6. First stage regression of Column (4) in Table 2.

	(1) Average technology readiness (-)	(2) Relative income x Average technology readiness (-)
Power Distance	0.0279	0.0618***
	(0.0381)	(0.0108)
Individualism	0.783***	-0.0757***
	(0.0322)	(0.00912)
Masculinity	-0.563***	-0.0604***
	(0.0361)	(0.0102)
Uncertainty Avoidance	0.161***	0.00136
	(0.0251)	(0.00712)
Long-term Orientation	0.733***	-0.00253
	(0.0240)	(0.00680)
Indulgence	0.568***	0.0195***
	(0.0250)	(0.00709)
Power Distance x Relative income	-0.301***	-0.343***
	(0.0847)	(0.0240)
Individualism x Relative income	-1.112***	0.337***
	(0.0623)	(0.0177)
Masculinity x Relative income	0.567***	-0.0726***
	(0.0626)	(0.0177)
Uncertainty Avoidance x Relative income	-0.653***	-0.264***
	(0.0562)	(0.0159)
Long-term Orientation x Relative income	-0.695***	0.384***
	(0.0498)	(0.0141)
Indulgence x Relative income	-1.347***	-0.238***
	(0.0732)	(0.0208)
Relative income x Relative income	247.5***	2.194
	(9.711)	(2.754)
Observations	2794	2794

Note: Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Coefficients of constants are not reported to save space.

Table A7. Growth and technology, OLS and IV regression (2 dimensions)

	Relative decadal growth					
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV
Relative income	-0.0605***	-0.0727***	-0.0609***	-0.0639***	-0.0245***	-0.109***
	(0.00344)	(0.00537)	(0.00309)	(0.00474)	(0.00828)	(0.0144)
Relative income x Average technology readiness (-)	0.000720***	0.000619***	0.000603***	0.000562***	0.00325***	0.000900**
	(0.0000768)	(0.000147)	(0.0000689)	(0.000130)	(0.000192)	(0.000381)
Average technology readiness (-)	0.000492***	0.000602***	0.000498***	0.000525***		
	(0.0000255)	(0.0000457)	(0.0000229)	(0.0000402)		
Observations	3726	3726	3726	3726	3726	3726
Year fixed effect	-	-	yes	yes	yes	yes
Country fixed effect	-	-	-	-	yes	yes
R-square	0.188	0.184	0.361	0.361	0.496	0.475
First-stage F-stat		222.8		221.2		613.3
First-stage Sargan-test		9.674		10.42		29.15

Notes: Coefficient estimates from ordinary least squares regressions at the country-year level. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. The dependent variable is the relative annualized decadal growth of real GDP per capita, compared to the growth in the US. Relative income is the relative real GDP per capita from the initial year of the decade (US's real GDP per capita at the same year equals 1). Average technology readiness in the regression represents the average ranking for technology readiness. A higher number means a better ranking, and higher technology readiness. This variable is instrumented in column (2) (4) (6), by 2-dimensions of country specific attitudes, namely long-term orientation, and indulgence. First stage F-stat and Sargan test for over-identification are both reported. Regressions in all columns have the same sample to ease comparison. The coefficient estimates on constant are not reported to save space. Column (1) and (2) has no fixed effects, while column (3) and (4) is added with year fixed effects. In column (5) and (6), we added country fixed effect to replace the linear term of average technology readiness, in order to capture country specific characteristics in addition to technology readiness. The main variable of interest in all columns are the technology readiness, interacted with relative income from the initial year. This coefficient has been significant through all columns. Countries involved this regression are listed below.

Table A8. Technology and growth, OLS and IV (first principle component)

	Relative decadal growth					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Relative income	-0.0525***	-0.0315***	-0.0558***	-0.0534***	-0.0654***	0.0776***
	(0.00297)	(0.0104)	(0.00266)	(0.0101)	(0.00656)	(0.0261)
Relative income x Average technology readiness (-)	0.000691***	0.000380	0.000662***	0.000865***	0.00275***	0.00776***
	(0.0000756)	(0.000248)	(0.0000672)	(0.000236)	(0.000174)	(0.000900)
Average technology readiness (-)	0.000383***	0.000150	0.000407***	0.000386***		
	(0.0000262)	(0.000114)	(0.0000234)	(0.000111)		
Observations	2794	2794	2794	2794	2794	2794
Country fixed effect	-	-	-	-	yes	yes
Year fixed effect	-	-	yes	yes	yes	yes
R-square	0.201	0.151	0.382	0.380	0.555	0.416
First-stage F-stat		31.60		23.44		131.2

Notes: Coefficient estimates from ordinary least squares regressions at the country-year level. Standard errors are given in parentheses. * p<0.1, ** p<0.05, *** p<0.01. The dependent variable is the relative annualized decadal growth of real GDP per capita, compared to the growth in the US. Relative income is the relative real GDP per capita from the initial year of the decade (US's real GDP per capita at the same year equals 1). Average technology readiness in the regression represents the average ranking for technology readiness. A higher number means a better ranking, and higher technology readiness. This variable is instrumented in column (2) (4) (6), by the first principle component of the 6 dimensions of attitude. First stage F-stat is reported. Regressions in all columns have the same sample to ease comparison. The coefficient estimates on constant are not reported to save space. Column (1) and (2) has no fixed effects, while column (3) and (4) is added with year fixed effects. In column (5) and (6), we added country fixed effect to replace the linear term of average technology readiness, in order to capture country specific characteristics in addition to technology readiness. The main variable of interest in all columns are the technology readiness, interacted with relative income from the initial year. First stage regression of column (4) is provided in Appendix Table A6, and the weights in the first component is reported in Appendix Table A7.

Table A9. First stage regression of column (4) in Table A8

	(1) Average technology readiness (-)	(2) Relative income x Average technology readiness (-)
Attitude	-9.434*** (0.703)	2.189*** (0.237)
Attitude x Relative income	16.19*** (1.197)	-6.931*** (0.404)
Relative income	91.99*** (1.947)	-8.251*** (0.657)
Constant	-73.92*** (3.235)	-8.618*** (1.092)
Observations	2794	2794

Table A10. Principle Component of Attitude

	Principle Component
Power Distance	0.6
Individualism	-0.6
Masculinity	0.1
Uncertainty Avoidance	0.3
Long-term Orientation	0.2
Indulgence	-0.4