UNIVERSITY OF CENTRAL ASIA
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WORKING PAPER #47, 2018

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Abstract:
This paper examines the recent technological performance of Afghanistan, Kyrgyzstan and Tajikistan and identifies opportunities for their technological and industrial upgrading in the context of the current global technological trends. The manuscript develops a three-pronged industrial upgrading strategy centered on the application of information and communication technologies, along five core value chains based on the existing mining, energy and agricultural sectors of these economies and discusses various government policies in support of this modernization programme.

Keywords: technological modernization, industrial upgrading, information and communication technologies, development

JEL classification: O3, O4, P2.

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Abbreviations

ADB	Asian Development Bank
AKDN	Aga Khan Development Network
AKT	Afghanistan, Kyrgyzstan and Tajikistan
ATM	Automatic transfer machine
BB	Broadband
CAREN	Central Asian Research and Education Network
CASA	Central Asia — South Asia
EEU	Eurasian Economic Union
EGDI	E-Government Development Index
GATS	General Agreement on Trade and Services
GDP	Gross domestic product
GRI	Government research institution
GVC	Global value chain
FDI	Foreign direct investment
ICT	Information and communication technologies
IIoT	Industrial Internet of Things
ITU	International Telecommunication Union
IXP	Internet Exchange Point
LDC	Least developed country
Mbps	Megabit per second
MCIT	Ministry of Communication, Information and Technology
MIT	Massachusetts Institute of Technology
MVA	Manufacturing value-added
NATO	North Atlantic Treaty Organization
PPP	Purchasing power parity
SME	Small and medium enterprises
STEM	Science, technology, engineering and math
R&D	Research and development
REE	Rare earth element
TALCO	Tajik Aluminium Company
TNC	Transnational corporation
TFP	Total factor productivity
TRIM	Trade related investment measures
UN	United Nations
UNCTAD	United Nations Commission on Trade and Development
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic Social Commission for Asia & the Pacifics
UNESCO	United Nations Education & Science Commission
USAID	United States Agency for International Development
WEF	World Economic Forum
WIPO	World intellectual Property Organization
WTO	World Trade Organization

Executive Summary

This monograph analyses the recent technological performance of Afghanistan, Kyrgyzstan and Tajikistan (AKT) and identifies opportunities for their technological and industrial upgrading in the context of the current global technological trends. More specifically, the manuscript develops a three-pronged technological and industrial upgrading strategy along five core value chains based on the existing mining, energy and agricultural sectors of these economies and discusses various government policies in support of such technological modernization.

Following a decade of economic expansion driven by the global commodity boom of the early 2000s, growth has stalled in all three countries. The external growth drivers – the global commodity demand and worker remittances – are not what they once were. AKT do not export in any significant way, nor produce high value-added manufacturing products. The manufacturing value-added per capita is as low as US$64 in Afghanistan, US$160 in Kyrgyzstan and US$101 in Tajikistan. Instead, their exports are concentrated in a few primary commodities, like gold, aluminium, raw cotton and fruits. Consequently, AKT have one of the lowest export diversification and sophistication indices in the world, pointing to their poor technological performance. More seriously, the low diversification and heavy reliance of the AKT economies on a few primary commodities make them vulnerable to commodity price and demand volatility, thereby jeopardizing their long-term sustained growth.

Against this backdrop, it is evident that Afghanistan, Kyrgyzstan and Tajikistan will not be able to achieve long-term balanced development without rectifying the severe structural economic imbalances and producing more diverse and sophisticated products, which are in turn impossible without radical technological upgrading of their industries and agriculture.

In this light, the pervasive penetration of information and communication technologies (ICTs) and the concomitant shift towards digitalization of all economic and social spheres open up unique opportunities for Afghanistan, Kyrgyzstan and Tajikistan. First, ICTs can help these countries overcome their geographic remoteness and integrate into global markets. In particular, ICTs can enable AKT to insert their firms into global value chains and benefit from technology and knowledge transfers within these chains. Second, AKT can take advantage of the increasing global market segmentation and product differentiation – hallmarks of the current technological cycle – by producing higher-margin, differentiated goods for niche markets, e.g. boutique metals, organic food and eco-tourism, instead of competing in low-margin, standardized commodities markets. Third, by capitalizing on their geographic centrality and developing their ICT sectors, Afghanistan, Kyrgyzstan and Tajikistan can transform themselves into a regional communication and transportation hub.

As far as industrial modernization is concerned, the paper proposes a three-pronged strategy. First, AKT should upgrade their existing industries with the aid of ICT and other edge technologies. The upgrading can take the form of new products (e.g. new crops and structured metals) or new processes (e.g. automation of production and logistics). Second, AKT should climb up the technological ladder by establishing new, higher-value sectors, i.e. by undergoing intersectoral upgrading. Such upgrading would allow AKT to diversify their presently unbalanced industrial structure. New strategic sectors should be chosen so as to build complete, vertically integrated value chains based on the countries' existing extractive industries and comparative advantages. Moreover, these industries should generate strong multiplier effects through backward and forward linkages with other industries. Finally, AKT should sow the seeds of future hi-tech industries, e.g. bio- and nano-technologies, by investing in R&D in knowledge-intensive sectors, e.g. new materials, advanced machinery and renewable energy, and by expanding and enhancing education at all levels.

The monograph also develops a potential industrial structure that is consistent with the above strategy and fleshes out each individual component. In a nutshell, the proposed industrial structure is organized along five core value chains underpinned by the existing sectors: mining, agriculture and energy. Built upon mining and agriculture are the associated processing industries: ore processing and metallurgy grounded in mining; and food processing and textiles rooted in agriculture. These processing sectors, which used to exist or indeed still exist in Tajikistan and Kyrgyzstan, need to be revived, expanded and modernized. As for Afghanistan, processing industries need to be built from scratch, jointly with the related extractive industries as integrated value chains.

The next level of the value chains – mid-tech industries – includes chemical and machine-building sectors. These sectors would serve as a foundation for future high-tech industries such as nano-materials, robotics and biotech. Lastly, the energy value chain comprises: (i) electricity generation based on hydropower, (ii) a renewable energy industry (e.g. solar, windpower, biomass), and (iii) an energy storage and distribution industry based on modern digital technologies. The paper also pins down specific technologies and key reforms required to carry out industrial upgrading along the agricultural, mining and manufacturing value chains.

Finally, the paper provides a comprehensive discussion of government policies in support of the proposed technological and industrial modernization programme. These policies are grouped into two broad categories: vertical or industrial policies, and horizontal policies. Industrial policies include those concerning foreign direct investment and technology transfer, financing mechanisms, infant industry protection, industrial clusters and zones, local content policies, as well as the choice of priority sectors, production scale and ownership forms for enterprises. The second group of horizontal policies aims at the creation of a general conducive environment for technological development and encompasses infrastructure development, human resources development, R&D promotion and SME support.

Whatever there be of progress in life comes

not through adaptation but through daring.

Henry Miller

1. Introduction

The last few decades have seen unprecedented proliferation and penetration of information and communication technologies (ICT), and their spin-off digital technologies, into all spheres of human life. Pervasive digitalization is fundamentally transforming people's lives and business processes in virtually all economic sectors, disrupting some existing technologies and putting large numbers of people out of jobs.

All these developments have led many scholars and practitioners, like Klaus Schwab, Chairman of the World Economic Forum[1] (WEF), to the notion of the Fourth Industrial Revolution – a profound technological paradigm shift – characterized by the fusion of the physical and biological worlds on the basis of digital technologies. The new technological paradigm has the potential to dramatically improve the efficiency of businesses and individuals around the globe by connecting them through extensive digital networks. It also holds promise for developing countries to help them leapfrog into a new digital economy and achieve sustained and inclusive growth.

What challenges and opportunities does this technological paradigm shift present for Afghanistan, Kyrgyzstan and Tajikistan? Are they ready to face these challenges and to seize these opportunities? How can these countries harness ICTs and other emergent technologies to propel their development? What kind of policies can their governments pursue to promote technological and industrial upgrading in their economies?

This monograph attempts to shed light on these questions by examining the recent global technological trends, and in that context, the technological performance and capability of Afghanistan, Kyrgyzstan and Tajikistan (AKT) to absorb and deploy ICTs and other emerging technologies to further their development agendas. Based on this analysis, the paper then identifies and develops technological and industrial upgrading options for various economic sectors along with the required government interventions.

The findings of the paper paint a mixed picture of the technological performance of AKT. As may be expected, Afghanistan, Kyrgyzstan and Tajikistan are lagging behind most developing countries in their technological development. In 2016, Kyrgyzstan and Tajikistan ranked, respectively, 95th and 114th out of 139 countries in WEF's Global Technology Readiness Index. Their performance in the Global Innovation Index has similarly been subpar: Kyrgyzstan and Tajikistan are placed, respectively, 94th and 95th out of 124 countries. Meanwhile, Afghanistan is not ranked at all. The three decades of incessant war and insecurity have caused near-total economic collapse in Afghanistan, claiming the lives of millions of civilians, destroying infrastructure, and disrupting industrial and agricultural production. The devastating war has also set the country's technological development at least a century back.

Aside from the war and more generally, such poor technological performance can be attributed to the low capital accumulation (which includes investments into related technologies) and the severe structural imbalances in the AKT economies. Gross fixed capital formation as a percent of GDP is below the world average (23 percent) for Afghanistan and Tajikistan, and is slightly better, but still lacklustre, for Kyrgyzstan. The AKT imports of machinery and equipment, on average, account only for 3 percent of the countries' imports, or a minuscule one-tenth of the global average.

1 https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab

Furthermore, the AKT economies are narrowly specialized in primary commodity industries (precious and non-ferrous metals, raw cotton and agricultural products). The manufacturing value-added (MVA) per capita is as low as US$64 in Afghanistan, US$160 in Kyrgyzstan and US$101 in Tajikistan, far below the global average of US$1,689, reflecting the drastic deindustrialization of Kyrgyzstan and Tajikistan since the break-up of the Soviet Union. And even such modest manufacturing industries are centred on the production of low-technology products like semi-processed ore concentrates and construction materials, while mid- and hi-tech products make up only 5.7 and 2.3 percent of Kyrgyzstan's and Tajikistan's MVA, respectively.

Afghanistan, Kyrgyzstan and Tajikistan do not export in any significant way, nor produce high value-added manufacturing products. Instead, their exports are concentrated in a few primary commodities, like gold, aluminium, raw cotton and fruits. Consequently, they have one of the lowest export diversification and sophistication indices in the world, which again points to their poor technological performance. As is well known, diversification and sophistication of exports are a direct reflection of the level of productivity and technologies that exists in a country. Indeed, Kyrgyzstan and Tajikistan have experienced a sharp decline in total factor productivity, which measures technology's contribution to total national output, see Figure 8. More seriously, the low diversification and heavy reliance of the AKT economies on a few primary commodities make them extremely vulnerable to commodity price and demand volatility, thereby jeopardizing their long-term sustained growth.

As for more direct measures of technological advancement, gross expenditure on R&D in both Kyrgyzstan and Tajikistan constitutes a meagre 0.12 percent of their GDPs (20 times less than the global average of 2.3 percent); while no R&D data are available for Afghanistan. Patent applications are almost non-existent in Afghanistan, and their numbers are negligible in Kyrgyzstan and Tajikistan.

Nevertheless, not everything is as hopeless as it might look at first glance. Kyrgyzstan and Tajikistan enjoy relatively high levels of human capital, and in particular, technical and engineering personnel inherited from the Soviet Union, which would allow them to carry out technological modernization by mastering and adapting digital technologies, and in the long-run, by developing their own indigenous technologies. Afghanistan is catching up rapidly by expanding and improving education at all levels. As discussed in Section 2.2, Afghanistan has made significant strides in building its human capital over the past decade. In addition, it has a sizeable expatriate population of scientists and engineers who could be brought back home to jumpstart the country's technological modernization.

Moreover, a micro-level assessment of the technological performance of specific industries reveals some technological progress in the ICT and service sectors of the three countries. In particular, the Afghan telecom infrastructure (fibre optic backbone and microwave network) has expanded considerably over the last decade. Telecommunication is the most dynamically developing sector of the Afghan economy, generating more than 12 percent of the total government revenue and more than 14,000 direct and indirect jobs. The Kyrgyz telecom sector has also recorded relatively high growth, while growth in the Tajik telecom sector is hampered by the prohibitive transit prices and underdeveloped infrastructure.

Next, the mobile phone and mobile broadband penetration levels have surged in all three countries. As mobile broadband technologies are becoming the main mode of Internet access in developing countries, their increasing adoption by AKT's businesses and individuals stands to significantly boost Internet connectivity in these countries, and more importantly, to induce the development of mobile applications and other new, e.g. e-governance, e-commerce, e-learning and e-health, products on their basis.

Some important steps in this direction have been made in Afghanistan, where private telecom companies, e.g. Roshan, have launched mobile payment systems, which have not only revolutionized the Afghan financial and retail landscapes, but also curtailed corruption. There is also a number of ICT start-ups in Kyrgyzstan and Tajikistan, engaged in the design of desktop software and mobile apps, including apps for e-commerce, transport (e.g. e-aggregators), entertainment (e.g. games), and restaurant and catering services. In particular, the analysis of the Kyrgyz patent pool shows that the majority of patents occur in the service sector and involve software and databases for accounting, business processes (e.g. scheduling, budgeting, salary payment), education, healthcare and legal practice.

Furthermore, Kyrgyzstan and Tajikistan have recently made significant progress in increasing electric power generation from domestic hydro resources and, thus, in securing energy independence. Afghanistan is yet to follow their suit by building hydropower stations and tapping into its natural gas reserves. In the short-run, the current electricity deficit in Afghanistan is going to be partially met by electricity exports from Kyrgyzstan and Tajikistan via the CASA 1000 transmission lines.

Last, the investigation into the AKT industrial sectors exposes their poor technological development, or lack thereof. Most of the Kyrgyz and Tajik manufacturing plants fell into decay or fully disintegrated after the collapse of the Soviet Union. Only a few flagship plants – the Tajik Aluminium Company and the Tajik Cement Plant in Tajikistan, and Dastan Enterprise and the Mayli-Suu Electric Lamp Factory in Kyrgyzstan – have retained and upgraded their technologies. And Afghanistan's manufacturing sector is just beginning to shape up. Other notable exceptions are the Kyrgyz apparel industry, and the Tajik garment and textile industries, which not only have exceeded their pre-independence production levels, but have also managed to modernize their equipment and raise their productivity. As a result, this allowed them to carve out niches in the Russian and Kazakh markets.

Against this background, it is evident that Afghanistan, Kyrgyzstan and Tajikistan will not be able to sustain current growth rates and to achieve long-term balanced development without rectifying the severe structural economic imbalances and producing more diverse and sophisticated products, which are in turn impossible without radical technological upgrading of their industries and agriculture.

In this light, the current technological paradigm shift opens up unique opportunities for Afghanistan, Kyrgyzstan and Tajikistan. First, ICTs can help these countries overcome their geographic remoteness and integrate into global markets. In particular, ICTs can enable AKT to insert their firms into global value chains (GVC) and benefit from technology and knowledge transfers within these chains, by leveraging their cheap labour and energy resources.

Second, AKT can take advantage of the increasing global market segmentation and product differentiation – hallmarks of the current technological cycle – by producing high-margin, differentiated goods for niche markets, instead of competing in razor-edge-margin, standardized commodities markets, which is, *a priori,* a futile enterprise given AKT's remoteness and prohibitive transportation costs. For example, AKT can supply 'clean environment' products, e.g. organic food or eco-tourism. Further, they can manufacture 'boutique' metals (e.g. structured steel, aluminium) with new, modified properties, presently in high demand from the aerospace, precision instruments and consumer electronics industries.

Third, by capitalizing on their geographic centrality and by developing their ICT sectors, Afghanistan, Kyrgyzstan and Tajikistan can become a regional communication and transportation hub. AKT can serve as a land bridge between Europe and Asia if a web of new railways is laid down between China and Europe. Recent years have witnessed some positive developments in this respect, including the China-sponsored expansion of a network of railways throughout the region and the joint Indo-Iranian project on the construction of the Chabahar seaport, which would open up a new transit route and access to the Indian Ocean.

As far as industrial modernization is concerned, the paper suggests a three-pronged strategy. First, AKT should upgrade their existing industries with the aid of ICT and other edge technologies. The upgrading can take the form of new products (e.g. new crops and structured metals) or new processes (e.g. automation of production and logistics). Second, AKT should climb up the technological ladder by establishing new, higher-value sectors, i.e. by undergoing intersectoral upgrading. Such upgrading would allow AKT to diversify their presently unbalanced industrial structure. New strategic sectors should be chosen such as to build complete, vertically integrated value chains based on the countries' existing extractive industries and comparative advantages. Moreover, these industries should generate strong multiplier effects through backward and forward linkages with other industries. Finally, AKT should sow the seeds of future hi-tech industries, e.g. bio- and nano-technologies, by investing in R&D in knowledge-intensive sectors, e.g. new materials, advanced machinery, bio-technologies, medicine, energy, and by expanding and enhancing education at all levels.

The paper also develops a potential industrial structure that is consistent with the above strategy and fleshes out each individual component thereof. In a nutshell, the proposed industrial structure is organized along the five core value chains underpinned by the existing sectors: mining, agriculture and energy. Built upon these existing sectors are the associated processing industries: ore processing and metallurgy grounded in mining, and food processing and textiles based on agriculture. These processing sectors, which used to exist or indeed still exist in Tajikistan and Kyrgyzstan, need be revived, expanded and modernized. As for Afghanistan, processing industries need to be built from scratch, jointly with the related extractive industries as integrated value chains.

The next level – mid-tech industries – of the value chains includes chemical and machine-building sectors. These sectors would serve as a foundation for future, cutting-edge, high-tech industries such as nano-materials, robotics and biotech. Lastly, the energy value chain comprises: (i) electricity generation based on hydropower, (ii) a renewable energy industry (e.g. solar, windpower, biomass), and (iii) an energy storage and distribution industry based on modern digital technologies. The paper also pins down specific technologies and key reforms required to carry out industrial upgrading along the agricultural, mining and manufacturing value chains.

Finally, the paper provides a comprehensive discussion of government policies in support of the proposed technological and industrial modernization program. These policies are grouped into two broad categories: vertical or industrial policies, and horizontal policies. Industrial policies include those concerning foreign direct investment and technology transfer, financing mechanisms, infant industry protection, industrial clusters and zones, local content policies, as well as the choice of priority sectors, production scale and ownership forms for enterprises. The second group of horizontal policies aims at the creation of a general conducive environment for technological development and encompasses infrastructure development, human resources development, R&D promotion and SME support.

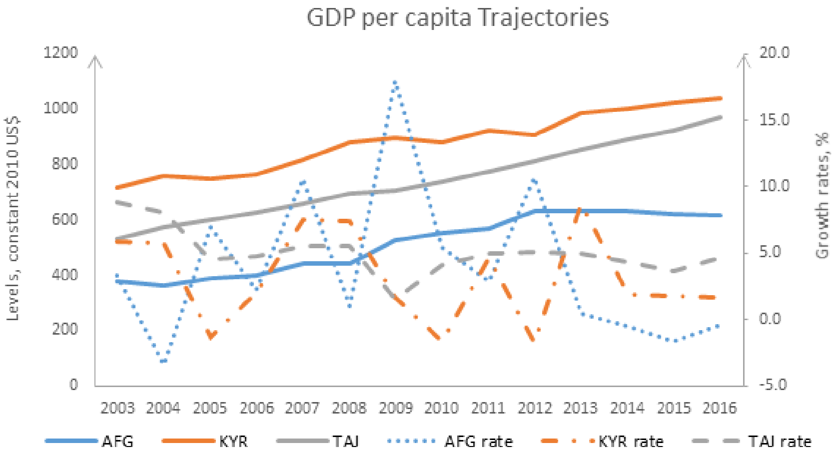
The rest of the paper is structured as follows. Section 2 examines the current state of the technological development of Afghanistan, Kyrgyzstan and Tajikistan. Section 3 develops a general conceptual framework to guide the subsequent discussion of possible technological paths for AKT. One such potential technological and industrial upgrading model is presented and elaborated upon in Section 4. Lastly, Section 5 explores various government policy options that can be pursued to implement technological and industrial modernization in the AKT economies.

2. Current State of the Technological Development

2.1. Economic Structure and Performance

Overall, Afghanistan, Kyrgyzstan and Tajikistan have seen steady GDP per capita growth since 2003. Afghanistan's real GDP per capita (Figure 1, solid blue line) has surged 64 percent, though from a low base, reaching US$618 in 2016. Growth was driven by post-crisis recovery, massive foreign aid injections, and US troop procurements. However, with the reduction of foreign aid and subsequent withdrawal of the US troops, GDP per capita growth rate has tumbled, slipping into the negative (-0.5 percentage points) territory in 2014 (Figure 1, dashed blue line). The total value of aid has fallen from an annual average of US$ 12.5 billion in 2009-2012 to US$ 8.8 billion in 2015.[2]

Figure 1. GDP per capita Trajectories, 2003-2016



Source: World Bank (2017). World Development Indicators

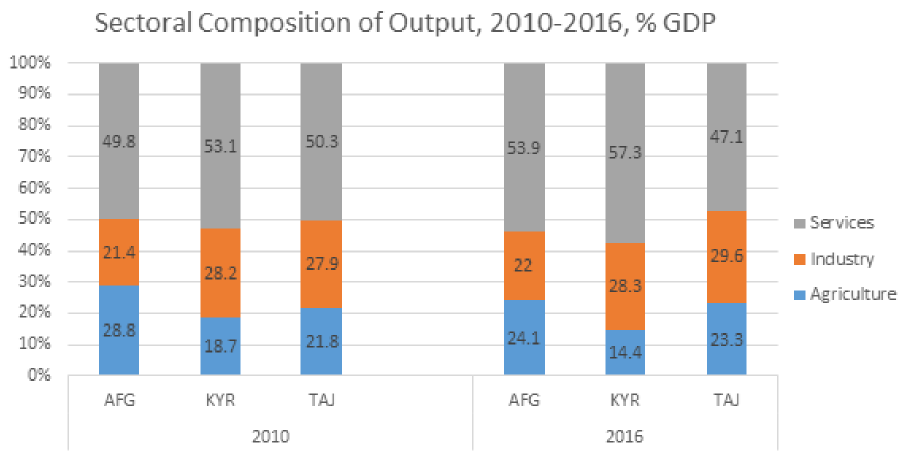
Next, growth in Kyrgyzstan and Tajikistan was fuelled by the global commodity price boom and the upsurge in remittances by migrant workers from Russia and Kazakhstan. Since the 2008 global financial crisis, growth has slowed down in both countries, fluctuating around 2.2 percent in Kyrgyzstan and around 4.2 percent in Tajikistan. Growth rates in Kyrgyzstan have been lower and more erratic than in Tajikistan.

Interestingly, once laggard, Tajikistan has recently outstripped Kyrgyzstan, exhibiting more robust and stable growth dynamics. Such progress can be attributed to the active industrial and infrastructural policies pursued lately by the Tajik government. Since the political crisis of 2010, Kyrgyzstan has in turn undergone frequent government changes, which has undermined the effectiveness of economic reforms.

In terms of structural composition, the AKT service sectors make up the largest shares of their output, while their industry's shares in GDP remain modest, within the 20 percent range, see Figure 2. Between 2010 and 2016, the output composition changed little in all three countries. Nonetheless, Tajik and Kyrgyz industries have recently shown some dynamism, registering higher growth rates (16 and 6 percent, respectively) than their agriculture and service sectors and thus becoming the largest contributors to GDP growth, see Table 1.

[2] World Bank (2017). Afghanistan Development Update

Figure 2. Sectoral Composition of GDP, 2010 and 2016



Source: ADB (2017). Key Indicators for Asia and the Pacific

In 2016, the industrial sector accounted for about 69 and 45 percent of GDP growth in Tajikistan and Kyrgyzstan, respectively. Agriculture was the second largest growth contributor in Tajikistan, and services – in Kyrgyzstan.

Table 1. Sectoral Contributions to GDP Growth, 2016

	Growth rate	Agriculture			Industry			Services		
		Growth rate	% GDP	Percent contri-bution to growth	Growth rate	% GDP	Percent contribu-tion	Growth rate	% GDP	Percent contri-bution to growth
Afghanistan	3.6	12.0	24.1	80.3	-1.9	22.0	-11.6	2.1	53.9	31.4
Kyrgyzstan	3.8	3.0	14.4	11.4	6.0	28.3	44.7	2.9	57.3	43.7
Tajikistan	6.9	5.9	23.3	19.9	16.0	29.6	68.6	1.7	47.1	11.6

Sources: Computations based on ADB (2017). Key Indicators for Asia and the Pacific; World Bank (2017). Word Development Indicators

In contrast, Afghanistan's industry contracted by 1.9% in 2016, pulling GDP growth down by almost 12 percent. Afghanistan's agriculture, which grew by 12 percent, was responsible for much (eighty percent) of the GDP growth, while the service sector recorded modest growth of two percent.

However, higher growth in the industrial sectors of Kyrgyzstan and Tajikistan is mainly driven by the expansion of their mining industries, rather than manufacturing, and in particular, by the rising exports of precious and non-ferrous metals such as gold, aluminium, lead and zinc, see Table 2. Indeed, in 2016, Tajikistan's exports were led by raw aluminium (13.2% of total exports), followed by lead ore (6.3% of total exports) and zinc ore (4.2% of total exports), while Kyrgyzstan's exports were dominated by gold (21.3% of total exports), followed by other ores, such as antimony and mercury (2.3% of total exports), and refined petroleum (2.1% of total exports).

Afghanistan's export basket has a somewhat different structure, and is more concentrated in agricultural products such as grapes, nuts, vegetables and raw cotton rather than mineral resources. However, starting from 2016, there has been a shift in the Afghan export composition towards gold and mineral fuels, reflecting the recent commencement of mining operations. Indeed, the 2016 exports were led by gold, but the second and third positions were still held by grapes and vegetable-related products.

Table 2. Export Volumes and Structure, 2016

Country	Exports, billion US$	GDP, billion US$	Exports% GDP	Share of top three items, %	Top three export products
Afghanistan	2.78	19.47	14.3	36.9	gold, grapes, unspecified vegetable saps[3]
Kyrgyzstan	3.73	6.55	56.9	25.7	gold, other ores, refined petroleum
Tajikistan	1.49	6.95	21.4	23.7	aluminium, lead, zinc

Source: MIT Observatory of Economic Complexity, https://atlas.media.mit.edu/en

Table 2 reveals the heavy reliance of Afghanistan, Kyrgyzstan and Tajikistan on a few primary commodities. Although the share of the top-two commodities – aluminium and cotton – in Tajikistan's exports has declined from 65 percent in 2013 to 34.4 percent in 2016 and its Hirschman Herfindahl export concentration index has improved, Tajikistan's export diversification index however remains quite poor hovering around 0.8,[4] see Figure 3. Kyrgyzstan does not score well on both indices either, depending heavily on exports of gold from one single deposit, Kumtor. Afghanistan is the worst performer with a product diversification index of 0.83, which is quite close to diamond-dependent Botswana's index of 0.91. In addition, the Afghan exports are also highly concentrated in terms of destinations, with the top-three export partners (Pakistan, Iran, and Russia) accounting for 70% of total exports in 2016.

Such low diversification of the AKT economies and their heavy reliance on a few primary commodities make them extremely vulnerable to commodity prices volatility and abrupt changes in global demand. In fact, Kyrgyzstan and Tajikistan have recently experienced significant volatility in their exports, emanating from the global crisis and the knock-on effects of sluggish growth in advanced countries.

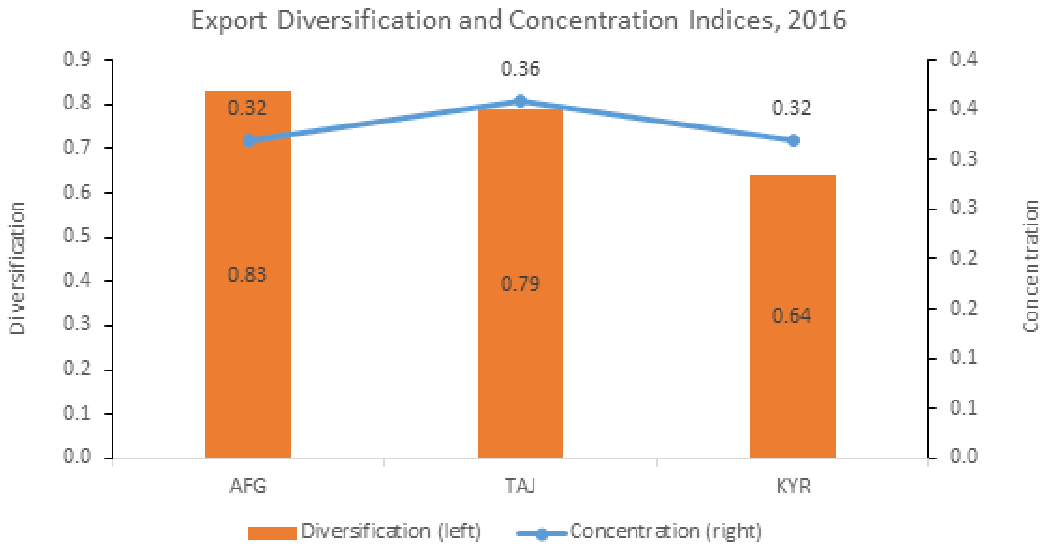
Meanwhile, the countries also do not display much sophistication in their exports. The Hausmann-Klinger EXPY (Hausmann & Klinger, 2006) sophistication index stands at 9,521 and 12,134 for Kyrgyzstan and Tajikistan, respectively.[5] In comparison, Vietnam had a sophistication index of 18,785 in 2015, ranking 71st in the world.

3 Excludes illegal opium sales, which is the leading export product.

4 Export diversification index ranges from 0 to 1, with the higher indices indicating low diversification. Conversely, the higher the HH export concentration index, the more concentrated are country's exports.

5 Higher values of EXPY correspond to greater sophistication. Switzerland has the world's highest EXPY index of 37,287 (2015). Sources: ADB (2010). Structural Transformation in the Kyrgyz Republic: Engineering Future Paths of Capability Accumulation; ADB (2014). Tajikistan: Promoting Export Diversification and Growth. Index is unavailable for Afghanistan.

Figure 3. Export Diversification and Concentration Indices, 2016



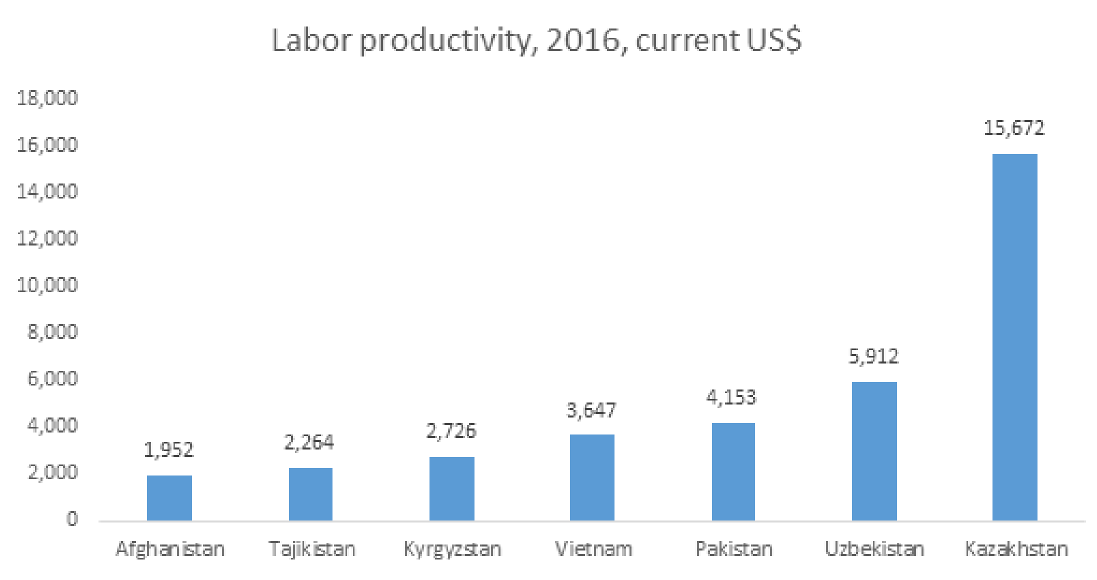
Source: UNCTAD (2017). Handbook of Statistics

The EXPY index measures a country's product and technological sophistication by comparing its exports with those of high income countries. The composition and sophistication of exports patently reflect the level of productivity and technologies that exists in a country. Higher levels of export sophistication are linked to technology-intensive products, and technological sophistication is in turn associated with advanced manufacturing. Yet, Afghanistan, Kyrgyzstan and Tajikistan do not export in any significant way, nor produce high value-added manufacturing products. Consequently, they lag behind their regional neighbours in labour productivity, see Figure 4, with most of their labour force being concentrated in the low-value, low technology-intensive agricultural sector (79 percent in Afghanistan, 48 percent in Kyrgyzstan, and 43 percent in Tajikistan).

Finally, Kyrgyzstan and Tajikistan are among the world's biggest exporters of labour. In 2016, worker remittances accounted for 31 percent of Kyrgyzstan's GDP and 26 percent of Tajikistan's GDP. Worker remittances to Afghanistan are negligible, floating around 1.5-2 percent of GDP, see Figure 5. The figure uncovers an interesting downward trend in Tajikistan's worker remittance: the share of remittances in GDP has diminished twofold from 50 percent of GDP in 2013 to 26 percent in 2016; the remittances have also declined in absolute terms from US$4.2 billion to US$1.8 billion over the same period. In contrast, remittances to Kyrgyzstan have remained more or less stable at around 30 percent of GDP, and currently exceed (both in absolute and relative terms) those of Tajikistan. Yet, given the pessimistic economic forecasts for Russia and Kazakhstan, remittances to Kyrgyzstan are likely to dwindle in the future.

To sum up, economic growth has stalled in Afghanistan, Kyrgyzstan and Tajikistan; the external growth drivers – the commodity price boom and remittances – are not what they once were. The countries are heavily dependent on exports of a few primary commodities, which render their long-term growth prospects precarious. To escape the commodity trap, Afghanistan, Kyrgyzstan and Tajikistan need to identify and mobilize internal sources of long-term sustained growth by rectifying the severe structural imbalances and producing more diverse and sophisticated products. And all these goals are unattainable without commensurate development of the countries' technological capabilities – the issue we investigate in the following sections.

Figure 4. Labour Productivity (as GDP per employee), 2016, current US$



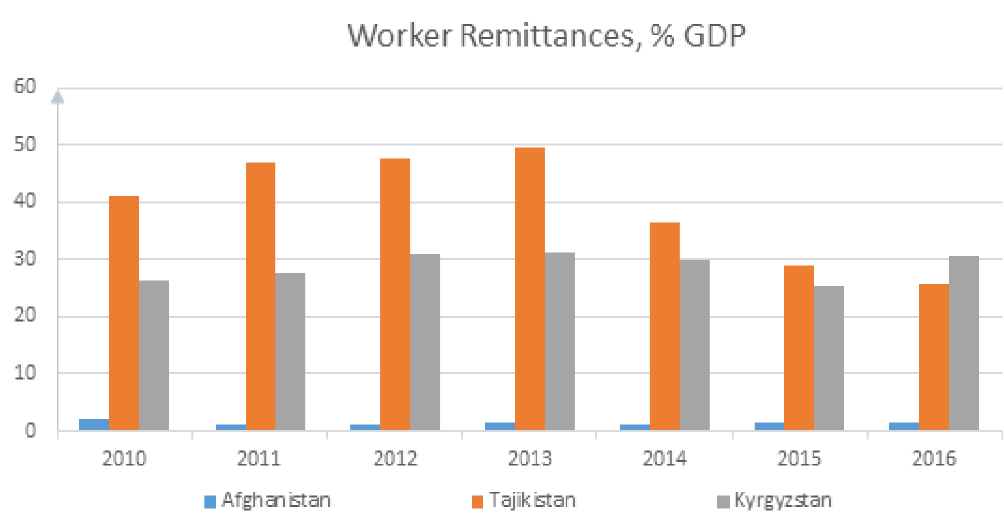
Source: World Bank (2017). World Development Indicators

2.2. Macro-level Technological Performance

This section reviews the overall technological performance of Afghanistan, Kyrgyzstan and Tajikistan at the macro-level. The subsequent sections discuss the technological advances (or lack thereof) in specific sectors, i.e. at the micro-level.

Generally, measuring the technological performance of a given nation is fraught with a number of methodological and practical difficulties. Technological development results from the intricate interplay between a nation's capital stock, labour force and technological capabilities. While the contents of the first two components are more or less delineated and understood, the last ingredient – technological capabilities – is elusive, and yet essential, without which machinery and workforce are not fully productive, just as a ship and sailors without a captain steering them.

Figure 5. Dynamics of Worker Remittances, % GDP



Source: ADB (2017). Key Indicators for Asia and the Pacific

National technological capabilities are a complex amalgam of a country's scientific, technical and organizational infrastructure, knowledge and skills that enable the creation/absorption and the deployment of technologies. On the methodological side, technological capabilities do not lend themselves to direct and precise measurement unlike a country's physical capital stock or workforce. Proxies such as technical and research personnel, patents and inventions, R&D expenditures and other activities provide an indirect and incomplete characterization of national technological capacity. In the case of developing countries, this problem is compounded by practical difficulties stemming either from the absence of such activities or the lack of systematic data collection on them.

With these caveats in mind, let us look at a snapshot of the technological state of the AKT economies presented in Table 3. The proxy indicators are grouped into three categories: physical capital, human capital and technology.

Table 3. Selected Technological Development Indicators

	Afghanistan	Kyrgyzstan	Tajikistan	Global Average
Physical Capital				
Gross fixed capital formation in 2016, billion current US$ (as % GDP)	3.45 (17.71%)	2.25 (32.48%)	1.20 (14.1%)[6]	85.86 (23.19%)
Gross domestic savings in 2016 (as % GDP)	-24.4	-1.8	-30.0[6]	24.57
FDI net inflows in 2016, billion current US$ (as % GDP)	0.099 (0.51%)	0.466 (7.12%)	0.344 (4.95%)	10.70 (3.05%)
Capital goods imports in 2014, billion current US$ (as % imports)	0.029 (3.25%)	0.034 (2.68%)	0.022 (2.81%)	24.92 (30.24%)
Manufacturing value-added in 2016, current US$ per capita (as % GDP)	64 (11.82%)	160 (16.64%)	101(11.19%)[6]	1,689 (16.62%)[7]

Human Capital				
Total labour force in 2017, million (as % total population)	10.94 (31%)	2.59 (43%)	3.42 (38%)	19.50 (46%)
Secondary education enrolment ratio in 2016	55.11	97.57	87.44[7]	76.43
Tertiary education enrolment ratio in 2014	8.48	46.27	24.51	35.29
Science & engineering graduates in 2014 (as % of tertiary graduates)	n.a.	18.28[6]	28.07	n.a.
Technical & vocational students in 2017, headcount	21,809	61,405	15,038[7]	273,041
Government education expenditure in 2015 (as % total government expenditure)	12.51	16.27	16.44	13.97
Government expenditure per tertiary student in 2014, PPP US$	795.01	187.19	557.59	n.a.

Technology and Innovation				
Patent applications, 2016	8	138	16	13,396
R&D expenditure in 2015, % GDP of which % in engineering & technology	n.a. n.a.	0.121 20%	0.120 8%	2.228 n.a.
R&D expenditure per capita, 2015, PPP US$	n.a.	4.17	3.09	191[6]
Researchers per million people, 2015, of which % in: engineering & technology natural sciences medical sciences	n.a.	579 13.80 23.07 11.01	291 4.05 24.81 15.93	1,151

6 These figures are for 2013.

7 These figures are for 2015.

Sources: World Bank; Asian Development Bank; UNESCO Institute of Statistics; WIPO Statistics

By and large, AKT's investments in fixed capital are subpar. Gross fixed capital formation, i.e. domestic investment into plants, machinery and buildings, as a percent of GDP in Afghanistan and Tajikistan are below the world average of 23 percent. Gross fixed capital formation is somewhat better, but still lacklustre, for Kyrgyzstan. In comparison, China's fixed capital investments have averaged 43 percent of GDP over the last decade.

The AKT gross domestic savings even slid into negative territory in 2016 due to excessive government spending. The low levels of domestic investment in capital stock are also mirrored by the capital goods import statistics: the AKT imports of machinery and equipment, on average, account only for 3 percent of the countries' imports, or a meagre one-tenth of the global average. Needless to say, foreign technologies come together with machinery and capital goods, and yet the countries are not even adequately replacing their worn-out capital stock, let alone purchasing new advanced machinery and equipment.

The inflows of foreign direct investments (FDI), which could have substituted for the scant domestic capital investment, are also scarce. FDI is not only a source of capital but is also one of the leading channels of technology and knowledge transfer to developing countries. Foreign investors are wary of the continued insecurity in Afghanistan, while inadequate property rights protection and corruption seem to be the main deterrents in Kyrgyzstan and Tajikistan.

Last, the extent of capital- and technology-intensive manufacturing also reflects the technological sophistication of countries since most technological innovations originate and diffuse from the manufacturing sector. Sadly, AKT are faring poorly in this dimension, too: manufacturing value-added (MVA) per capita is as low as US$64 in Afghanistan, US$160 in Kyrgyzstan and US$101 in Tajikistan, paling in comparison with other developing countries, e.g. Vietnam's MVA is US$308 per capita.

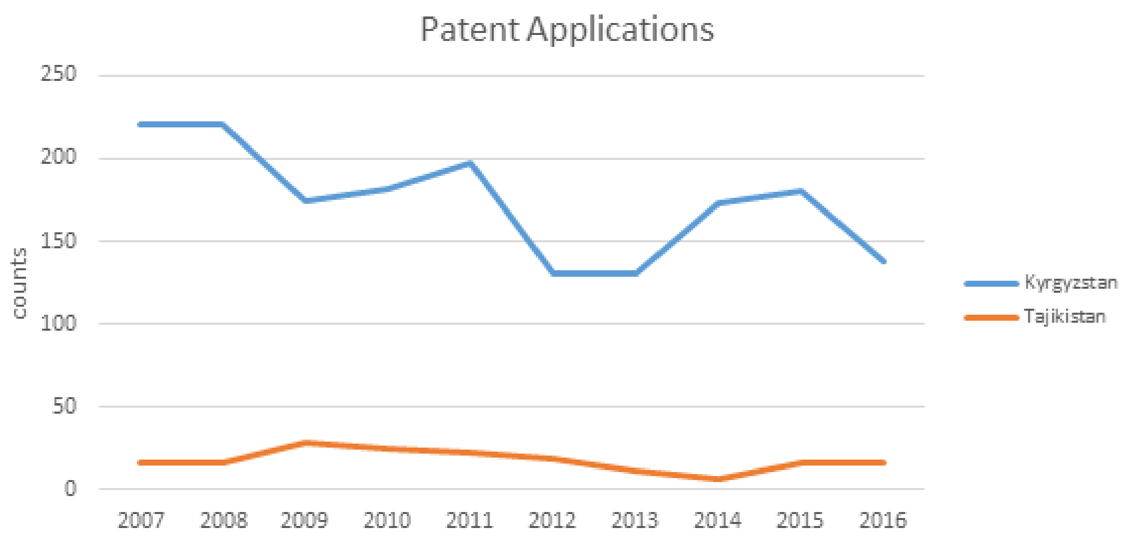
Turning to human capital, the general levels of education in Kyrgyzstan and Tajikistan are above the world average; both countries enjoy high secondary and tertiary enrolment. However, the quality and composition of their secondary and tertiary education seem to be inadequate to enable rapid technological advancement. And although science, technology, engineering, and math (STEM) graduates make up relatively sizable shares of the total pools of tertiary graduates, their absolute numbers are quite modest, and together with a few technical and vocational school graduates, they are insufficient to meet the needs of the AKT industries, see a more detailed discussion in Section 5.2.2.

Clearly, the situation is far worse in Afghanistan, which recorded 55 and 8.5 percent, respectively, secondary and tertiary enrolment rates in 2014, and suffers from one of the lowest literacy rates in the world. That being said, these figures do not do justice to the Afghan education system, which has made impressive progress since the Taliban era. The Afghan government has been making considerable efforts to expand education, by channelling both external aid and its own resources to the sector. The number of primary school students has soared from 770,000 in 2001 to more than 6 million 2016; meanwhile the number of high school graduates and the number of public university enrolments have both increased 30-fold since 2002. Moreover, the Afghan government is currently among the world's top spenders on tertiary education, with US$795 (in PPP terms) per tertiary student. In contrast, government spending on education has declined in Kyrgyzstan and Tajikistan, partly due to the growing private education segment and partly due to simple neglect. For instance, the Kyrgyz government spending per tertiary student has plunged from around US$550 in 2013 to US$187 in 2014.

Finally, the technology and innovation indicators in Table 3 paint a rather gloomy picture for all three countries. Patent applications are almost non-existent in Afghanistan, and their numbers are negligible (136 and 16 in 2016, respectively) in Kyrgyzstan and Tajikistan, suggesting that a great deal of innovations may go unpatented due to inventors' scepticism concerning intellectual property protection. Intellectual property right enforcement remains a huge problem in these countries. The number of patent applications has been stagnant in both countries since 2007, hovering around 170 applications per year in Kyrgyzstan, and around 17 – in Tajikistan, see Figure 6.

Analysis of the content of the patent pool in Kyrgyzstan, see Figure 7, reveals that the majority of patents occur in the service sector, and involve software and databases for accounting, business processes (e.g. scheduling, budgeting, salary payment), education, healthcare and legal practice.

Figure 6. Patent Applications in Kyrgyzstan and Tajikistan



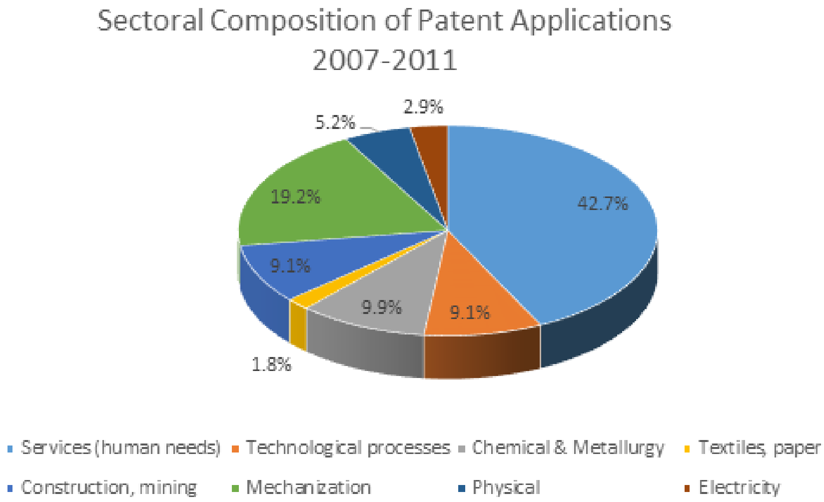
Source: WIPO Statistical Database

The second and third largest categories (mechanization, chemical and metallurgy) mainly comprise automated control systems for irrigation and mining. Since 1993, the number of granted patents for software has reached 492, and for databases – 40, thereby bringing the total number of ICT patents to 532. The number of granted patents for selected crops and animal varieties stands at 52. Unfortunately, no information on the sectoral composition of the Tajik patents is available.

Going back to Table 3, gross expenditure on R&D in both Kyrgyzstan and Tajikistan constitutes 0.12 percent of their GDPs (20 times less than the global average of 2.3 percent) or, equivalently, US$4.17 and US$3.09 (in PPP terms) per capita for, respectively, Kyrgyzstan and Tajikistan, while the world spends about US$191 (in PPP terms) per capita. In addition, only tiny portions of the already miniscule R&D expenditure are devoted to engineering and technology: 20 percent in Kyrgyzstan, and 8 percent in Tajikistan. At the same time, there seem to exist relatively large pools of researchers, inherited from the Soviet Union, in virtually all fields who could potentially spearhead R&D in these two countries, see Table 3. As for Afghanistan, it has a sizeable expatriate population of scientists and engineers who could be brought back home to help launch the country's technological modernization.

Another widely used measure of national technological capability is total factor productivity (TFP). Roughly, it is the portion of total output not explained by the amount of the capital and labour inputs used in the aggregate production, and, therefore, is equivalent to the technology's contribution to total national output. As such, TFP measures how efficiently and intensely the capital and labour inputs are utilized in production.

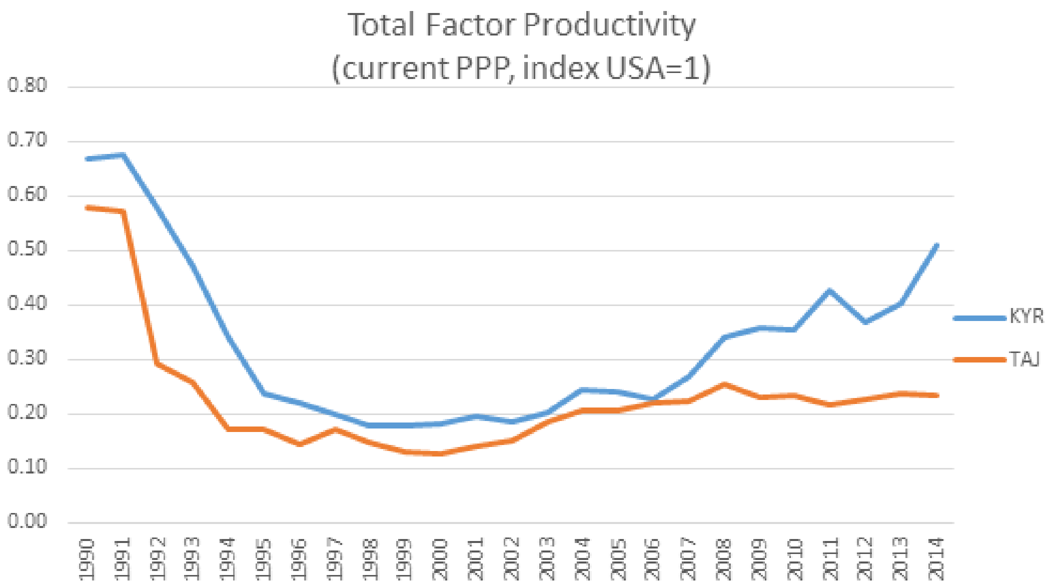
Figure 7. Sectoral Distribution of Patent Applications in Kyrgyzstan



Source: Kyrgyz Patent Office (2011). Analytical Report

Figure 8 depicts TFP paths of Kyrgyzstan and Tajikistan for the period 1990-2014. As evident from the figure, the countries experienced a sharp decline in TFP, and hence a decline in technological prowess, after the collapse of the Soviet Union due to the drastic structural transformation from technology-intensive sectors, e.g. manufacturing, to labour-intensive sectors, e.g. agriculture and mining. TFP hit its nadir in 2000 and thereafter has slowly recovered only to 76 percent and 41 percent of its pre-independence levels in Kyrgyzstan, and Tajikistan, respectively.

Figure 8. Total Factor Productivity in Kyrgyzstan and Tajikistan



Sources: University of Groningen, Federal Reserve Bank of Saint Louis

Against this backdrop, the low rankings of AKT in terms of technologies and innovation should come as no surprise, see Table 4. The first of these indicators – Global Innovation Index – measures countries' innovation performance, calculated as a weighted average of 81 basic indicators measuring human capital, research capacity, quality of institutions and infrastructure, market and business sophistication, some of which are already reported in Table 3. In this index, Kyrgyzstan and Tajikistan rank, respectively, 94 and 95 out of 127 countries; Afghanistan is not ranked. Similarly, Kyrgyzstan and Tajikistan perform poorly in the Global Technology Readiness Index, which gauges specifically the capacity of countries to leverage information and communication technologies to further their economic development. A detailed assessment of the AKT's ICT sectors is given in Section 2.3.

Table 4. Global Technology Indices and Rankings

	Global Innovation Index Rank, 2017 (out of 127)	Global Technology Readiness Index Rank, 2016 (out of 139)	Global Competitiveness Index Rank, 2017 (out of 137)
Afghanistan	n.a.	n.a.	n.a.
Kyrgyzstan	94	95	102
Tajikistan	95	114	79

Sources: 1. WIPO, Cornell University, INSEAD. Global Innovation Index 2017; 2. WEF, INSEAD, Cornell University. Global Innovation Technology Report 2016; 3. WEF. Global Competitiveness Report 2017-2018.

Lastly and somewhat unexpectedly, Tajikistan has made notable progress in the Global Competitiveness Index, at 79th place, above the likes of Brazil, Argentina and Ukraine, whereas Kyrgyzstan is trailing way behind, at 102nd place. Tajikistan's remarkable performance is largely due to the improvements made in institutional quality and labour market efficiency. The Global Competitiveness index is a more comprehensive indicator built upon 12 pillars, including (but not limited to) technology and innovation, which are both nowadays driven by advances in ICT – the theme we take up in the next section.

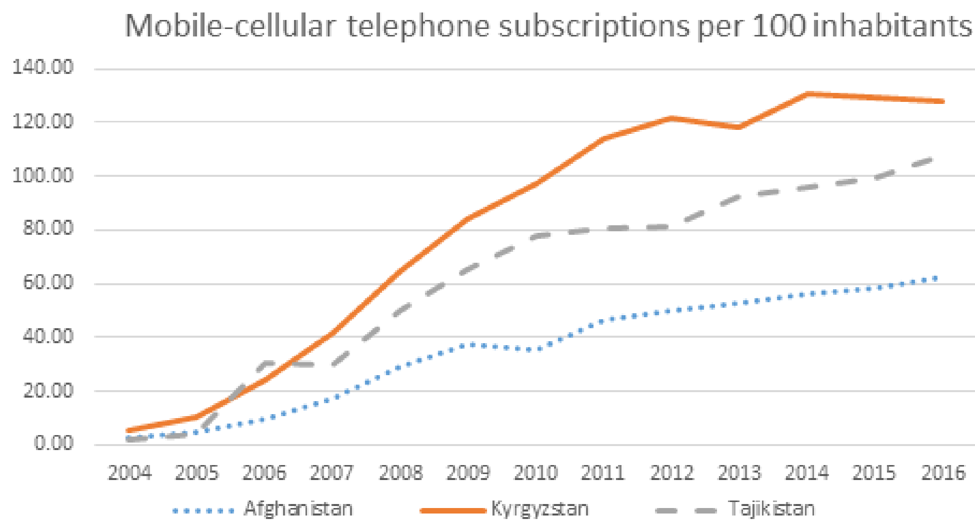
2.3. ICT Sector

As ICT is emerging as the key, general-purpose technology used as an operational platform by all other sectors, we begin our micro-level review with the AKT telecommunication sectors and Internet connectivity.

2.3.1. Mobile Phone Penetration

Mobile phones have come to replace traditional landline phones as the principal voice communication technology. Moreover, with the advent of 3G broadband transmission, mobile phones are increasingly turning into the predominant means of Internet access in developing countries, where fixed-line Internet connection remains largely unaffordable.

Figure 9. Mobile Phone Penetration, 2004-2016



Source: ITU (2017). World Telecommunications/ICT Indicators Database

Spurred by declining smartphone prices and expanding cellular coverage, the number of mobile subscriptions in AKT has risen dramatically since 2004. Specifically, the number of subscriptions in Afghanistan has soared from 2.5 per 100 inhabitants in 2004 to 62.34 per 100 inhabitants in 2016. Kyrgyzstan and Tajikistan have also witnessed a drastic rise in mobile subscriptions over the same period: from 5.23 to 127.84 per hundred inhabitants in Kyrgyzstan, and 2.01 to 107.6 per hundred inhabitants in Tajikistan, see Figure 9.

The Afghan mobile customer base is mainly divided between five[8] major mobile network operators – Aftel, AWCC, Roshan (whose majority stake is owned by the Aga Khan Fund for Economic Development), MTN and Etisalat –, all providing 3G services with geographic coverage for more than 90% of the population. AWCC, Roshan and Etisalat commenced 4G/LTE services in 2017, while Etisalat is set to launch its 4G services in the first quarter of 2018. The Kyrgyz mobile market is shared by three major operators – Beeline, Megaphone and O! – providing 4G services in urban areas, and 3G/2G services in rural areas. Similarly, the Tajik mobile market is fairly competitive and represented by six operators – Tcell, Babilon-Mobile, MegaFon, Beeline, TK-mobile and Tajiktelecom Mobile – offering 4G/3G services in the main metro-areas of Dushanbe, Khujand, Qurghonteppa and Kulob.

The ITU figures in Figure 9 count the number of unique SIM cards rather than unique users, so they may, in a sense, overstate the actual uptake of mobile-cellular technology. Yet the overall picture is quite clear: mobile-cellular penetration seems to have reached its saturation points in Kyrgyzstan and Tajikistan, while there is still room for growth in Afghanistan. This has important ramifications: mobile-cellular technology has become a ubiquitous infrastructural technology in AKT that can serve as a principal Internet access mechanism and, thus, a foundation for various sectors of a digital economy.

2.3.2. Internet Penetration

Unlike mobile penetration and despite steady growth over the last decade, Internet penetration remains limited (and below the regional and global averages), with only 11, 35 and 21 percent of the population enjoying Internet access, respectively, in Afghanistan, Kyrgyzstan and Tajikistan,

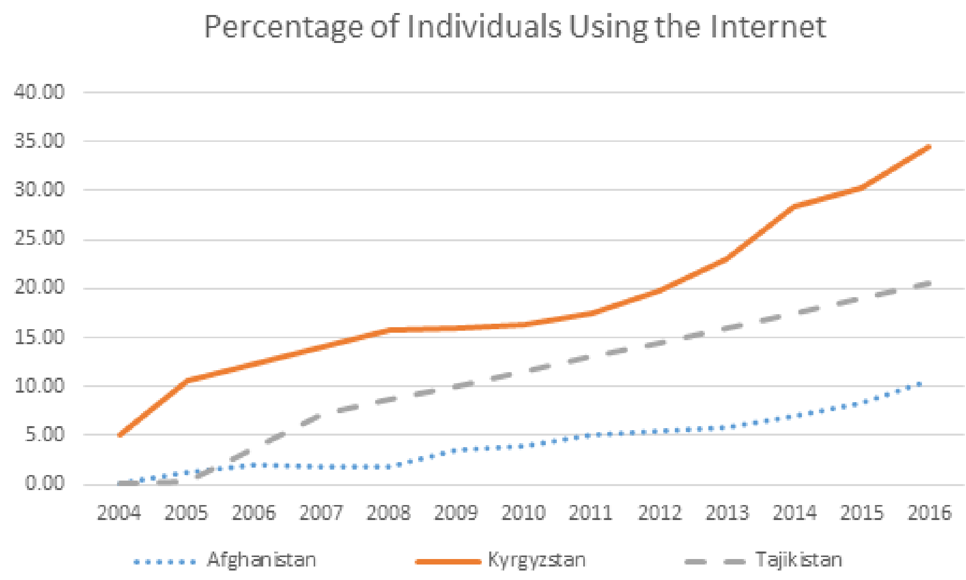
[8] There are other smaller operators in the Afghan mobile market. Given the firms' shrinking revenues, there are currently plans to consolidate the Afghan mobile market.

see Figure 10. Such low access rates can be explained both by supply- and demand-side factors: high costs and poor infrastructure, on the supply side, and limited digital skills and content relevance, on the demand side.

Broadband (or wide-frequency-range transmission), carried by various media such as optical fibre, coaxial cable and radio, is presently the main transmission technology for high-speed Internet. Broadband comes in two forms: fixed-line broadband and mobile broadband. Satellite-based Internet is prohibitively expensive and used primarily by large corporate customers and governments as a back-up, emergency line.

Being landlocked, all three countries have no direct access to international submarine broadband cables and depend on their neighbours for Internet transit, thus facing steep transit costs. The monthly cost of transit is as high as US$30-100 per Mbps/month in Kyrgyzstan, and about US$100 per Mbps/month in Tajikistan,[9] both of which access Internet mainly via Kazakhstan. Afghanistan has better transit options and shorter routes (via Pakistan, Iran, Turkmenistan, Uzbekistan and Tajikistan) and, therefore, pays less, about US$35 per Mbps/month.[10]

Figure 10. Internet Penetration, 2004-2016



Source: ITU (2017). World Telecommunications/ICT Indicators Database

The broadband providers further pass the high international transit costs onto their customers. According to Terabit Consulting, in 2014, the prices of fixed and mobile broadband amounted to, respectively, 5.6% and 2.2% of monthly per capita income (in PPP terms) in Kyrgyzstan, 64.9% and 26.4% in Tajikistan, and 123.6% and 42.2% in Afghanistan. Clearly, fixed broadband Internet is simply unaffordable for the majority of Tajiks and Afghanis, and is moderately affordable for the Kyrgyz, while mobile broadband is cheaper and more affordable in all three countries. Fixed broadband services are restricted to major cities, whereas rural dwellers mostly use mobile broadband.

Compounding the transit problem, the rugged mountainous terrain makes laying fibre optic cables a difficult and costly task. Consequently, AKT suffer from poor domestic broadband infrastructure and coverage, especially in rural areas. Low urbanization and sparse populations fur-

9 UNESCAP (2014), An In-Depth Study of Broadband Infrastructure in North and Central Asia

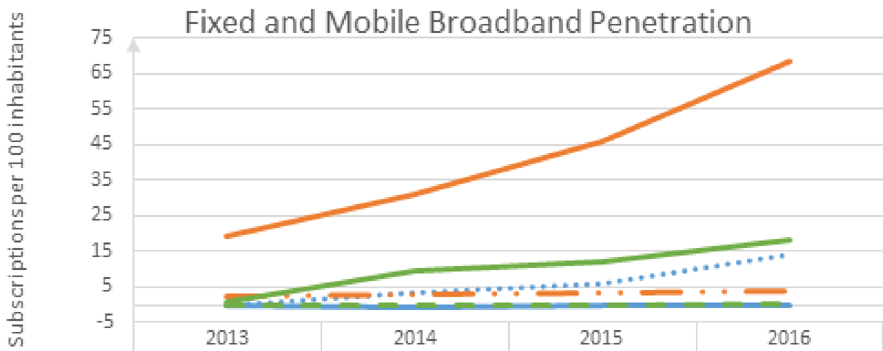
10 UNESCAP (2015), An In-Depth Study of Broadband Infrastructure in Afghanistan and Mongolia

ther discourage providers from expanding their coverage and lowering prices, thus preventing them from realizing economies of scale.

On the demand side, the populations' lack of digital skills is the main impediment to Internet adoption. Another constraint is the limited content relevance: the majority of Internet traffic is in English and content-wise irrelevant for local users; domestically relevant content in local languages is scarce. Generally, the Internet speed is low and latency (i.e. download delays) is high in all three countries, which further dampen the demand. Finally, the insufficient supply and insufficient demand reinforce each other through dynamic feedback loops, creating a vicious cycle of low supply – low demand – low supply.

Nevertheless, there is a positive trend in broadband penetration, and namely, in the adoption of mobile broadband. Figure 11 portrays the trajectories of mobile broadband (shown in solid lines) subscriptions juxtaposed with those of fixed broadband (shown in dashed lines). As seen from the figure, not only do the absolute levels of mobile broadband adoption by far (more than tenfold) exceed those of fixed broadband, but the growth rates (i.e. slopes of the curves) of mobile broadband also outpace those of fixed broadband. This can be attributed to the lower fixed, infrastructural costs of mobile broadband compared to fixed broadband; mobile broadband requires building only microwave radio towers rather than costly terrestrial cables across mountainous areas. The trend indicates that mobile broadband is becoming the technology of choice for Internet access in AKT, and any commercial apps should target this market segment if they are to be successful.

Figure 11. Fixed and Mobile Broadband Penetration, 2013-2016



	2013	2014	2015	2016
AFG Fixed BB	0.00	0.00	0.02	0.03
AFG Mobile BB	0.0	3.2	6.0	14.3
KYR Fixed BB	2.4	3.0	3.6	4.0
KYR Mobile BB	19.1	31.0	46.1	68.5
TAJ Fixed BB	0.07	0.07	0.07	0.10
TAJ Mobile BB	0.6	9.5	12.0	18.1

Source: Broadband Commission. The State of Broadband 2014-2017

2.3.3. Broadband Infrastructure and Suppliers

As discussed earlier, the poor international connectivity and underdeveloped domestic broadband infrastructure are the main obstacles for broadband penetration in all three countries.

This problem is particularly pronounced in Tajikistan, which has the highest transit costs, and perhaps the least developed domestic fibre optic infrastructure among the three countries. Most of the Tajikistan's international traffic comes from Russia via Kazakhstan and Kyrgyzstan, and costs ten times more than in Kazakhstan. There are also fibre links to Afghanistan and Uzbekistan, but they are of a limited use due to security problems in Afghanistan and prohibitive tariffs in Uzbekistan. Connectivity via Pakistan and Iran seems to be viable alternatives. In particular, the Pakistan route looks promising given that Pakistan is emerging as a regional communication hub, with its newly-built port in Gwadar and connections to five global submarine fibre optic cables. The Tajik domestic broadband backbone also compares poorly to that of its neighbours, covering mainly densely populated areas on the country's west and leaving out sparsely populated mountainous areas on the east, i.e. Gorno-Badakhshan Autonomous Region.

Similarly, Kyrgyzstan almost entirely depends on Kazakhstan for Internet transit, facing on average a threefold mark-up over Kazakhstan's Internet price. ElCat, a local ISP firm, has recently established an alternative fibre link to China in the country's south, which further links to Tajikistan. Yet this route is exposed to the Great Firewall of China, limiting Internet content and speed. As noted earlier, connectivity via Pakistan seems to be a more attractive option provided that security issues on the Afghan territory are resolved. It can be laid along the CASA 1000 electric power lines, exporting Kyrgyz and Tajik hydropower to Afghanistan and Pakistan. This project, also known as Digital CASA, is already underway, funded by a $25 million loan and $25 million grant by the World Bank. With a total length of 12,000 kilometres (including 2,719 kilometres of the main backbone), the Kyrgyz fibre optic network spans most of its territory, however, its density and quality remain low in rural areas.

As for Afghanistan, the story of its telecom sector has been one of success; devastated by a series of wars and incessant civil strife, the country's telecommunication sector has risen from the ashes strong and rejuvenated. Telecommunication is the most dynamically developing sector of the Afghan economy, generating more than $200 million of annual revenue — about 12% of the total government revenue – and providing more than 14,000 direct and indirect jobs.[11]

Afghanistan's national telecom infrastructure consists of a national fibre optic backbone and a national microwave network. Connected to all Afghanistan's neighbours except China, the national fibre optic backbone circles around the country's Ring Road and branches out to 25 Afghan provinces.[12] The national backbone is being extended to the remaining nine provinces and is expected to reach 4,400 kilometres in length. There are also plans to connect the backbone to China and to build additional fibre links to Iran, Uzbekistan and Tajikistan. Some 2,500 kilometres long, the national microwave network comprises more than 5,383 towers and provides the basis for wireless broadband.

The AKT mobile broadband markets are fairly competitive. There are six mobile providers in both Afghanistan and Tajikistan, and five – in Kyrgyzstan. In contrast, the fixed broadband markets in all three countries are dominated by state-owned telecom companies. Afghan Telecom holds monopoly over the country's fixed-line infrastructure and CDMA network. In 2006, it licensed out the local wireless segment of the CDMA network to Wasei Telecom, a UAE-owned company, which primarily services rural areas. The country's last mile connection segment is crowded: as of 2014, there were 58 registered Internet Service Providers (ISPs).

Kyrgyz Telecom operates the fixed broadband infrastructure and accounts for 60% of the Kyrgyz fixed line market. The rest of the market is divided between ElCat, Aknet, Asiainfo, Megaline, Saima Telecom, Citynet, Homeline, Maxlink and Fastnet. There are also more than ten ISPs at the last mile level. In Tajikistan, Tajik Telecom provides about 80% of the fixed broadband services, with the remaining 20% claimed by four firms: Babilon-T, Intercom, Eastera and Telecom Technology. The last mile level is represented by six ISPs, much less than in Afghanistan.

11 MCIT. "Summary Reports." Annual Achievements Summary 2006 - 2014 ed.

12 https://www.telegeography.com/products/commsupdate/articles/2017/10/06/mcit-to-pilot-system-for-telecom-tax-collection-fibre-reaches-25-provinces/

2.4. Service Sectors

The low levels of ICT penetration in AKT are not only due to the supply-side problems such as the high costs of infrastructure development, inadequate capital investments and prohibitive transit prices, but are also consequences of the sluggish demand from businesses and individuals, insufficient local Internet content and a lack of digital literacy among the populace. The anaemic demand discourages service providers from expanding their infrastructure and services, thus preventing them from reaping economies of scale and cutting prices. This further dampens the demand, resulting in a vicious, self-reinforcing cycle.

To address these demand-side challenges, the AKT governments need to raise digital literacy and encourage or even create new demand for digital products. Such interventions are critical not only for fostering their ICT sectors but are also important steps towards building a digital economy. In this section, we review the degree of ICT deployment in the AKT service sectors. Generally, service sectors – finance, retail, governance, education, health care and transport – have proved more receptive to ICT than all other economic sectors, by swiftly integrating the latest ICT innovations into their business processes and creating new software applications and products on their basis.

(a) Finance

In 2007, Roshan, Afghanistan's biggest telecom company, jointly with the UK's Vodafone launched a mobile phone payment system, called M-Paisa.[13] Modelled upon the Kenyan M-Pesa system, M-Paisa was initially piloted as an electronic salary transfer system for Afghan policemen, and was later extended to execute all kinds of payments, including those for retail merchandise, utilities, insurance, healthcare, school fees, micro-finance loan payments, and international and domestic transfers. The system is easy to use: the needed amount is transferred via a simple text message over a mobile phone.

M-Paisa currently has over 3 million subscribers, located mainly in rural areas. The latter fact is critical since only 7-8 percent of Afghanis have access to bank services, while 63 percent have mobile phones, see Figure 7. M-Paisa users do not have to have a bank account to use it; there is a network of retail outlets that accept M-Paisa payments and can also disburse money to users.

The M-Paisa system has not only revolutionized the Afghan financial and retail landscapes, but also had the unintended consequence of curtailing corruption. The amounts that the Afghan policemen received via M-Paisa were 30 percent greater than what they used to get before,[14] thus closing a big loophole for cash skimming by corrupt officials. The system also obviates the need for transporting large amounts of cash around an insecure country. Last but not least, the wide-coverage and flexible payment platform, alternative to the formal banking system, brings the country's sizeable informal sector back into the formal economy and contributes to the development of small and medium businesses (SMEs).

Roshan's successful business model has prompted its rivals – Afghan Wireless, Etisalat and MTN – to enter this emergent market with their own mobile payment systems. Yet, lacking interoperability, these diverse platforms are currently causing a range of coordination problems, which discourage further expansion of the market.

Unfortunately, Kyrgyzstan and Tajikistan do not yet have such mobile phone payment systems, despite the acute need on the part of their sizeable migrant labour and rural populations. Instead, these countries have commercial bank-owned electronic payment systems, e.g. ELSOM operated

13 https://www.ifc.org/wps/wcm/connect/cad6888049585efe9e8abf19583b6d16/Tool%2B6.9.%2BCase%2BStudy%2B-%2BM-Paisa%2BAfghanistan.pdf?MOD=AJPERES

14 https://www.wired.com/2014/05/how-digital-currency-could-end-corruption-in-afghanistan/

by the KICB bank in Kyrgyzstan or the electronic system operated by Eskhata in Tajikistan, which still require a bank account for their use.

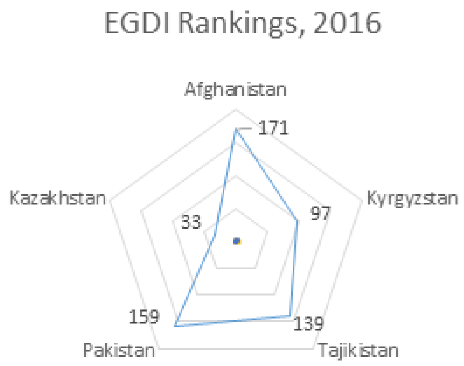
As noted in Section 2.1, worker remittances account for 30 and 26 percent, respectively, of the Kyrgyz and Tajik GDPs, see Figure 7. Kyrgyz and Tajik migrant workers wire transfer money from Russia and Kazakhstan to their families, predominantly residing in rural areas. Often times, both sides – the workers (many of them are illegal) and the families – do not have bank accounts or have to travel long distances to reach the closest bank branches. The introduction of a mobile phone-based money payment system would facilitate significantly remittance transfers to Kyrgyzstan and Tajikistan. Moreover, it would help integrate their large informal sectors into the formal economy and reduce the costs of doing business for small and medium scale businesses, by eliminating a whole host of exorbitant bank fees they currently face.

(b) E-government

Aside from being the lead promoters of ICT, governments themselves are major users of ICT. Over the last decade, governments around the globe have made a quantum leap in the digitalization of their operations and services. ICT technologies are increasingly used to deliver virtually all government services online, starting from recording citizens' births and deaths and the issuance of certificates and permits to collecting taxes and voting in elections.

Such rapid penetration of ICT into the government sphere led the United Nations to introduce E-Government Development index (EDGI), comparing national governments' performance in ICT adoption. As expected, the Afghan, Kyrgyz and Tajik governments do not rank well on EDGI, see Figure 12. In 2016, Kyrgyzstan was placed 97th out 193 countries, Tajikistan – 139th, and Afghanistan – 171st, trailing behind the regional leader Kazakhstan, in 33rd place. Kyrgyzstan and Tajikistan both performed better on EGDI than Pakistan, however, are still below the Asian region's average of 0.513.

Figure 12. Rankings in the UN E-Government Development Index, 2016

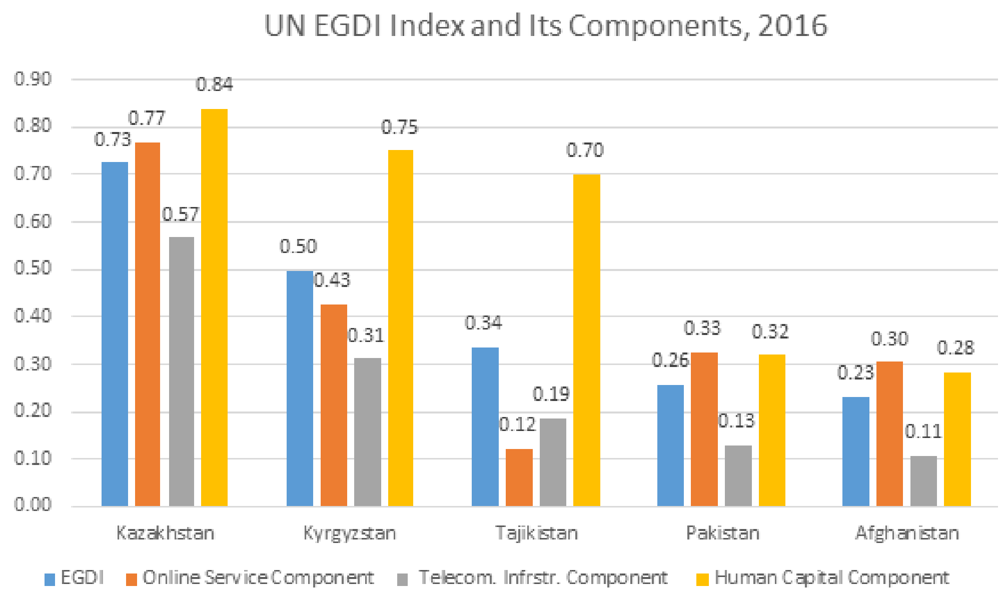


Source: United Nations (2017). United Nations E-Government Survey 2016

A more detailed breakdown of the EGDI index into online service, telecom infrastructure and human capital development components is given in Figure 13. As seen from the figure, Kyrgyzstan and Tajikistan both possess high levels of human skills in ICT, above the global and regional averages, and thus have strong potential to absorb and assimilate ICT, but do poorly on the ICT infrastructure component, as already discussed in the proceeding sections. Afghanistan is disadvantaged in all dimensions, with the exception of the online service component. The governments in all three countries have web portals, webpages and offer some e-services, but of varying extent and quality.

Interestingly, the Afghan government's online service delivery is currently superior to that of the Tajik government and only marginally behind, or perhaps on the same level, as Kyrgyzstan's and Pakistan's online government services. This owes to the Afghan government's vigorous drive to digitalize government services through a comprehensive E-Government strategy adopted in 2011.

Figure 13. UN E-Government Development Index and Its Components, 2016



Source: United Nations (2017). United Nations E-Government Survey 2016

As part of this programme, an electronic identification card system, E-Tazkira, and a national data repository centre have been established. Further, all government agencies have developed their own websites, where one can access a wealth of information, which cannot be said about Tajikistan. Further, recognizing that mobile phones are the main mode of Internet access in the country, the Afghan Ministry of Communications, Information and Technology has created, with the help of the World Bank and USAID, a mobile service platform[15] – HOSA – to provide citizens with online access to virtually all government services and information.

The Kyrgyz government has recently inaugurated an overarching E-government programme – Taza Koom – encompassing four main strategic priorities:[16] (i) **developing a modern ICT infrastructure**; (ii) **nurturing a favourable ICT ecosystem by improving legislation, regulatory policies and** building human and institutional capacity; (iii) delivering digital public services to citizens and businesses in all spheres: governance, healthcare, education, commerce, finance, and agriculture; and (iv) **stimulating the creation and development of ICT-oriented innovations and partnerships, e.g.** ICT incubators, cluster hubs, networks of business angels, and venture financing.

However, given the frequent changes and lack of continuity between Kyrgyz government cabinets, successful implementation of the Taza Koom programme remains uncertain. While progress has been made in some areas, such as electronic identification cards, e-visa, online applications for some licences, electronic health records and prescriptions, and electronic traffic surveillance

15 http://mcit.gov.af/en/page/public-documents/6005

16 http://tazakoom.kg/site/concept/22

systems in big cities, Kyrgyz citizens carry out most of public service-related transactions in old-fashioned ways. For instance, most Kyrgyz wait in long lines at local postal offices to pay for their utilities or apply and pay in person for business permits and taxes at government offices.

The Tajik government is one of the worst (the third worst in Asia and only superior to North Korea and Turkmenistan) performers in the region in terms of online service provision. Despite numerous programmes on the development and implementation of e-governance,[17] and the fact that some 20 Tajik government agencies are now connected into a single e-governance system, the provision of government e-services remains subpar in Tajikistan.

Some of the few achievements made by the Tajik government include an e-card pension payment system, introduced in 2009 with the help of ADB, and an e-visa system, introduced in 2016. In particular, the pension payment system, which covered 596,000 retirees in 15 out of 68 districts of Tajikistan, was not truly an online service. Pensions were disbursed through Amonatbank, a state-owned bank, and retired people used plastic cards to withdraw their pensions at ATM terminals. While the system brought a lot of convenience and time savings in the cities, the number of ATMs was insufficient to cover all rural locations, and many pensioners located in such areas had to travel long distances to reach the nearest ATMs and thus experienced long waiting times.[18]

As it follows from this brief overview, the Kyrgyz and Tajik governments are lagging behind their regional neighbours in e-governance implementation. Neither have they invested in mobile phone applications for e-services, instead focusing on more traditional desktop applications. By contrast, the Afghan government has either developed itself or provided grants to private firms to develop mobile applications for the country's agricultural, health and education sectors. To date, a number of mobile applications have been deployed to offer Afghan farmers real-time market information on crops, fertilizer prices and weather conditions, in addition to the salary payment applications discussed above.

Instead of the Kyrgyz and Tajik governments, the Kyrgyz and Tajik private sectors have pioneered the development of mobile applications. There are quite a few ICT start-ups in Kyrgyzstan, engaged in the design of mobile apps based on both the Android and iOS platforms, including apps for e-commerce, transport (e.g. e-aggregators), entertainment (e.g. games), and restaurant and catering services. The Tech Farm group is one of the leaders in the Kyrgyz apps market with its own applications for taxis (Namba-taxi), catering (Namba-food), cloud-based e-commerce platform (Sellbeing), online payment system (N-Pay) and its own social entertainment platform (Namba).[19] In Tajikistan, the Neuron company has recently launched an electronic payment system, Hisob, and e-wallet, Tez-pardoht. Hisob provides Tajik households with a single electronic account to pay for all utility services (electricity, water, landline phone) and other services (mobile phones, Internet, NGN telephony) through a single integrated payment system, resulting in considerable effort and time savings.[20]

(c) Education

The educational sector is another important user of ICT technology. The Internet holds great promise to increase access to and to enhance the quality of education at all levels. However, AKT educational institutions largely lack basic Internet connectivity, especially those in rural areas. And even connected schools often cannot take full advantage of ICT technologies to explore e-learning opportunities due to high costs and slow speed of connection as well as the lack of personnel with ICT skills; few teachers in AKT primary and secondary schools are digitally literate. These problems are faced not only by AKT, but also by other countries in the region.

[17] For instance, Decree #643 of December 30, 2001 on "Concept of formation of e-governance in the Republic of Tajikistan", or the State Program on "Development and implementation of ICT in the Republic of Tajikistan, 2014-2017"

[18] https://www.adb.org/sites/default/files/publication/30339/electronic-pension-payment-system-tajikistan.pdf

[19] http://techfarm.vc/

[20] https://paylogic-software.com/about-the-company/news/hisobintegration/

To help the region overcome these obstacles and to promote collaboration among its higher educational institutions, the North Atlantic Treaty Organization initiated the Virtual Silk Highway Project in 2002, covering the five Central Asian countries and the three South Caucasus states. Originally, the Project provided educational and research institutions in the participating countries with high-speed internet access via satellite. Later, in 2010, connectivity was upgraded to fibre optic broadband. The Central Asian component of the project was handed over to the European Union and became known as the Central Asian Research and Education Network (CAREN). The Afghan component remained with NATO and the US State Department under the name SILK-Afghanistan Programme.

The SILK-Afghanistan Programme[21] presently brings together 34 Afghan universities and covers 90 percent of their bandwidth costs. The Programme enables Afghan teachers and researchers to pursue distance learning programmes or to collaborate on research projects with their counterparts abroad. Furthermore, the Program ensures high-speed access to online libraries, scientific article depositories and electronic course reserves such as Coursera and Code Academy.

Another bottleneck in the Afghan educational system is the shortage of student places at higher educational institutions, especially at public universities. To fill this gap, some Afghan universities and government agencies began partnering with foreign institutions to deliver distant learning programmes. Examples include the Afghan German Management College, which offers business training based on lectures by German professors, the Afghan Mining Professionals Online Training Programme based on the course content produced by Iranian mining institutions, and the Afghan Ministry of Finance Executive Master Programme in Economic Policy delivered both online and in-class by the University of Central Asia, based in Bishkek, under the aegis of the Aga Khan Development Network (AKDN).

As for Kyrgyzstan and Tajikistan, online courses at the tertiary level are currently offered via broadband technology by the University of Central Asia, the Kyrgyz-Turkish Manas University, and the Kyrgyz-Russian Slavonic University. Moreover, the CAREN Programme connects Kyrgyz and Tajik scholars with one another and with their colleagues abroad, and provides them with online access to electronic courses, journals and article depositories. Yet, these services are available only to researchers in the capitals, Bishkek and Dushanbe. In addition, three Tajik universities, with the World Bank's help, have trained Tajik teachers on course creation using open-source learning resources.

All these initiatives are clearly insufficient to meet the growing e-learning needs of AKT. Both the quantity and quality of e-learning should be boosted. In particular, e-learning programmes need to be extended from tertiary institutions to secondary schools and from urban to rural locations. The main challenge is to connect primary and secondary schools in rural areas to high-speed Internet. ICT studies, e.g. basics of informatics and computer sciences, should be incorporated into the AKT secondary school curricula, and adequate teacher training should be provided. Another emergent challenge is to integrate increasingly ubiquitous mobile phone apps and mobile networks into educational applications.

(c) Healthcare

Healthcare is one of the least developed sectors in Afghanistan. The country is experiencing acute shortages of clinics, qualified doctors and medical supplies. A lot of wealthier Afghans travel abroad to get medical services, e.g. to Iran and Pakistan, spending there about US$300 million annually, while most of the poor Afghans, especially in rural places, are completely deprived of medical services. Similar, but not as severe, problems also exist in Kyrgyzstan and Tajikistan. There are no basic first-aid stations and doctors in some remote mountainous areas of Tajikistan and Kyrgyzstan, e.g. in Gorno-Badakhshan Autonomous Region of Tajikistan and Naryn Oblast of

[21] https://www.nato.int/cps/ic/natohq/topics_53359.htm

Kyrgyzstan, and their dwellers have to travel several hours to get to the nearest health centres, some dying en route to hospital.

Given such a deplorable situation, development of telemedicine, which would extend much-needed medical services at minimal marginal costs to remote areas, is of the utmost importance. In recent years, some critical steps in this direction have been made in Afghanistan. The first Afghan Telemedicine project was initiated in 2007 by the AKDN in collaboration with the Roshan telecom company, the French Medical Institute for Children and the American technology company Cisco.[22]

The Afghan Telemedicine project enables foreign doctors, e.g. from France and Pakistan, to provide real-time medical services via a high-speed broadband technology to a number of hospitals throughout Afghanistan. The services include advanced radiology and ultrasound diagnostics, consultations in dermatology, infectious diseases, neurology, and orthopaedics. Currently, the project covers hospitals in Kabul and a number of provincial towns. Their doctors are also given online training in medical diagnostics. The AKDN has also been implementing similar e-health programmes in Kyrgyzstan, Tajikistan and several other Asian countries. These important AKDN contributions were recognized by the Manhattan Award in eHealth in 2014.

Furthermore, the Kyrgyz National Centers of Cardiology and Maternity & Child Healthcare with the financial support of UNDP extended online diagnostic and medical consultations on various heart diseases and pregnancy complications to the Batken Hospital, located in one the most remote and underdeveloped regions of Kyrgyzstan. To deliver services, a mobile broadband communication system and diagnostic equipment were installed at the hospital.

Finally, in addition to e-education and e-research, the CAREN Programme has established a network of Central Asian hospitals and doctors, including Kyrgyz and Tajik ones, connected via real-time video-conferencing technology. The Programme has enabled the provision of online diagnostic services and consultations to patients with limited access to health services. Moreover, the programme has hosted a number of video-conferences and online training sessions for the region's doctors and medical researchers, thereby facilitating regional collaboration and an exchange of best practices.

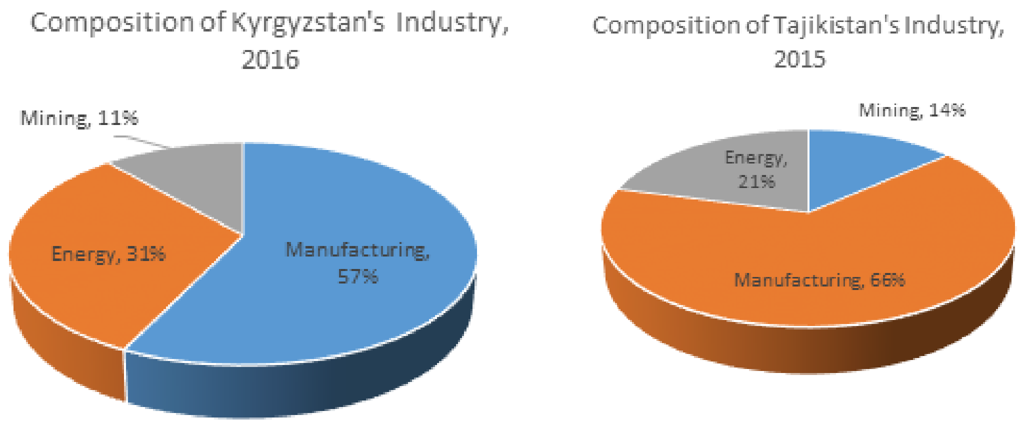
2.5. Industrial Sectors

Kyrgyzstan and Tajikistan share a similarly skewed industrial structure that is dominated by low-technology manufacturing, followed by the mining and energy sectors, see Figure 14. Their manufacturing sectors are concentrated in primary processing of non-ferrous metal ores, and the food, textile and apparel industries. In addition, Tajikistan has a modest, but a high growth-potential, chemical industry.

Afghanistan's industrial structure is even more lopsided. The protracted war and ensuing political instability left the Afghan industry reduced to food processing, construction, textile (carpet-weaving) and some mining (coal and crude oil); the energy sector is almost non-existent, see Figure 15. More technology-intensive manufacturing industries are just beginning to shape up in Afghanistan.

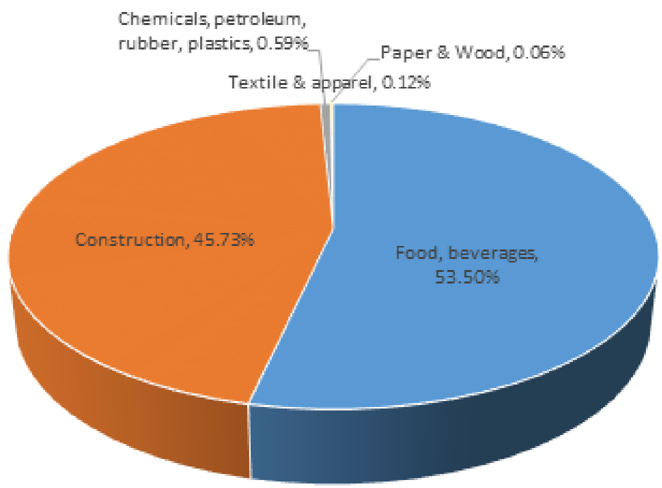
[22] The Aga Khan Development Network, http://akdnehrc.org/ehealth_programme/, http://www.akdn.org/press-release/roshan-announces-expansion-afghanistans-first-telemedicine-project-bamyan-region

Figure 14. Composition of the Kyrgyz and Tajik Industries



Sources: Kyrgyz National Statistical Agency. Statistical Yearbook, 2017; Tajikistan's Statistics Agency, https://www.stat.tj/en/tables-real-sector

Figure 15. Composition of the Afghan Industry, 2016



Source: Afghan Central Statistics Organization, 2017. "National Accounts, 2016-17"

(a) **Mining Industry**

Lacking substantial reserves of hydrocarbons, Kyrgyzstan and Tajikistan nevertheless possess abundant reserves of other mineral resources such as gold, silver, copper, molybdenum, antimony, mercury, lead, zinc, fluorspar, rare earths, and construction materials (gypsum, limestone, granite, and marble). As a result, their mining industries are specialized in non-ferrous metals and construction materials.

However, Kyrgyzstan and Tajikistan add little value to their mineral products, exporting mainly unprocessed or semi-processed ores, e.g. gold ores or lead concentrates, perhaps with the exception Tajikistan's aluminium. And this is despite the fact that both countries have a number of ore-processing plants built in the Soviet era. There are four major ore refining plants in Kyrgyzstan: (i) gold affinage plant in Kara Balta – Kara Balta Ore Mining Combine – producing 999.9 grade gold, (ii) Kyrgyz Chemical-Metallurgical Plant in Orlovka, (iii) Kadamjay Antimony Plant, and (iv) Haydarkan Mercury Plant. Tajikistan's major refineries include: (i) Tajik Aluminium

Company (TALCO), producing aluminium from mainly imported bauxites; (ii) Adrasman mining-beneficiation complex, producing silver, lead and zinc, (iii) Anzob mining-beneficiation complex, producing antimony and mercury, (iv) Zarafshon gold processing plant, and (v) Zarnisor ore-processing plant, producing lead and zinc.

These processing plants are either shutdown or operating below their capacity due to obsolete technology, lack of investments or shortage of raw materials. For instance, under the Soviet Union, the Kara Balta Combine used to process uranium ore from Kyrgyz and Kazakh deposits. With the depletion of Kyrgyz uranium deposits and the discontinuance of Kazakh uranium ore supplies, the plant is now on the verge of closure, refining only gold and molybdenum ores.

Once the Soviet Union's flagship metallurgical factory, the Haydarkan Mercury Plant is too teetering on the brink of bankruptcy, with its main shops and production lines shut down because of its outdated, inefficient equipment. The plant is currently producing small amounts of mercury, fluorite and antimony based on antiquated technological processes. For example, the ore in a shaft is extracted manually with hammers; it is then loaded manually on rail cars and lifted out of the shaft. Japanese experts, who inspected the mine in 1998, pointed to the lack of automation and measuring equipment. In addition, there is no technology used for separating toxic arsenic from the ore, which is preventing the exploitation of several mercury deposits.

The situation is no better at the Kadamjay Antimony Plant, which is now operating below its capacity despite the copious reserves in nearby deposits. It met only 7 percent of its production target in 2014 due to its worn-out machinery and obsolete technologies. Another striking example is the Orlovka Plant in Kyrgyzstan, which used to produce lead, zinc, tin and the highest grade rare earth metals of the entire lanthanide group. The plant fell into decay after the collapse of the Soviet Union and is now producing only mono-crystal silicone. In fact, the plant's mono-crystal production is based on cutting-edge Russian technology, yielding the purest silicone crystals used as photovoltaic elements in solar batteries. Yet, all other production lines are still suspended. In 2011, the Canadian Stans Energy company acquired the plant's rare earth shop along with the mining licences for two rare earth metal deposits – Kutisay-2 and Kalisay – for US$5.5 million; the deal was however broken in 2014.

As for Tajikistan's refineries, their productivity has also been eroded by worn-out machinery, outmoded technologies and a lack of investments to modernize them. The Tajik Aluminium Plant, which has been in existence for 43 years, still relies on Soviet-era equipment and manual electrolysis processes. Maintenance of the existing machinery is costing the plant millions of dollars annually. Besides, it does not have its own iron foundry. There are plans to automate and augment the plant's capacity with Chinese aid.

Next, the Adrasman mining-beneficiation complex, based on the largest Konimansur silver deposit, stopped its operations in 2013 owing to the sharp fall in global silver prices and the subsequent withdrawal of its main investor from Kazakhstan. The Anzob mining-beneficiation complex has been using only a half of its installed annual capacity of 700,000 tons per year. In contrast, the Zarafshon processing plant – the country's leading gold producer – has recently upgraded its processing machinery and mining infrastructure at the Jilao and Tarror gold mines, which boosted gold production by about 25 percent. Moreover, the state-owned Tajik Gold company holds an automatic sorting technology for extracting gold from quartz-containing ores.

Afghanistan is a treasure trove of some of the most prized, and thus far untapped mineral resources, including natural gas, petroleum, coal, rare earths, lithium, copper, gold, iron ore, cobalt, lead, zinc, precious and semi-precious stones. A recent US Geological Survey (USGS) puts Afghanistan's reserves of copper at 240 million metric tonnes, rare earth elements – at 1 million metric tonnes, and iron ore – at 2.2 trillion metric tonnes. Moreover, substantial deposits of petroleum (about 3.8 billion barrels) and natural gas (444 billion cubic meters) have been discovered. The unconfirmed reserves of hydrocarbons are believed to be even larger. According to USGS geologist Jack Medlin, there are at least 24 world-class mineral deposits in Afghanistan.

In spite of its rich mineral resource endowments, the Afghan mining industry is still in an embryonic state. Out of the above-cited minerals, only a handful of coal and gold deposits are currently operating. Coal is mined by local companies in the northern provinces of Takhar and Badakhshan, using outmoded technologies, equipment and, sometimes, child labour. Some briquetted coal is also produced. Active gold mines, located mainly in the country's north, are run by small artisanal miners. The largest gold deposits are Zarkashan and Samty, with an estimated capacity of 20 to 25 tons. Further, in 2008, Afghanistan signed a contract for the development of the Aynak copper mine, the country's largest copper deposit, with the Chinese Metallurgical Company. However, the mine development and envisaged construction of the adjacent transportation roads have stalled due to the plummeted copper prices. Finally, an Indo-Canadian consortium of companies is expected to invest $14.6 billion into developing the Hajigak iron mine, the country's largest iron deposit, near Kabul.

To sum up, given their rundown physical productive capacity and the lack of modern technologies, Kyrgyzstan and Tajikistan are now operating at the lowest level of the mining value chain adding little value to their minerals, while Afghanistan has not even begun full-scale development of its mines.

(b) **Energy Sector**

The Kyrgyz and Tajik energy sectors are dominated by hydropower generation from powerful mountainous tributaries of two major rivers of Central Asia – Syr Darya and Amu Darya – originating on their territories. Until recently, the two countries were dependent on natural gas and oil imports from neighbouring Kazakhstan and Uzbekistan, which caused frequent electricity supply disruptions and downtime in industrial production. For instance, natural gas disruptions from Uzbekistan in 2012-2013 caused a 21 percent production contraction at the Tajik Aluminium Plant and brought to a complete halt cement production at the Tajik Cement Plant. Cheap and uninterrupted electric power is especially critical for the Tajik energy-intensive aluminium industry.

Since 2010, Kyrgyzstan and Tajikistan have been making significant efforts to attain energy security through expansion of their hydropower generation capacity. The installed hydropower capacity in Tajikistan and Kyrgyzstan stands at 5,190 MW and 3,786 MW, respectively, mainly represented by two giant cascades: Nurek (capacity – 3,015 MW) on the Vakhsh River in Tajikistan, and Toktogul (capacity – 2,910 MW) on the Naryn River in Kyrgyzstan. Yet both countries are currently utilizing only about 10 percent of their total hydropower potentials, estimated at 527,000 GWh/year for Tajikistan and 150,000 GWh/year for Kyrgyzstan.

To tap its unused hydropower potential, Kyrgyzstan entered into an agreement with Russian state-controlled RusHydro to build Kambarata-1 Dam (planned capacity – 1,940 MW) and the Upper Naryn cascade, comprising four smaller dams. The plants are envisaged to secure Kyrgyzstan's energy independence. However, Kyrgyzstan revoked the agreement with RusHydro due to delays in 2015. After a second unsuccessful attempt with the Czech company Liglass in August 2017, Kyrgyzstan is still looking for investors to build the Kambar-Ata Dam.

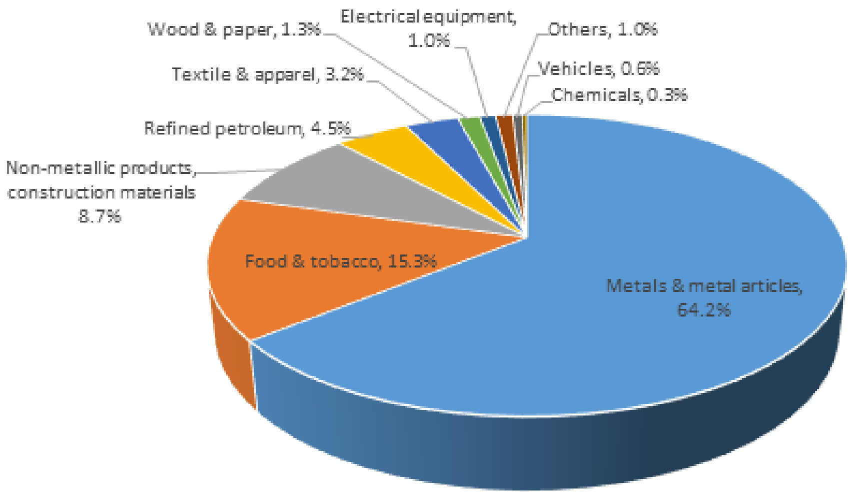
Tajikistan has been more successful than Kyrgyzstan in pursuing its ambitious Rogun Dam project on the Vakhsh River, with a planned capacity of 3,600 MW. After similar unsuccessful arrangements with Russian investors and despite political pressure from Uzbekistan, Tajikistan proceeded unilaterally by raising US$1.8 billion through a sovereign bond issue. The construction of the Rogun Dam was launched in 2016 and is expected to be completed in 2018.

Afghanistan's energy sector, and in particular its hydropower plants largely destroyed during the war are insufficient to meet the domestic electricity demand. Afghanistan imports about 1,000 MW from neighbouring Iran, Turkmenistan, Uzbekistan and Tajikistan. Only 33 percent of its population has access to electricity, so at least an additional 2,000 MW are still needed. There are plans to construct the CASA 1000 electric grid, connecting Kyrgyzstan, Tajikistan, Afghanistan and Pakistan, that would bring Central Asian electricity to South Asia.

(c) Manufacturing

The latest compositions of the AKT manufacturing sectors are presented in Figure 16 and Figure 17. As seen from these, the Kyrgyz manufacturing sector is dominated by nonferrous metals production, followed by food production, while these two industries also lead the Tajik manufacturing sector but in the reverse order. Finally, the Afghan manufacturing sector is concentrated in food production and construction.

Figure 16. Composition of the Kyrgyz Manufacturing Sector, 2016



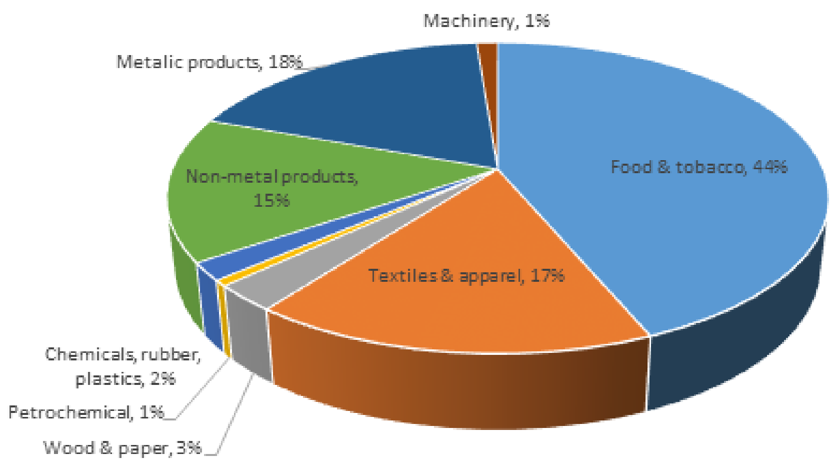
Source: Kyrgyz National Statistical Agency. Statistical Yearbook, 2017

However, these figures obscure the technological and export potential of various manufacturing industries. For example, even though the food industry makes up the largest share in Tajik and Afghan manufacturing, it adds little value and plays an inconspicuous role in the countries' exports, servicing only domestic demand. Furthermore, the share of mid- and high-tech exports is very low in total manufacturing value-added, averaging 5.7 percent for Kyrgyzstan and 2.3 percent for Tajikistan, see Figure 18. These numbers are somewhat misleadingly high in the case of Afghanistan (annual average of 8.6 percent), since even small exports of basic chemicals (lac, resins) and appliances may look disproportionately large relative to the negligible total magnitude of manufacturing value-added.

To increase the value, diversity and sophistication of their manufacturing products, AKT have to develop more technology- and capital-intensive machinery, chemical and textile industries. We now take a more detailed look at these specific industries, by examining their existing levels of technological development.

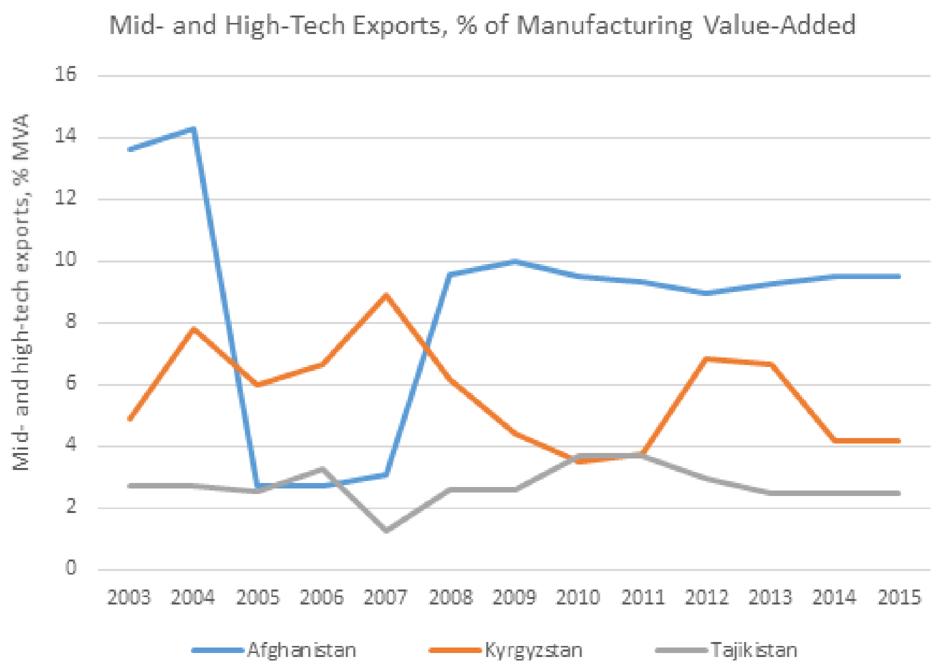
Under the Soviet Union, Kyrgyzstan had a relatively developed and diversified machinery sector. It ranked second in Central Asia, only behind Uzbekistan, producing more than 200 different products, including agricultural and food-processing machinery, trucks, automobile parts, computer components, electronic appliances, bulbs, cables, bullets, and even torpedoes.

Figure 17. Composition of the Tajik Manufacturing Sector, 2015



Source: Tajikistan's Statistics Agency, https://www.stat.tj/en/tables-real-sector

Figure 18. Mid- and High-Tech Exports, as % of Manufacturing Value-Added



Source: World Bank (2017). World Development Indicators

Most of Kyrgyzstan's industrial capacity was built during World War II, when an array of heavy industry plants was evacuated from the European part to the periphery of the Soviet Union. For example, the Lenin Plant traces its origins to the Russian Lugansk ammunition factory founded by Katherine the Great. During the Soviet period, the factory used to produce bullets and a broad spectrum of machinery, ranging from agricultural and food processing machinery to electronic equipment (e.g. transformers, induction regulators, and stabilizers for TV sets) and household appliances. The products were exported to India, Iran, Cuba and the Eastern European countries.

After the collapse of the Soviet Union, the Lenin Plant was split into Bishkek Machine-Building Factory and Bishkek Heavy Electric Machine Plant. Presently, the successor plants manufacture only simple equipment sold in local markets, including cargo-lifting machines, metal-cutting tools, small household fittings and appliances.

The fate of other flagship plants – Bishkek Agricultural Machinery Plant (aka Frunze Plant), Kyrgyz Automotive Plant (aka KyrgyzAvtoMash), Bishkek Computer Plant and Bishkek Metal-Concrete Factory – has been even less fortunate. They all lie in tatters today, with their equipment sold for metal scrap to China and their land plots being used as warehouses or pastures for grazing domestic animals.

Today, only two of the former Soviet-time machinery plants – Dastan Enterprise and Mayli-Suu Electric Lamp Plant – have more or less advanced technologies and produce higher value-added products. Dastan was a strategic military enterprise producing torpedoes for the Soviet Union and India. The Russian technologies were withdrawn and the production ceased after the demise of the Soviet Union. The plant, however, retained a unique technology for manufacturing high-speed industrial centrifuges used in the atomic and medical equipment industries. There are only two plants worldwide that own this technology. Similarly, Mayli-Suu Electric Plant is up and running, exporting a variety of lamps and bulbs across the Central Asian region.

Unlike Kyrgyzstan, Tajikistan did not have a large machine-building industry even under the Soviet Union. The production was limited to manufacturing textile equipment and ancillary low-voltage electrical equipment, transformers and cables. The sector quickly fell apart after the demise of the Soviet Union. In contrast, the Tajik chemical industry is relatively well-developed due to its rich resource base (sodium chloride, potassium chloride, fluorites) and cheap electricity. The largest chemical enterprise is the Yavan Electro-Chemical Plant, specializing in the production of nitrogen fertilizers, explosives, paints, coatings, caustic soda, pesticides, and chorine-containing products for household use, including detergents and bleaches.

Furthermore, Tajikistan has 13 cement plants (included under 'non-metal products' in Figure 17) with a total production capacity of 4.7 million tons/year. The sector is dominated by the Tajik Cement Plant located in the capital, Dushanbe. The operations at the plant came to a halt in 2013 due to the natural gas disruptions from Uzbekistan. This incident prompted the Tajik government to contract the Beijing Uni-Construction Group of China to switch the plant's fuelling from natural gas to coal. The plant resumed its operations later in 2014. In addition, three new large cement plants have recently been commissioned with the help of Chinese investors: the Yavan Cement Plant in Khatlon Province, the Ghayur-Sughd plant, and the Chjuntsay-Taboshar plant. As a result, the country has fully secured cement supply for domestic needs and begun exporting the surplus to Afghanistan, Kyrgyzstan and Uzbekistan.

In contrast, the Kyrgyz construction material industry is limited to extracting basic raw materials (sand, clay, gypsum and limestone) and manufacturing bricks, cement, concrete and glass from them. These materials are mainly sold in domestic markets, except for glass produced at the Tokmok Interglass Plant. In recent years, Kyrgyz firms have begun exporting shell-limestone, called *sary-tash*, used as façade and wall covering in buildings. The Tokmok Interglass Plant uses relatively modern and sophisticated German technology, which allows it to export high-quality glass to neighbouring countries. In contrast, antiquated technologies and equipment are used in the extraction/production of construction materials, e.g. explosives to extract marble or granite from bedrock which severely fracture slabs.

By and large, Afghanistan does not have a full-fledged machinery industry. Some early efforts have been made to launch the production of agricultural (e.g. threshing machines, vehicle-pulled trolleys) and food processing machinery, home appliances and construction materials, see Section 4.5. As for the construction materials sector, the main cement plants in the country include Ghori plant with the capacity of 1,000 tonnes a day and a smaller plant near Kabul with the capacity of 100 tonnes a day. The plants' productivity is severely undermined by their old, worn-out equipment. Afghanistan also has considerable potential to export marble, but its industrial extraction has not taken off yet.

Unlike the machinery and construction material sectors, AKT light industries are more sizeable both in terms of employment and value generated. Under the Soviet Union, the Tajik and Kyrgyz textile industries were large and relatively developed, dwarfing their garment industries both in terms of revenue and employment. Tajikistan used to produce 150 million meters of fabric per year in 30 different varieties of fabric, including cotton, silk, wool and knitted fabrics. In addition, Tajikistan had a sizeable carpet-weaving industry.

Kyrgyzstan's textile industry was dominated by the production of wool and knitted fabrics, e.g. at Bishkek Worst Cloth Combine, due to its then extensive sheep breeding sector. Kyrgyzstan also had a silk weaving plant in Osh, now non-operational, and several smaller cotton fabric manufacturing enterprises. With the demise of the Soviet Union, the Kyrgyz and Tajik textile industries faded away due to the tumbled demand, outdated machinery and lack of finances which severely eroded the sectors' competitiveness. While the Tajik textile industry has demonstrated some positive dynamics in recent years, the Kyrgyz fabric manufacturing has not recuperated ever since.

On the contrary, the Kyrgyz and Tajik garment industries have shown remarkable resilience, quickly recovering and surpassing their pre-independence production levels by 2008. The Kyrgyz garment industry benefited from the country's WTO membership and trade with China, which secured a steady flow of cheap fabrics and exposed Kyrgyz apparel firms to the Chinese technological frontier in cloth manufacturing through demonstration and imitation effects.

More importantly, Kyrgyz and Tajik garment-makers have managed to carve out niches in the Russian apparel market by leveraging cheap labour and material inputs. For instance, some Tajik firms now specialize in the production of kimonos, jeans and men's sportswear for large Russian retailers, e.g. Russian Judo Federation, while Kyrgyz firms have been successful in sewing women dresses, warm jackets and knitted coats, occupying third place in the Russian apparel market in 2012. However, Tajik and Kyrgyz apparel firms are still operating at the low-value segments of the apparel value chain, by performing simple cutting and sewing, and not product design and marketing, see Section 4.5.

Finally, the Afghan textile industry mostly consists of carpet-weaving. Exports of handwoven rugs peaked at US$215 million in 2006 and have since been contracting, falling to US$43.1 million, or 3.1 percent of total exports, in 2016. The shrinking demand can be attributed to the poor quality and shortage of raw materials, such as wool and dyes. Domestic wool meets only 40 percent of the carpet industry demand, while the remaining 60 percent of wool, of a rather low grade, is imported from Pakistan, which spoils the quality of Afghan rugs.

Moreover, there is lack of carpet finishing facilities for cutting, washing, dyeing, drying, and trimming, etc. In the absence of modern carpet-weaving and processing machinery, age-old manual processes are employed. Because of the lack of finishing facilities, the bulk of Afghan carpets are shipped as intermediate goods to Pakistan, where they are finished and re-exported under Pakistani brand names. Aside from infringement of copyright, such practices result in huge value losses for Afghanistan. Finally, the design, colour palette and print patterns of Afghan rugs have also been lacking innovation, as Afghan artisans have no incentive to deliver them in the absence of copyright protection. As a result, the Afghan carpet industry is losing competitiveness to its Iranian, Turkish and Pakistani rivals.

3. Technology & Innovation Conceptual Framework

Due to pervasive globalization, analysis of the technological development of any country or region requires a thorough understanding of global technological trends and, specifically, the world's dominant technological paradigm.

3.1. Technological Paradigms and Kondratiev Cycles

A technological paradigm is the prevailing, most efficient, at that particular historical junction, way of organizing production based on a constellation of interlinked technologies. At the heart of this constellation lies a *carrier* technology that interweaves all other technologies and underpins the production process. The all-pervasive carrier technology defines the cost-efficiency standards in all sectors of the economy. Information and communication technologies are a carrier technology for the existing global technological paradigm, also known as the Age of Information, which established itself in the 1970-80s with the advent of low-cost micro-processors and home computers.

The emergence and evolution of technological paradigms are believed to correspond to the so-called long waves or cycles in the world economy, discovered statistically by Kondratiev (1925). Long waves or K-waves are a recurring pattern of alternating, 40-to-60-year intervals of expansion, stagnation, and recession of economic activity. According to Kondratiev (1925), seeds of breakthrough technological innovations pop up during the downswing phase of an old cycle and crystallize into a new technological paradigm at the beginning of the upswing phase of a new cycle. Schumpeter (1935) attempted to identify the causal mechanism of the observed cyclicality. To him, radical innovations that lead to the 'creative destruction' of old technologies are the key driving force behind economic cycles.

The Industrial Revolution of 1770-1850, with water-powered mechanization as a carrier technology, coincides with the first K-wave, followed by the Age of Steam and Railways (1850-1900) – the second K-wave – with steam-powered and iron-made machinery as a carrier technology. The third K-wave (1900-1940), known as the Age of Steel and Electricity, was carried by electrification and steel-based heavy engineering, while the fourth (1940-1970) cycle was characterized by the mass production of oil-powered machines using internal combustion engine (e.g. automobiles, tractors, aircrafts) and the related petrochemical industry. The current, fifth K-cycle, which started in the 1970s, is grounded on information and communication technologies. It is characterized by the proliferation of information-intense products like computers, smartphones, and software and the related services.

Finally, we can conjecture that the carrier technology for the sixth technological paradigm, presently at the gestation stage, will be robotics and artificial intelligence – natural outgrowths of information and communication technologies. Robots are already making inroads into many economic sectors, replacing humans and raising productivity by orders of magnitude. In the future, robots are to take over an increasing number of jobs, and in so doing displacing more people from their jobs.

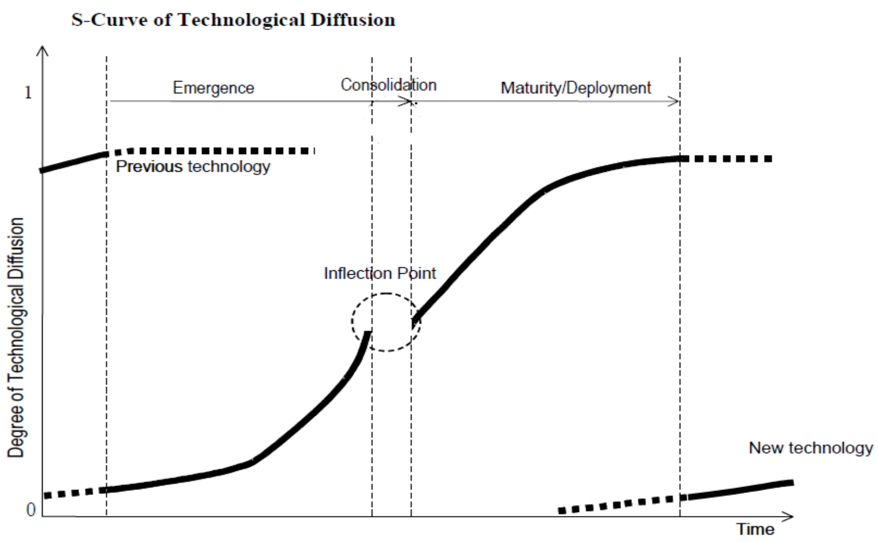
Other researchers believe that biotechnologies (e.g. genetic engineering), nanotechnologies and their applications to medicine will be the main engines of economic growth in the twenty-first century. Whether robotics or bio- and nano-technologies, or their combination will become the drivers of the next technological paradigm remains to be seen; nonetheless, what is now clear is that any new carrier technology will be deeply rooted in and will require ICT as a basic platform for operation.

Apart from the technological innovation theory, there are also alternative explanations of the Kondratiev cycles, including the credit or financial instability hypothesis (Minsky, 1992). Generally, the K-wave theory has been extended and modified by numerous authors. For instance, shorter, infrastructural swings, within a long K-wave (Kuznets, 1931) or a series of progressively shrinking long cycles (Šmihula, 2009) have been proposed. Perez (1998) takes the Schumpeterian model a step further by examining diffusion of technological paradigms. Overall, there is no agreement among economists as to the causes, dates and duration of long economic cycles. Nevertheless, whatever the duration or causal mechanisms of K-waves, a strong correlation between technological paradigms and long economic cycles is an undeniable empirical fact.

3.2. Diffusion of Technological Innovations

The process of technological diffusion follows an S-shaped curve, see Figure 19. A prominent example is a logistic curve used widely in the natural sciences to model the spread of diseases or the growth of populations under resources constraints. The S-curve was introduced to the innovation theory by French sociologist Gabriel Tarde in 1903 and has since been used by numerous authors in this literature.

Figure 19. S-Curve of Technological Diffusion



The S-curve may describe the diffusion of both an individual innovation and an entire technological paradigm, with time plotted on the horizontal axis and the degree of diffusion (on the scale from zero to one) – on the vertical axis. One can distinguish three consecutive phases in the diffusion of an innovation in technologically-advanced countries: *emergence*, *consolidation*, and *maturity*. Technologies arise one after another in overlapping waves: the emergence of a new technology overlaps with the consolidation or maturity phase of the preceding technology, see Figure 19. For instance, the current technological cycle is now at the end of its deployment phase, being superseded by the new technological paradigm based on robotics and artificial intelligence.

The process of technological diffusion in developing countries differs from that in advanced countries. Linsu Kim (1997), who studied the technological development of South Korea in 1960-1995, observes that developing countries usually take the reverse course, beginning with mature technologies and, if successful, moving onto emerging ones. Lacking domestic technological capacity, developing countries have to gain access to technologies, typically, by performing assembly or other simple operations for advanced countries.

For example, the Korean automobile companies (e.g. Hyundai, Daewoo, Kia) started by assembling Japanese and American automobiles in the 1960s. In doing so, they obtained critical technical knowledge either directly from Japanese and American engineers or by reverse engineering and duplicative imitation of purchased technologies. Having accumulated the requisite knowledge and financial capital, the companies then progressed to the production of their own brand cars.

Thus, developing countries are largely technology followers rather than innovators, and innovation in developing countries initially amounts to industrial upgrading through the acquisition of mature technologies.

In general, developing countries can acquire technologies in a variety of ways: foreign patent licencing, foreign direct investment (FDI), turnkey (or 'off-the-shelf') plant acquisition, purchase of other capital goods, and the poaching of technical personnel from abroad. For instance, to avoid foreign ownership of its firms, South Korea largely resorted to foreign patent licencing, and the purchase of turnkey plants and other capital goods. Korean scientists and engineers then cracked and imitated the associated technologies (Linsu Kim, 1997).

Unfortunately, the Korean experience cannot be replicated by developing countries nowadays, not only because of Korea's unique starting conditions (an educated and hard-working populace, and US aid and protection in the wake of the Korean War etc.) but also due to the drastic changes in the global economic environment. First, the strict intellectual property rights legislation makes imitation of patented technologies extremely costly, if not entirely unfeasible; just take the example of the piles of lawsuits for patent infringements facing modern China. Second, with the establishment of the World Trade Organization (WTO), it became much harder for developing countries to protect their fledgling industries, as East Asian countries did it in the 1960s-1970s. Third, the purchase of turnkey plants or foreign patent licencing requires big money, which most developing countries lack.

For these reasons, foreign direct investment and integration into global value chains appear to be one of the main avenues for technology transfer to most developing countries, unless or until they can build up their indigenous technological capabilities and generate home-spun technologies. Given this, understanding how global value chains operate is essential for any developing country seeking to access technologies and to secure a higher value niche in the global economy. According to Business News Daily,[23] a value chain is "the full range of activities — including design, production, marketing and distribution — businesses go through to bring a product or service from conception to delivery."

3.3. Outsourcing and Global Value Chains

Presently, transnational corporations (TNCs) control most technologies and exercise immense power over global value chains (GVCs). Until the 1960s, the global economy was dominated by big vertically-integrated corporations (e.g. Ford, General Motors, General Electric, Siemens), which centralized and concentrated their activities in only a few locations, thereby realizing economies of scale. Later, many TNCs began outsourcing their manufacturing activities to low-income countries.

This shift was chiefly driven by two factors. First, in pursuit of maximal profit margins, the global industrial capital, personified by TNCs, found it advantageous to relocate assembly to countries with cheap and abundant labour, setting into motion the process of vertical disintegration of TNCs. The dismantling of the world's colonial system after World War II and the opening of the Asian economies gave additional impetus for outsourcing. Second, mass production of standardized products – a hallmark of the fourth Kondratiev cycle – further deepened international specialization of labour and necessitated the creation of mass consumer markets. Thus, the countries hosting outsourced production emerged not only as world factories, but also as global consumption centres.

[23] http://www.businessnewsdaily.com/5678-value-chain-analysis.html

With the demise of the socialist camp and the triumphal march of capitalism around the globe, the *extensive* growth model of capitalism seemed to have reached its natural limits. This coincided with the sweeping penetration of ICT – the deployment phase of the fifth Kondratiev cycle – into all economic sectors. In search of new sources of demand, TNCs have adopted an *intensive* growth model based on rapid product obsolesce (short product life cycles), increased product diversity via product customization and new brand design supported by ICT.

These developments have raised both the significance and the costs of brand design and marketing – *intangible* sources of value – while commodifying and reducing the value of production and distribution – *tangible* sources of value. As a result, TNCs have increasingly been narrowing down their focus on R&D, brand development and marketing by outsourcing distribution and basic services (e.g. customer support), in addition to production.

The shift of emphasis from tangibles to intangibles along with declining transportation costs have intensified the process of vertical disintegration of TNCs, engendering GVCs that bring together geographically dispersed activities. In 2013, the TNCs' value of assets was estimated at a staggering $97 trillion, almost 127 percent of the world's GDP, and their investments into developing countries in the form of FDI amounted to US$778 billion, or 54 percent of the world's FDI (UNCTAD, 2014). Most of these TNCs operate through extensive and sophisticated global production networks, spanning all industries from food, textile and apparel to electronics, computer and aircraft manufacturing. Effective management of GVCs has, to a large extent, been enabled by dramatic improvements in information and communications technologies. ICTs facilitate efficient monitoring and control over all stages of the production process scattered around the world from a TNC's home base. Typically, TNCs specify and impose the exact product characteristics and production protocols upon producers in developing countries. Compliance and quality inspection are carried out in real-time through the ICT.

The proliferation of GVCs presents both opportunities and threats for developing countries. The opportunities include access to technologies, capital and export markets. Participation in GVCs can bring about the technological upgrading of developing countries' firms through the provision of new machinery, production processes, management practices and local personnel training by TNCs. The new technologies and practices can then be imitated by other domestic firms, while local personnel can move across firms and industries, i.e. there are economy-wide spillover and learning effects.

Next, firms in developing countries can gain access to otherwise sealed export markets, which forces them to further raise their productivity to endure global competition. Lastly, FDI is the primary investment vehicle for most developing countries with low domestic saving levels, and developing countries can enter capital-intensive industries through GVCs, without having to mobilize their own funds.

On the other hand, FDI and participation in GVCs do not always result in technological upgrading. TNCs tend to offshore only low-technology, labour-intensive segments of their value chains while keeping high-tech segments and R&D at home. Besides, TNCs may discourage domestic R&D if the latter is deemed to rival the former. Further, specialization in lower-end segments of GVCs generates limited linkages with other domestic industries, thus confining productivity growth to a particular (sub)industry.

Moreover, many assembly-related manufacturing activities, e.g. in consumer electronics and automobile industries, involve massive imports of intermediate goods, e.g. parts, which may cause huge current account deficits, and more seriously, prevent the emergence of domestic suppliers of these intermediate goods. For example, computer or mobile phone assembly from imported parts may thwart the development of a domestic semiconductor (e.g. integrated circuits) industry. Thus, developing economies may become locked into low-technology industries while being deprived of the opportunity to foster higher value-added industries.

Lastly, TNCs appropriate a lion's share of GVCs' profits through their control over most critical inputs – core technologies, product design and marketing – and, at the same time, drive down the share of labour-intensive segments, e.g. garment sewing, by periodically relocating them to new countries with lower wages –the phenomenon that became known as a 'race to bottom'. Through all these channels, participation in GVCs may perpetuate and even deepen the technological and economic backwardness of developing countries. The main challenge for developing countries is therefore to integrate themselves into GVCs in such a way as to maximize investments and transfer of advanced technologies to selected, preferably higher value, industries while minimizing the adverse impact of GVCs on the accumulation of productive capabilities in the whole economy.

3.4. Implications for Central Asia

The above discussion implies that developing countries are mostly technological followers rather than innovators. One way they can access advanced technologies and know-how is to join global value chains and move up to higher value segments of these value chains. The latter goal requires today's catch-up economies to embed ICT technologies into their production processes and to upgrade their existing industries to withstand fierce international competition. In this section, we explore the opportunities for Central Asian economies presented by the current technological paradigm by contrasting it with the previous technological cycles.

The main difference between the technological cycles involves the changing nature of dominant factors of production and sources of value. As discussed earlier, knowledge capital and intangible value-added are surpassing, respectively, physical and financial capital, and tangible value-added as the dominant resource and source of value. This fundamental shift sets the two technological paradigms further apart, giving rise to a series of differences in the organizational principles and supporting infrastructure.

First, while the fourth cycle involved the production of standardized products for mass markets, the ICT paradigm has spawned a wide range of differentiated products traded in specialized markets, which led to market segmentation. Market segmentation opens up unique opportunities for the Central Asian countries. They would no longer have to compete in the production of razor-edge-margin, standardized commodities for mass markets – a priori, a futile enterprise given Central Asia's remoteness, prohibitive transportation costs and lack of access to the mass markets of the US and Europe. Instead, Central Asian countries can produce high-profit-margin, differentiated goods for niche markets based on their comparative advantages. For example, Kyrgyzstan can sell 'clean environment' products, e.g. organic food and eco-tourism. Further, AKT can manufacture 'boutique' metals (e.g. structured steel, aluminium) with new, modified properties, currently in high demand from the aerospace, precision instruments and consumer electronics industries.

Second, the previous technological paradigm was centred on energy- and material-intensive products like automobiles, aircrafts and heavy machinery, whereas the ICT paradigm focuses on information-intensive products and services like miniaturized micro-processors, software development and intermediation in the software application. The Central Asian countries would benefit from this trend if they foster their ICT-related service industries. For example, by taking advantage of its geographic centrality, Central Asia can become a regional communication and transportation hub. Such an economic re-orientation is not only a policy option, but a matter of life-or-death for the region, as the world is phasing out its consumption of hydrocarbons and is switching to new energy sources like hydrogen and electricity.

Third, vertical integration and centralized management were the major organizing principles for production in the fourth Kondratiev cycle. Typically, production is managed centrally, and is concentrated in only a few places with abundant cheap labour. In contrast, production disintegration and decentralized management are the leading organization principles in the current cycle. Production is distributed across different regions based on their resource or location advantages and is connected through decentralized ICT-managed firm networks. Nowadays, ICT offers tremendous efficiency and flexibility in the coordination of such networks, inconceivable until recently. In addition, the Internet lowers the barriers for developing country firms' entry to GVCs, by providing a fast and low-cost linkage mechanism.

ICT would thus allow the Central Asian countries to integrate seamlessly into global value chains by leveraging their advantageous location, low cost labour, cheap energy resources (e.g. electricity, natural gas, oil) and resource endowments (e.g. rare earth metals). For example, Kyrgyzstan, Tajikistan and Afghanistan can host energy-intensive production stages outsourced from technologically-advanced countries for different products of aerospace, chemical, textile, and food industries. On top of cheap electricity, the proximity to final consumers in the large markets of China and Russia would make such outsourcing appealing to TNCs. The prospects look particularly favourable as TNCs are now seeking new, cheap-labour manufacturing locations in Asia to replace China with its rising wages.

Last, there are also fundamental differences in the supporting infrastructure between the current and previous technological paradigms. The latter relied on analog telecommunications and networks of seaports, airports and highways, while the existing ICT paradigm is making use of digital telecommunications and high-speed, increasingly autonomous, unmanned transportation, including drones, electric cars, and magnetic levitation (maglev) trains.

Telecommunications infrastructure is increasingly gaining in importance over the traditional infrastructure of highways, railroads, and pipelines. As a digital signal recognizes no boundaries and no distances, the transition towards telecommunication-based industries and services would enable the region to overcome its geographic isolation – a major barrier impeding its growth. Central Asia may serve as a land bridge between Europe and Asia if a web of railways is further expanded between China and Europe. China has recently built a network of roads and railways to Europe, traversing Central Asia, which markedly reduced the transportation costs and time for non-perishable goods. Furthermore, in 2016, Iran and India reached an agreement on the construction of the Chabahar seaport, on the Iranian side of the Persian Gulf. This port would open up a new transit route and access to the Indian Ocean for Afghanistan, and through it, for the other landlocked Central Asian countries.

By taking advantage of its geographic centrality and favourable regulatory climate, Bishkek may become a major node within this transport corridor, providing transit, logistics and storage services. In particular, Bishkek's Manas Airport is capable of handling large volumes of heavy cargo, including military-related, and has a relatively well-developed telecommunication infrastructure and plenty of space. It may therefore serve as a regional warehouse and distribution centre for Chinese e-commerce, fulfilling orders placed by Russian and Central Asian customers. Kyrgyzstan has already accumulated experience in storing and re-exporting Chinese consumer goods, e.g. through Dordoi Market, to Russia and other Central Asian countries, which can be now extended to e-commerce merchandize.

Success in all these areas hinges upon the availability of an extensive and well-developed telecommunication infrastructure as well as a cheap and reliable electricity supply. Unfortunately, AKT presently lack in both, but these constraints are not insurmountable. As discussed in Section 2, efforts are underway to expand and diversify broadband fibre-optic connectivity of AKT, for example, through construction of the new Pan-Central-Asian Fibre Optic Route, linking Kyrgyzstan and Tajikistan with Pakistan via Afghanistan. Moreover, Kyrgyzstan and Tajikistan have recently made significant strides in increasing electric power generation from domestic hydro resources. Afghanistan is yet to follow their suit by building hydropower stations and deploying its natural gas reserves. Looking closer, the current electricity deficit in Afghanistan is going to be partially met by exports from Kyrgyzstan and Tajikistan through the CASA 1000 transmission lines.

Finally, Afghanistan, Kyrgyzstan and Tajikistan should carefully pick industries and activities they would engage in through GVCs. These industries should hold the greatest potential in terms of achieving economy-wide productivity growth and generating linkages with other industries.

Based on the considerations of Section 3.3, it seems reasonable for AKT to join those (mainly, manufacturing) GVCs in which they lack basic technologies and experience while staying away from GVCs in which they already hold some expertise. For instance, AKT should shun agricultural and food-processing GVCs since giant TNCs, like Nestle or Danone, can simply bankrupt and devour their small farmers and agribusinesses – the mainstay of their economies – thereby wreaking major social and political havoc on the countries.

By contrast, participation even in labour-intensive, low-technology manufacturing activities, like the assembly of cars, TV sets, refrigerators and other electronic appliances, would be a significant technological leap for Afghanistan. Kyrgyzstan and Tajikistan should seek to insert their firms into more advanced manufacturing GVCs, for example, aircraft, nuclear equipment or precision instrument manufacturing value chains by leveraging their raw materials, e.g. REEs and aluminium, and their existing productive capabilities in these sectors, e.g. Dastan Enterprise in Kyrgyzstan and Tajik Aluminium Company (TALCO) in Tajikistan.

4. Technological and Industrial Upgrading in AKT Economies

We now sketch, in broad brush strokes, the type of industrial upgrading and targeting AKT can pursue to jumpstart economic growth. This discussion is speculative and should by no means be construed as a recommendation. Priority economic sectors and related innovation strategies can only be identified and developed based on careful technical analysis through a broad participatory approach, involving all stakeholders: governments, businesses, academia and research institutions in the concerned countries. And once developed, the strategies and policies will have to be continuously modified and adapted to changing circumstances.

That said, the framework of the previous section suggests a three-pronged strategy for industrial modernization of AKT economies. First, AKT should upgrade their existing industries with the aid of new technologies. The upgrading can take the form of new products (e.g. new crops and structured metals) or new processes (e.g. automation of production and logistics).

Second, AKT should climb up the technological ladder by establishing new, higher-value sectors, i.e. by undergoing intersectoral upgrading. Such upgrading would allow AKT to diversify their presently unbalanced industrial structure. The new strategic sectors should be chosen such as to build complete value-added chains based on the countries' existing extractive industries, comparative advantages and global demand. Moreover, these industries should generate strong multiplier effects through backward and forward linkages with other industries.

Last but not least, AKT should sow the seeds of future hi-tech industries, e.g. bio- and nano-technologies, by financing R&D in knowledge-intensive sectors (e.g. new materials, advanced machinery, bio-technologies, medicine, energy) and by expanding and enhancing education at all levels.

As discussed earlier, AKT are starting from a low industrial base with ample underutilized physical capacity. There is therefore no threat of worker displacement by machines in the short-to-medium term. The proposed measures envisage reviving presently idle, abandoned plants and/or building new production facilities and, therefore, stand to create rather than to shred jobs. Moreover, the envisaged technological modernization would help the countries anticipate and mitigate future labour force redundancy problems precipitated by the upcoming technological paradigm.

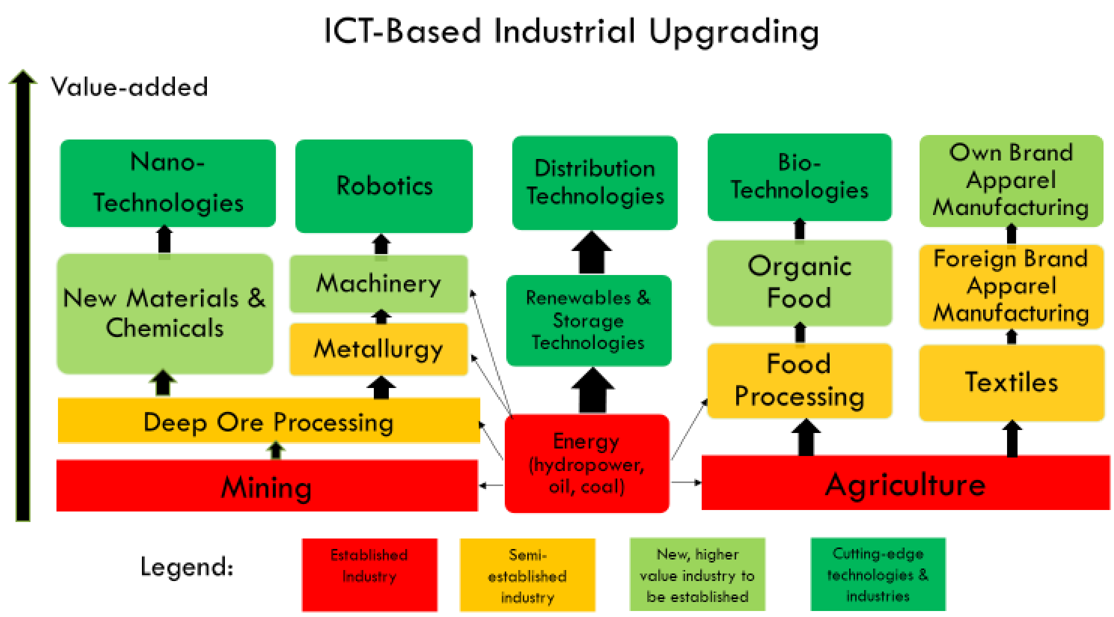
4.1. Potential Industrial Structure

One possible industrial structure for the AKT economies consistent with the proposed industrial strategy is depicted in Figure 20. It is organized along the five core value chains underpinned by the existing sectors: mining, agriculture and energy, all shown in red. Built upon these existing sectors are the associated higher-value, processing industries: ore processing and metallurgy grounded in mining, and food processing and textiles rooted in agriculture, shown in yellow. These processing sectors either used to exist or still exist in one or another form in Tajikistan and Kyrgyzstan. They should be revived, expanded and modernized. A more detailed discussion of these industries is given below. As for Afghanistan, processing industries should be built from scratch, jointly with the related extractive industries as integrated value chains.

The next level – mid-tech industries – of the value-added ladder, shown in light green, comprises the chemical and machine-building sectors based on mining, and own brand apparel manufacturing and 'green' products based on agriculture. These sectors would serve as a foundation for cutting edge, technology-intensive sectors such as nano-materials, robotics and biotech, marked in dark green.

Among the mid-tech sectors, machine-building based on locally produced materials is the key to technological modernization. Perhaps, none of the worlds' technologically advanced countries have attained this status without being engaged in machine production at one stage or another of their development. A strong manufacturing base is indispensable for building a technologically advanced, prosperous nation. Even today with the shift to knowledge-based economies, the role of advanced manufacturing is difficult to overestimate. For example, critical parts for modern aircrafts or medical equipment still need to be manufactured and assembled by skilful metal turners and welders. And, clearly, these parts need to be made of special durable materials supplied by an advanced chemical industry. In the longer run, chemical industry and machine-building would serve as a stepping-stone to high-tech industries, including nano-technologies and robotics. Likewise, an advanced agro-processing industry based on R&D would spur the development and deployment of new biotechnologies.

Figure 20. Potential Industrial Upgrading in AKT Economies



Next, the centre of the diagram illustrates potential upgrading based on the energy sector. A robust and flexible energy sector that fuels and fosters technological development of all other sectors is the prerequisite for the industrial modernization of AKT economies. At the heart of such energy industries is the electricity system. The twenty-first century has opened a new page in the electrification process, which is assuming, like a century ago, a central role in global technological development. This time, electricity generated from non-hydrocarbon sources is penetrating large sectors of the economy like transport and heating, presently dominated by oil and natural gas. Apart from higher efficiency, 'green' electricity is critical for curbing carbon emissions. Electric vehicles are predicted to make up about 10% of the global car stock by 2030 owing to exponentially declining battery costs, e.g. lithium-ion batteries.

Furthermore, there is a trend towards the diversification and decentralization of electricity generation and storage. As renewables, e.g. solar and wind, become increasingly economical and widespread, there is a growing need for new electricity storage technologies. For instance, solar energy can be collected during sunny hours, e.g. via rooftop solar photovoltaic (PV) technologies and used to smooth the demand during peak evening hours, thereby offloading the central grid pressure and cutting costs. Effective storage technologies thus render the electricity system flexible by allowing the energy to be stored and discharged when it is needed most. Renewables and distributed generation could be the only viable options in rugged mountainous terrains of Afghanistan, Kyrgyzstan and Tajikistan where it is very costly to lay new infrastructure.

Moreover, the electric power distribution system – grid – itself is becoming increasingly distributed or decentralized. Conventional large-scale, centralized grids carrying electricity in one direction from a central generating station to customers are being replaced by flexible grids accommodating bidirectional electricity flows and real-time energy management by customers. In such systems, customers may choose and schedule their consumption based on price signals received via smartphone apps, e.g. lower prices at off-peak times. And in the long run, electric power grids could become completely wireless, using the emerging magnetic induction and resonant coupling technologies. Finally, there is a wide range of digital technologies that could increase the efficiency of existing electricity networks, including smart meters, smart sensors, remote control, optimization and aggregation platforms.

The Kyrgyz and Tajik electricity systems fuelled by clean hydropower are pretty much on this global energy trend. Smart meters and sensors are being installed in Kyrgyz industrial and residential units to reduce losses and theft. In addition to the completion of the ongoing hydropower dam constructions, these countries need to diversify their generation capacity to include renewables, e.g. solar, wind and biogas, and to strengthen and optimize their existing electricity systems by adopting distributed storage and transmission technologies discussed above. Of particular relevance are micro-grid systems based on solar energy and mini- and micro-hydropower stations suitable for remote mountainous areas.

Unfortunately, lacking even the most basic electricity infrastructure, Afghanistan presently cannot adopt cutting-edge grid technologies. However, it has the 'last mover's' advantage of learning from others' experiences and putting its new infrastructure on a modern technology footing from the outset, which is less costly than to fix an old infrastructure. Moreover, all three countries can capture the benefits of the current global energy trends by supplying lithium-ion batteries, PV elements and other parts made of local rare earth elements.

4.2. ICT-Based Industrial Upgrading – Digital Industry

Having sketched the general picture, we now flesh out the individual components of the proposed industrial strategy. The existing industries – mining, energy and agriculture – can leverage digital technologies to automate and optimize their production processes and logistics.

Automation shrinks costs and raises productivity by performing operations carried out manually or with man-controlled machinery. For instance, the Tajik Aluminium Plant is in dire need of modernization; maintenance of the existing equipment is costing the plant millions of dollars annually. Negotiations are now underway with Chinese Yunnan Construction and Investment Holding Group on the purchase and installation of an energy-efficient, fully-automated electrolysis technology, which is to replace the traditional manually-handled electrolysis process. The existing aluminium conglomerate will also be augmented with a new plant with the capacity of 503,000 tons a year, consisting of iron foundry and anode production branches. Some 1,100 new jobs are expected to be created.

Similarly, the Kyrgyz mining industry also needs drastic modernization. As discussed in Section 2.5, Haydarkan Mercury Plant and Kadamjay Antimony Combine are using outmoded technologies; their production processes are not automated and most of their operations, like ore drilling and loading, are performed manually. In addition to automating production, Kyrgyzstan's mining industry should also adopt new ore processing technologies. Traditional cyanide-based gold refining can, for example, be replaced with cleaner non-cyanide technologies, e.g. gold flotation and gravity separation processes. One such technology has recently been pioneered by the Kurandy Developing company in the Chui Province of Kyrgyzstan.[24]

Moreover, a broad array of digital technologies, including robots and artificial intelligence, big data and analytics, 3D printing, blockchain and the Industrial Internet of Things (IIoT), is coming onboard to deepen and consolidate automation itself. Combining these technologies could magnify exponentially their individual capabilities and production capacity in general. Currently, most automated hardware performs a single function and needs human supervision. IIoT can connect disparate, fragmented functions into a seamless and efficient process. IIoT is made of four interconnected layers: (i) hardware that captures data, e.g. sensors, chips, actuators, radio devices, (ii) wired and wireless communication technologies that transmit the data to (iii) the data analytics layer that extracts useful information and passes it onto (iv) the service layer that takes actions based on this information.

Big data analytics is a collection of statistical and analytical techniques used to uncover statistical relationships and patterns in the system's performance from large volumes of structured and unstructured data – big data – and to predict, on that basis, the system's future behaviour. Some examples include data mining, cleaning and visualization tools, machine learning algorithms (classification methods, regressions, support vector machines, hierarchal tree and graph methods), and fast numerical optimization algorithms. All these tools enable firms to process and generate real-time insights from big data.

Moreover, blockchain technologies can facilitate, and even revolutionize, the payment, contracting, tracking and delivery processes in all economic sectors: industry, finance, retail, transport, healthcare and other service industries. Blockchain technology combines two key functionalities of digital record keeping (i.e. database) and distributed digital record sharing (i.e. network). Every transaction is encrypted and recorded on a block, and multiple parallel copies of an encrypted transaction are run on the network in real-time. No single node in the network contains all the information required to extract or alter the record; at least half of the nodes in the network must approve a transaction. The technology thus enables fast, transparent and secure decentralized execution of financial, contractual, logistical and other transactions. As a result, the blockchain can enhance the efficiency and transparency of the business processes both in the service sectors, industry and government.

Despite their current economic state, Afghanistan, Kyrgyzstan and Tajikistan may embrace these digital technologies, as they are increasingly becoming affordable. Some of these technologies are now free of charge, e.g. open-source software. As for commercial tools, AKT can purchase or develop data analytics software for industrial usage. The latter is not beyond the reach of Kyrgyzstan and Tajikistan. They may mobilize their own IT and engineering capacity inherited from the Soviet Union to design home-spun data analytics tools. An increasingly large number of start-ups, research institutions and private individuals in Kyrgyzstan are developing and selling their software and mobile applications. For instance, the Farm, a Kyrgyz IT start-up, launched a range of transportation, e-commerce and e-services mobile apps, including Namba taxi, Namba food, the e-commerce platform Sellbeing and others.

With the cost of a sensor dropping from $2 to 60 cents, IIoT offers an efficient and fast instrument of predictive maintenance in all industries. It can be deployed at a reasonable cost through-

[24] Kyrgyz Tuusu No 94, 5 December 2017, p.8, accessed online at http://www.gezitter.org/interviews/65810_gendirektor_osoo_kurandyi_developing_maksat_jeenaliev_myi_ne_ispolzuem_tsianid_v_proizvodstve_zolota/

out the AKT mining, energy and processing industries. For example, sensors and chips implanted in equipment can send signals on its performance via a wireless mobile network, the analytics layer can then process the data in near real-time and generate information that would allow immediate intervention to prevent equipment failures. Thus, digital technologies can enable an effective asset life cycle management.

If the equipment still breaks, 3D printing can come to its rescue. 3D printing or additive manufacturing is the process of making 3-dimensional objects based on a digital model by depositing successive layers of material. The technology can create objects of any configuration and complexity, ranging from clothes and houses to complicated instruments and human bodies. The 3D technology may drastically reduce the inventory and transportation costs by allowing just-in-time and on-the-spot creation of required objects. For example, replacement parts of critical equipment, whose downtime is either too costly or unacceptable, can be printed right on the spot. Of course, this requires prior availability of high quality digital blueprints and proper material. The chemical industry of Tajikistan can produce chemical powders and plastics that serve as ‘ink’ for 3D printing.

Not only can digital technologies make hardware more reliable and efficient, they can also empower and safeguard workers in the mining sector. For example, workers at dangerous mining sites can be equipped with smart wearables (e.g. glasses, helmets) and smart gadgets, connected with each other via a wireless communication technology. Smart sensors alert workers to environmental hazards, e.g. unsafe doses of poisonous substances, and smart connected gadgets enable workers to coordinate and carry out their tasks more efficiently.

As with the mining sectors, the AKT agricultural and agro-processing sectors can be furnished with ICT technologies for crop farming, livestock breeding and food processing. Satellite monitoring systems can alert farmers to impending frosts, droughts, floods and other inclement weather conditions, thus reducing crop losses. Vegetable harvests are particularly sensitive to soil quality, temperature and moisture levels. Wireless sensor networks can monitor and transmit real-time data readings on the moisture, carbon, nitrogen, potassium, calcium and magnesium levels of the soil. Sensors and biosensors can also be employed for quality and process control within the AKT agro-processing industries. Another example is the use of radio-frequency identification devices for tracking cattle and sheep to prevent their theft or loss in mountainous pastures.

Furthermore, ICT technologies can facilitate the modernization of irrigation infrastructure. The existing wasteful surface or spate irrigation practices in AKT can be replaced with digitally-controlled irrigation systems supplying each crop with the amount of water it needs, neither too much nor too little. Sprinkle irrigation practices are especially relevant for arid and hot regions of Tajikistan and Afghanistan. Remote control devices installed on farmers’ mobile phones can aid in the distant operation of irrigation pumps and canals. Moreover, rainwater harvesting technologies could also be introduced, especially in Afghanistan which relies mostly on melting snow and rainfall. Afghan farmers may however lack the literacy to be able use ICT-based tools for irrigation, and, at the beginning, they would need to be trained. The operation of rainwater harvesting systems can be delegated to local authorities in Afghanistan.

These are just a few examples of how digital technologies can be harnessed to modernize the existing AKT industries. However, automation and digitalization of the existing extractive industries and agriculture alone are insufficient for genuine industrial upgrading of the AKT economies. Afghanistan, Kyrgyzstan and Tajikistan should not merely extract their natural resources but should progress to higher value-added production. The processing industries such as ore refining, metallurgy, chemical, food processing and textile industries are natural transitory steps in this process. We take up this theme in the following sections.

4.3. Upgrading along the Agricultural Value Chain

Kyrgyzstan's and Tajikistan's agricultural exports are mainly concentrated in unprocessed cotton and tobacco, while Afghanistan also exports some limited volumes of raw cotton (about 2.9% of total exports). The prices of these primary commodities have fallen markedly over the last decades, and at the same time, with rising global health awareness, horticulture (fruit and vegetable cultivation) has become the fastest growing agricultural sub-sector.

Given their climatic conditions, all three countries are well positioned to become exporters of fresh and processed fruits and vegetables to global markets. For instance, Kyrgyzstan's recent accession to the Eurasian Economic Union (EEU) may potentially open the vast (around 180 million people) markets of the member countries (Russia, Kazakhstan, Belarus, and Armenia) to Kyrgyz agricultural products. Moreover, AKT could also take advantage of the international sanctions placed on Russia by filling in for the EU's fruit and vegetable exports to Russia.

Fresh and dried fruits and nuts already occupy top positions in Afghanistan's export basket in 2015: edible nuts (5% of total exports), and grapes and raisins (11% of total exports). There are around a million farms and 2,000 wholesalers in horticultural products in Afghanistan. With additional investment, it is possible to expand commercial farming in horticulture crops. Afghanistan has already established a well-known brand and gained popularity for raisins, pomegranates, pistachios and almonds in the neighbouring markets of China, India, Iran and Pakistan. The reputation for fresh fruits can be extended to a broader variety of processed food and beverages with some marketing effort.

Against this background, the agricultural export strategy in AKT should focus on: (i) boosting exports of vegetables and fruits rather than unprocessed cotton or tobacco, (ii) attaining import substitutions and food security in basic crops consumed domestically such as wheat and rice, and (iii) raising the share of export-oriented, higher value-added segments such as cotton textiles (instead of unprocessed cotton), cigarettes (instead of tobacco), processed food and organic food production. These goals are of a particular importance for Afghanistan which is grappling with the eradication of illegal opium production and looking for alternative livelihoods for its large rural population. Moreover, the development of a vigorous food-processing industry would generate demand for downstream industries in AKT, including agricultural machinery, chemicals, packaging, and bottling.

Parallel to the demand growth, competition and quality requirements in global agricultural markets have also become intense. As discussed earlier, these markets are now dominated by global value chains (GVCs) run by TNCs. GVCs are imposing increasingly stringent standards on the quality of agricultural products, including their chemical content (which is primarily determined by soil quality, moisture and temperature regimes), phytosanitary, certification, and packaging requirements.

These developments necessitate the modernization of the AKT agriculture sectors along the entire value chain, from land management practices through agro-processing to the distribution systems and output marketing. AKT agrobusinesses cannot reach these overarching objectives without government support. AKT governments need to formulate and implement comprehensive modernization programmes for their agricultural sectors. A detailed discussion of policies is given in Section 5. Here, we outline some key reforms.

Despite being predominantly agricultural economies, Afghanistan, Kyrgyzstan and Tajikistan use only a small fraction of their total land mass for crop cultivation because of their mountainous terrain and arid climate; only 6% of the Afghan total land mass is arable, and these figures for Kyrgyzstan and Tajikistan are, respectively, 6.8% and 5.8%. Furthermore, about 90% of forests in Afghanistan have been lost to illegal logging. Deforestation coupled with overgrazing has led to considerable soil erosion and desertification in all three countries.

In this light, one of the priorities in agricultural modernization in AKT should be the reclamation and amelioration of highland soils for crop cultivation. The governments should involve domestic research institutes in the development of new land cultivation techniques, including zoning, soil preparation and tillage, crop rotation, and irrigation practices. For example, various legume varieties, e.g. alfalfa, peas, beans, lentils, peanuts, can be cultivated in nutrient-poor soils of arid and semi-arid areas of AKT. The roots of legumes host some nitrogen-fixing bacteria that reduce the need for fertilizers and increase harvests. Further, land rotation schemes between crop cultivation and animal husbandry, e.g. rotation legumes with wheat, barley or tree planting, should be widely employed to rescue pasture lands.

Moreover, new varieties of drought-resistant grass, e.g. from Africa, can be introduced to increase forage production for domestic animals. This could boost production of both beef and milk in all three countries. 'No-till', or zero direct drilling, agriculture techniques can also be experimented with in the areas where farmers lack access to tractors and ploughing machines. Lastly, acid soils, e.g. former mining sites, can be reclaimed by pouring large amounts of chalk and pulverized limestone – mined in Tajikistan and Kyrgyzstan on an industrial scale.

More generally, the AKT governments should develop integrated agricultural clusters, encompassing all segments of the production chain from land and animal husbandry through product processing to packaging and distribution. The existing packaging practices in AKT are outdated; they lead to considerable waste of agricultural harvests and undermine international competitiveness of the remaining produce. Establishment of a modern packaging industry for agricultural products is therefore critical for all three countries.

General policies in support of clusters are discussed in Section 5. Here, we just give some examples of agricultural clusters. For example, fruit and vegetable clusters can be founded in Issyk-Kul and Batken oblasts of Kyrgyzstan, Sughd Region of Tajikistan and Helmand Province of Afghanistan. These clusters can produce fresh, dried or canned apricots, grapes, plums, apples, pears, peaches, melons, tomatoes, beans, pomegranates and juices thereof. Similarly, pistachio-processing clusters can be created in Badghis and Samangan provinces, and a potato-processing cluster in Bamiyan Province of Afghanistan. The Tajik and Afghan governments can also set up new export-oriented industries centred on the production of sunflower oil.

The AKT governments should promote coordination and collaboration between cluster businesses and research institutions as well as support argo-businesses in the acquisition of modern technology, construction of processing plants, purchase of modern dryers, juice-making and packaging equipment, development of marketing strategies and the provision of storage and transportation services. Furthermore, the AKT governments need to improve transport infrastructure and logistics to ensure fast and seamless movement of agricultural produce inside the countries.

Another obstacle in the cluster development involves achieving international reputation and quality certification. To overcome it, the AKT government can establish sanitary & quality control and certification centres. Such centres are particularly crucial for organic food producers. For instance, Bio Farmer, an organic food producers' association of Kyrgyzstan, comprises more than a thousand certified producers of cotton, sunflower seeds, beans, and medical and aromatic plants. To obtain certification, these producers had to pay, on average, US$10,000-12,000 to various foreign companies. Clearly, such expenses are beyond the means of most small farmers. Therefore, certification services should be provided free of charge in a centralized fashion by the governments. These centres would also help the agro-processing companies of Kyrgyzstan and Tajikistan secure long-term supply contracts with EEU supermarket chains.

4.4. Upgrading along the Mining Value Chain

4.4.1. Deep Ore-Processing

The current state of the AKT mining industries is reviewed in Section 2.5. Here, we discuss some new production and technological upgrading opportunities within these industries.

Despite the large scale of the existing mining (gold, silver, antimony, mercury, lead, zinc) operations in Kyrgyzstan and Tajikistan, most of their mined ore is exported unrefined or semi-refined, in the form of concentrates. For instance, gold ore from most Kyrgyz and Tajik gold mines is sold abroad either unrefined or semi-refined, e.g. in the form of doré bars. Except for TALCO, the existing ore-processing plants of Kyrgyzstan and Tajikistan do not have a complete metallurgical production cycle, producing concentrates rather than final metal output. Meanwhile, Afghanistan has not even begun developing its mines let alone processing ore or producing metals.

Since they all are sitting on the common Pamir-Tian-Shan geological plate, Afghanistan, Kyrgyzstan and Tajikistan have similar mineral endowments, albeit of different grades and sizes. Most of their deposits are characterized by complex mineralization, i.e. contain a range of valuable chemical elements instead of just one. For example, gold ore may contain copper, silver and rare earth metals, and these minerals are often disposed of as waste. The main reason for such inefficient use of resources is the lack of complex extraction and deep processing technologies. This problem is particularly acute in the case of Kyrgyzstan's rare earth elements (REE) – valuable and strategically important minerals. Because of the lack of REE processing technologies, Kyrgyzstan is forfeiting hundreds of million dollars annually.

Rare earth elements are a group of 17 chemical elements in the periodic table, including the 15 lanthanides, scandium and yttrium. Fibre-optic cables, wind turbines, electric cars, smartphones and other devices produced by aerospace, atomic, military, communication, pharmaceutical, electronics, and energy industries – all depend critically on components made of REE. In a way, REE are outstripping petroleum as the most strategic mineral resource. Although relatively widespread, REE rarely occur in concentrated forms, and are, therefore, costly to extract. Currently, China is the largest producer of REE, accounting for about 70% of the global supply. Until the early 2000s, China was the global monopolist with a market share of 97% and used its REE as a weapon in trade wars with the US and Japan. For this reason, the US and other industrial countries are presently seeking alternative sources of REE.

All three countries – Afghanistan, Kyrgyzstan and Tajikistan – have economically significant reserves of REEs, but do not possess adequate extraction and refining capacity. Presently, Afghanistan has no refineries. The ore-processing plants and refineries of Kyrgyzstan and Tajikistan, discussed in Section 2.5, are either shutdown or operating below their capacity due to obsolete technology or the shortage of raw materials. Thus, given their rundown physical productive capacity and lack of modern technologies, Kyrgyzstan and Tajikistan are now operating at the lowest level of the mining value chain, adding little value to its mineral exports.

To make the most of their mineral resources, AKT should upgrade their existing or build new ore processing and metallurgical plants with complete production lines, including refineries, rolling mills and pressing shops. Particularly, Kyrgyzstan's Kara Balta Combine should be equipped with copper- and silver-processing technologies to reach full capacity utilization. This would allow both economies of scope and more efficient processing of local composite gold-copper-silver ores. Next, a sufficient and stable local supply of bauxite from domestic deposits should be secured for TALCO, which presently depends on imported alumina. As for Afghanistan, it needs to start mining its rich lithium deposits and simultaneously launch production of lithium-ion batteries, currently in high demand in global markets.

Moreover, all three countries should obtain rare-earth metal extraction and refining technologies, for example, from Lynas Advanced Materials Plant in Malaysia. It is one the world's largest REE processing factories, operating with the industry's state-of-the-art technology. AKT could form joint ventures and/or purchase REE separation technologies from this company.

In addition to metal ores, Afghanistan is also rich in natural gas and oil. The country's crude oil reserves are estimated at 3.8 billion barrels; its natural gas reserves – at 444 billion cubic meters. Most of its oil and natural gas deposits occur in the northern provinces of Balkh and Jawzjan. In 2011, a contract for the development of three oil fields along the Amu Darya River was awarded to the Chinese National Petroleum Corporation. The Chinese company is to extract 1.5 million barrels of oil annually, and to build several oil refineries within four to five years. The oil production at these fields commenced in October 2012.

As Afghan oil and natural gas industries are sprouting up, Afghanistan needs to come up with an effective long-term strategy for the industry's development. Instead of restricting itself to the extraction of crude oil and natural gas, Afghanistan should operate along all segments of the hydrocarbon value chain – from upstream operations such as exploration, production and refinement of petroleum and natural gas to downstream ones such as marketing and distribution. It should also develop complementary industries such as drilling, construction and distribution. One way to accomplish this goal is to establish a petrochemical industrial cluster in Balkh and Jawzjan provinces, embracing all stages of production from drilling, recovering crude oil and natural gas through processing them into diesel, gasoline, kerosene and other petroleum products to manufacturing polymers and plastics. Natural gas should be used extensively for electricity generation, in addition to hydropower plants. Several natural gas fields, exploited during the Soviet occupation and frozen later under the Taliban regime, were brought back into operation under the Karzai government.

Finally, Afghanistan and Tajikistan should also exploit their precious stone endowments. In particular, Afghanistan's precious stone reserves are truly exceptional both in terms of composition and scale: emerald, ruby, sapphire, amethyst, garnet, lapis lazuli, jade, kunzite, spinel, tourmaline and peridot, just to name a few. More than 1,400 precious stone deposits have been discovered so far. These gemstones need to be mined and processed on an industrial scale by domestic mining companies, and then sold to domestic jewellers, instead of exporting them to India, to promote local value addition by small artisan businesses.

4.4.2. Metallurgy

Despite the presence of a broad raw material base, ferrous metallurgy is non-existent in all three countries, while the nonferrous metallurgy sectors are relatively sizeable in Kyrgyzstan and Tajikistan.

The importance of ferrous metallurgy feeding steel into the heavy machinery and construction sectors is difficult to overestimate. In fact, most of today's advanced economies, even those without raw materials, e.g. Japan, South Korea and China, have large iron and steel industries, and their industrialization began precisely with the establishment or modernization of their iron and steel industries, which propelled growth in all other sectors.

Kyrgyzstan and Afghanistan are now considering the development of their biggest iron deposits: Jetym deposit in Naryn Province of Kyrgyzstan, and Hajigak deposit in Bamiyan Province of Afghanistan. Thus, their prospective iron and steel sectors could fully source iron ore from domestic mines. The Afghan and Kyrgyz steel industries would in turn serve as a solid base for their machine-building sectors.

Kyrgyzstan and Afghanistan should build modern integrated metallurgical-rolling-mill plants with automated (scheduling, set-up and control) processes. In these automated systems, all computers, large and micro controllers are connected into a local area network to perform communications in an optimal way. The plants need to be located nearby the iron ore deposits to reduce transportation costs. Another advantage of these locations (Naryn and Bamiyan provinces) is the availability of substantial coal reserves to fuel the metallurgical plants. The equipment and technologies for steel plants could be purchased, leased or acquired through setting up joint ventures with large foreign corporations.

As for Tajikistan, it needs to modernize its giant Aluminium Plant – the backbone of its economy – by installing new equipment, augmenting production capacity and introducing new products. First of all, domestic supply of bauxite needs to be safeguarded; the plant presently depends on imported alumina, whose supply is running short. Second, as mentioned earlier, the outdated electrolysis equipment and processes need to be replaced with modern automated machinery and processes. Third, new aluminium rolling mills and pressing shops need to be built to expand the production of aluminium sheet and profiles. Fourth, ancillary metal ware and consumer goods shops need to be founded to manufacture higher value-added products from aluminium, e.g. Teflon appliances, automobile and bicycle wheels. As for new products, one of the most promising niches in non-ferrous metallurgy today are the so-called 'boutique' metals, i.e. metals with special upgraded properties, including structural steels and aluminium alloys. TALCO is well-positioned to adopt these technologies and launch the production of boutique metals for export.

4.5. Upgrading along the Manufacturing Value Chain

A well-balanced and sophisticated manufacturing sector is the key to technological and industrial upgrading of economies since manufacturing serves as the main generator and testing polygon for core technologies before they diffuse throughout the economy. The manufacturing sector is the producer of capital goods: the equipment and machinery employed by virtually all sectors of an economy are created by the manufacturing sector. Moreover, organizational and managerial practices of the manufacturing sector, such as assembly line, specialization of tasks and quality control, have penetrated other sectors. Because of its high receptiveness to technological innovations, e.g. automation and digitalization, the manufacturing sector generates the highest productivity growth in the economy, which further spills over the whole economy.

The advantages of manufacturing over agriculture and mining are well-known and undisputable. First, the manufacturing sector reaps higher profits owing to the predominantly oligopolistic structure of the markets in which its products are traded. In contrast, agricultural and mining commodities are traded in highly competitive commodity markets, controlled by global speculators rather than producers. As a result, the prices of primary commodities have been exhibiting a steady downward trend exacerbating by extreme volatility. A well-balanced manufacturing sector mitigates the country's exposure to the risks stemming from fluctuations in commodity prices. Finally, the manufacturing sector creates a greater number of higher skilled and higher paid jobs than mining or agriculture, thus building solid human capital on top of strong physical capital. All these factors make the manufacturing sector the main engine of economic growth.

Based on these considerations, the development of a robust and diversified manufacturing sector that relies on local inputs and generates strong linkages to other domestic industries is of the utmost importance for Afghanistan, Kyrgyzstan and Tajikistan, contrary to arguments put forth by sceptics of industrialization. The government policies to stimulate the manufacturing sector are detailed in Section 5. Here, we remark that the AKT governments need to remove all levies and other barriers on the imports of machinery and technology for their manufacturing sectors. The potential structure and specializations of these sectors are elaborated below.

4.5.1. Chemical, Construction and New Materials Industries

Tajikistan's chemical industry holds great promise due to the country's abundant raw material base and cheap hydropower energy. Presently, it is represented by the Yavan Chemical Plant, specializing in the production of nitrogen fertilizers, explosives, paints, coatings, caustic soda, and chorine-containing products for household use.

The Tajik chemical industry can be upgraded through its cross-pollination and integration with the country's metallurgical and oil refining industries. For example, a range of plastics and polymers can be manufactured from oil extracted in the Northern Tajikistan fields. Next, silver mined at the Adrasman mining complex can be fused with plastics to fabricate friction-resistant, durable parts for industrial machinery. Also, aluminium sulphate and other chemicals can be derived from aluminium supplied by the Tajik Aluminium Company. Over time, the industry can transition to more advanced chemicals.

Unlike Tajikistan, Kyrgyzstan does not seem to have any comparative advantage in the chemical industry. Nonetheless, the country can still carve out a niche at low ends of the composite- and nano-materials industry, by leveraging its REE resources. Specifically, Kyrgyzstan can obtain technologies for the synthesis of rare earth oxide and sulphide nanoparticles. REE nanoparticles exhibit a range of unique properties such as high surface area, low light scattering and quantum confinement effects. These properties have recently found a range of useful industrial applications, for example, as coatings in the electronics and automotive industries. These nanoparticles are expected to be employed widely in the pharmaceutical, biomedical and renewable energy industries in the near future.

In the longer run, once it builds sufficient technological capability, Kyrgyzstan may switch to the production of new materials with programmable properties, i.e. materials that can change their properties in a controlled fashion, e.g. nanomaterials. Yet, programmable materials are not limited to nanomaterials, but also include materials obtained through traditional physical and chemical methods, for example, electro-permanent magnets and piezoelectric elements, which are not beyond the realms of possibility for Kyrgyzstan. Production can be located at the Kyrgyz Chemical-Metallurgical Plant in Orlovka, which has a REE processing shop, and expertise in the fabrication of silicone mono-crystals – advanced photovoltaic material.

A prospective petrochemical industry for Afghanistan was already discussed in Section 4.4.1. Aside from basic petrochemicals like ethylene, propylene, and butadiene, it could manufacture higher-value, advanced polymers, plastics and aromatics. The petrochemical industry would thus enable Afghanistan to not only climb up the technological ladder but also to achieve import-substitution and security in such strategic resources as gasoline, diesel, kerosene and polymers. This prospective industry could become the country's main growth engine.

Finally, all three countries are endowed with massive deposits of construction minerals, including limestone, gypsum, sand, clay, gravel, granite and marble. Unfortunately, most of these construction materials are still imported to AKT. Of the three countries, Tajikistan has the largest construction material industry, and in particular, the largest cement plant – Tajik Cement Plant.[25] The product nomenclature includes cement, bricks, gypsum, steel-concrete blocks and marble slabs. Since 2011, the Tajik construction material sector has seen a sharp rise, orchestrated by the Tajik government. There were around 200 companies in the sector with a total turnover of US$175 million in 2014, of which 13 were cement plants with a total capacity of 2.34 million tons per year. The cement production now satisfies domestic demand, and the first cement exports to Afghanistan began in 2016.

Despite its extensive raw material base and growing domestic demand, the Afghan construction materials sector is in a rudimentary state, and most construction materials are imported from Pakistan and Iran. Presently, there are only two active cement plants in the country: Ghori plant with the capacity of a thousand tonnes a day and the other near Kabul with the capacity of one hundred tonnes a day. The plants are struggling with shabby equipment and intense competition from Pakistani producers. Afghanistan has abundant marble reserves, but its industrial extraction has yet to take off. The country should exploit its comparative advantage in construction materials to substitute imports and to diversify its economy.

[25] Here, we do not review the AKT construction sectors; they are sizeable and growing rapidly. The focus is on the production of building materials.

The Kyrgyz construction material industry is rather small, limited to extracting basic raw materials (sand, clay, gypsum and limestone) and manufacturing bricks, cement, concrete and glass therefrom. The sector's largest firm is the Tokmok Interglass Plant, exporting glass and glass-based products to neighbouring countries. The second largest export product is *sary-tash*, a local travertine-type shell-limestone used as façade and wall covering.

The AKT's construction material sectors should be expanded, diversified and modernized by: (i) increasing the production volumes of existing products (cement, concrete, bricks) to satisfy domestic demand and to substitute imports; (ii) introducing new, higher value-added products for export like marble and granite tiles, ceramic roofing materials; and (iii) deploying new machinery (e.g. automated stone-cutting machines) and new technologies such as modular construction materials, micro-structured light-weight materials and 3D printing. The development of this sector is especially crucial for the success of Afghanistan's efforts to kickstart its war-torn economy.

4.5.2. Electronics and Machine-Building Industries

Unlike its metallurgical and construction material sectors, Tajikistan's machinery industry, which manufactured low-voltage electrical and textile equipment played a minor role even under the Soviet Union, and disintegrated quickly after its collapse. There are presently plans to resuscitate the sector by setting up agricultural machinery production. Two Belarusian agricultural machinery companies intend to launch tractor assembly plants in the Hisor District of Tajikistan.[26]

Likewise, Afghanistan is attempting to mould its nascent machinery sector through a series of programmes aimed at enhancing the productive capacity of domestic SMEs. For instance, in 2011, the Afghan Ministry of Commerce and Industries jointly with the World Bank launched the Facility for New Market Development to help firms access technologies and market knowledge in processing and manufacturing industries.[27] For example, Jawed Factory, one of the programme's beneficiaries based in Jalalabad, has been making and supplying agricultural machinery, e.g. threshing machines, vehicle-pulled trolleys, to Afghan farmers for years. Afghan firms are also collaborating with their Iranian counterparts to set up the production of food processing machinery, home appliances and construction materials.[28]

All these examples indicate strong potential for the development of manufacturing industries not only in Kyrgyzstan and Tajikistan, but also Afghanistan. Neighbouring Uzbekistan's success in building its own automobile industry through active industrial policies is another encouragement for AKT. Of course, the countries should carefully choose their specializations, not only to maximize linkages with their existing industries and utilize efficiently their natural resource base, but also to anticipate changes in global markets and consumer tastes. For Tajikistan, two directions seem to be the most promising: first, agricultural machinery manufacturing, where some progress is now being made, and second, manufacturing of aluminium-based parts for the aerospace and automobile sectors, using materials supplied by TALCO.

Given its lack of productive capabilities, it seems more natural for Afghanistan to first enter low-technology, labour-intensive manufacturing, e.g. in the electronics and automotive industries, by performing assembly from imported parts for GVCs and then to gradually move to more technology-intensive manufacturing. Other potential manufactured products for export include lithium-ion batteries, copper cables and fixtures made of local raw materials.

[26] http://news.tj/en/news/belarusian-farming-machinery-manufacturers-launch-assembly-plants-tajikistan

[27] http://www.worldbank.org/en/news/feature/2015/10/28/made-in-afghanistan-agricultural-equipment-aims-to-meet-market-demand

[28] http://acci.org.af/component/content/article/38-news/655-1st-afghan-iran-production-machinery-and-light-industries-joint-expo.html

As for Kyrgyzstan, a detailed review of its machine-building sector is given in Section 2.5. As demonstrated there, there is significant production capacity in Kyrgyzstan inherited from the Soviet Union, which however, needs to be re-built and modernized. Kyrgyzstan needs to swiftly revive its machinery sector before the knowledge and skills accumulated during Soviet times are irreversibly lost.

In particular, Kyrgyzstan should restore the production of agricultural equipment, e.g. tractors, combines, on the basis of Bishkek Agricultural Machinery Plant, and launch the assembly of consumer electronics products (e.g. TV sets, refrigerators, washing machines etc.) on the basis of Bishkek Heavy Electric Machinery Plant. To this end, it should seek to forge partnerships with Bosh, Siemens, Samsung, LG and other big corporations in order to tap into their technologies and capital.

Moreover, the production processes at the two active plants – Dastan Enterprise and Mayli-Suu Electric Lamp Plant – need to be modernized, and new product lines need to be introduced. For instance, Dastan Enterprise can be upgraded to produce modern precision instruments, lasers and optical devices for the atomic and medical industries, while Mayli-Suu Plant can move onto the production of sophisticated TV and computer screens leveraging its existing capabilities and light-emitting diode technologies.

4.5.3. Textile and Apparel Industries

The current state of the AKT textile and apparel industries is reviewed in Section 2.5.

Over the last decade, Kyrgyzstan and Tajikistan have increased their apparel exports, by carving out niches in the Russian and Kazakh markets. Despite these successes, the majority of Kyrgyz and Tajik apparel firms still perform cut, make and trim functions, i.e. they sew cheaply for a specific buyer under the buyer's brand and using the buyer's designs and imported fabrics – the practice known as original equipment manufacturing. Yet they can dramatically increase their value by creating and marketing their own designs. There are a large number of young talented Kyrgyz and Tajik designers, who win prizes in international fashion competitions every year. Kyrgyz and Tajik apparel makers can design their own brands through collaboration with domestic designers and upgrade to own design manufacture, just as South Korean and Taiwanese firms did in the 1960s.

Furthermore, the Kyrgyz apparel industry depends on imported fabrics as the country's own fabric manufacturing industry is effectively dead. Some steps have recently been taken to revive it; for example, in 2017, a cotton spinning plant based on Uzbek raw cotton was inaugurated in the city of Tokmok. As for wool fabric manufacturing, the prospects of its renaissance look dim since much of Kyrgyzstan's fine merino sheep stock has been slaughtered, and much of the machinery has been sold for scrap.

By contrast, Tajikistan has preserved critical sector-specific knowledge and capabilities in the fabric manufacturing sector, which enabled it to launch a large-scale rehabilitation programme for the industry. In particular, seven new cotton spinning plants, predominantly Tajik-owned, equipped with state-of-the-art equipment from Italy and Central Europe have been put into operation. Together, these factories employ over 1,000 workers and have an annual capacity of more than 26,000 tons of cotton yarn. The foreign equipment suppliers have transferred the relevant technologies and provided technical assistance to the Tajik firms, some of which have even signed contracts to purchase the yarn. The combined sales of these seven plants are expected to exceed US$10 million per year.

The Tajik government is currently making considerable efforts to consolidate its garment and textile industries into vertically-integrated value chains based on domestic raw cotton. These value chains are to comprise all stages of production, ranging from yarn spinning, weaving and dyeing to apparel design, cutting, sewing, and marketing.

Tajikistan's strategy should be followed by Kyrgyzstan and Afghanistan. They, too, need to develop complete, vertically-integrated value chains in their textile and apparel industries. To this end, Afghanistan needs to establish, and Kyrgyzstan needs to revitalize their cotton and wool fabric manufacturing from domestic raw materials. Wool production is especially critical for the Afghan carpet industry, which is now experiencing severe shortages of high grade wool, see Section 2.5. Second, they need to upgrade their apparel industries by equipping them with modern sewing machines and technologies, and need to develop brand design capacity and switch to the own design manufacturing model. All three countries can become a possible destination for the re-localization of global apparel assembly from China, by capitalizing on their geographic location, cheap labour and materials as well as favourable international trade regimes.

Finally, Afghanistan and Tajikistan should expand and re-vamp their carpet-weaving sectors by strengthening the carpet design capacity, introducing quality control and developing an effective branding and marketing strategy. In particular, Afghanistan should set up the production of both natural and synthetic dyes for carpets and build modern carpet processing facilities in order to repatriate this higher-value added segment of the supply chain from Pakistan. The government should also promote the purchase of modern machinery by Afghan carpet-weavers and protect their designs by legislating and enforcing copyright laws.

5. Government Policies

Just as the technological structure of economies varies widely across countries, policies in support of technologies and related industries span the full spectrum of measures, from trade protection to trade openness, from establishment of large scale, state-owned corporations to promotion of small and medium private enterprises, from targeting specific sectors to creating a generally favourable environment.

Broadly speaking, technological policies can be classified into two categories: horizontal and vertical. Horizontal policies aim at the creation of a general conducive environment for technological development, including infrastructure development, human resources development, macroeconomic stability (low inflation, stable exchange rates, etc.), R&D promotion and SME support. In contrast, vertical policies target specific industries, providing them with tariff protection, subsidies, tax benefits, low interest loans, government procurement contracts, training and technical assistance.

To remain effective and relevant, policies should evolve in sync with the country's technological development and global economic environment; each stage of technological development demands its own set of policies tailored to its changing needs and realities. Governments should anticipate them and adjust accordingly their policies.

The required capacity of AKT governments required to implement these policies is a topic for a separate extensive study, and as such, is beyond the scope of this paper. While the lack of government capacity is a valid issue, its extent and ramifications are often exaggerated by opponents of industrial policy who advise governments not to embark on industrial modernization. This seems to be a fallacious, circular-reasoning argument: governments can only build this capacity by attempting such policies, i.e. through 'learning by doing'. And, as the experience of many newly-industrialized countries (e.g. South Korea and Taiwan) demonstrates, it does not have to be too long or too costly a process. What is more important is the absence of corruption and political will of governments to follow through the reforms.

Clearly, security and political stability are the two key factors that impinge upon the success of economic recovery and modernization in Afghanistan. Unfortunately, the lack of progress regarding these two pre-requisites is currently hindering FDI flows into the country. Yet, despite the difficult security situation, Afghanistan has recently managed to attract investments into its extractive and telecommunication sectors. The rents from these sectors can be used to pacify and co-opt local tribes into economic recovery efforts. Moreover, construction of a Turkmenistan-Afghanistan-Pakistan-India gas pipeline and CASA electric powerlines are also hoped to improve the livelihoods of local tribes. These socio-economic improvements would in turn help to curtail violence and thus contribute to building a lasting peace in the country. Thus, achieving political stability and economic recovery is an intertwined process.

In this paper, we do not make traditional policy recommendations. Instead, we discuss various policy options which the AKT governments may consider when shaping their policies. In areas as strategic and complex as industrial and technological upgrading, there cannot be easy solutions and prescriptions, and especially, those imposed by external consultants. We again stress that technological and industrial modernization programmes can only be conceptualized by the countries themselves based on a broad national consensus on the country's development priorities.

5.1. Vertical or Industrial Policies

Vertical policies, also known as industrial policies, have long been criticized and advised against by neoliberal economists. They are also discouraged under WTO regulations. In general, there are two main of schools of thought in modern economics concerning industrial policy: the neoclassical theory of comparative advantage, based on the Heckscher-Ohlin model, and the theory of infant industry promotion.

According to the theory of comparative advantage, a country must specialize in the production of goods in which it has a comparative advantage, and any attempt to change the country's export basket, e.g. through industrial policies, leads to a misallocation of resources and inefficiencies. The theory is premised on the assumption that all countries have the same technology and productive capabilities,[29] but differ only in their factor endowments such as capital, labour and natural resources – sources of comparative advantage. However, this assumption is not borne out by the reality: nations vary widely in their productive capabilities and access to technologies, which is precisely one of the root causes of the economic prosperity of some nations and the economic backwardness of others.

To overcome their backwardness and enter high value industries, less developed nations have to thus develop their productive capabilities and acquire advanced technologies. This is one of the central tenets of the theory of infant industry, first proposed by US Treasury Secretary Alexander Hamilton. The theory holds that governments of backward economies need to deliberately enhance their productive capabilities by nurturing and protecting their selected 'infant' industries through a mix of industrial policy instruments until these industries become strong enough to compete with producers of more advanced economies. Critics argue that given informational frictions, it is difficult, if not impossible, for governments to pick 'winners' – targeted industries – and there is a danger of rent seeking and capture by vested interests. Instead, they advocate *laissez-faire* and restrict the scope of government interventions to horizontal policies.

At the same time, a growing body of empirical evidence suggests that (i) economic growth is associated with diversification rather than specialization (Imbs and Wacziarg, 2003); (ii) specialization patterns are not determined solely by factors endowments, i.e. comparative advantages; many successful countries have defied their static comparative advantages and leaped to the global technological frontier through carefully crafted industrial policies; and (iii) growth accelerations are generally associated with structural changes in the direction of manufacturing.

Further, successful experiences of East Asian countries suggest that a properly crafted and implemented industrial policy that evolves in sync with global technologies and the country's econom-

29 Productive capabilities are personal and collective skills, productive knowledge and experience that are embedded in physical agents and organisations" (Andreoni, 2011).

ic trajectory can put a developing country on the path towards long-term sustained growth. For example, deviating from its comparative advantage in the labour-intensive textile, apparel and plywood industries, South Korea targeted the capital-intensive steel, chemical, automobile and shipbuilding industries in the 1970s, and later, in the 1980s, jumped to the knowledge-intensive semiconductor, computers and electronics industries, thereby debunking the theory of comparative advantage.

More generally, history shows that none of the existing advanced economies have achieved economic prosperity by relying on free markets alone. As Rodrik (2004) puts it: "It is not true that there is a shortage of evidence on the benefits of industrial policy. To the contrary, it is difficult to come up with real winners in the developing world that are not a product of industrial policies of some sort". Industrial policy is indispensable for technological advancement as it induces structural changes, creates demand for technologies and allocates resources to carry out technological modernization and diversification, thereby reducing the country's exposure to external shocks and driving its sustained economic growth.

5.1.1. Priority Sectors and Production Scale

Since the targeting of selected industries is at the heart of industrial policy, we begin with a discussion on potential priority sectors for Afghanistan, Kyrgyzstan and Tajikistan. Given their small domestic markets and resource constraints, all three countries – Afghanistan, Kyrgyzstan and Tajikistan – should target a few strategic industries that have the highest export and technological potential. These sectors should induce robust growth in other industries through backward and forward linkages, and serve as a launching-pad for high-tech, knowledge-intensive industries in the longer run. As discussed above, the economic theory suggests two alternative approaches: (i) focusing on industries in which the country has comparative advantage, i.e. factor endowments, and (ii) venturing into new industries in which the country has no comparative advantage but which promise high rewards and technological progress.

Based on their comparative advantages, AKT should pursue industrial upgrading along the two existing value chains: mining and agriculture, as elaborated in Section 4. This involves developing natural resource-processing sectors, including agro-processing, textile, apparel, non-ferrous metallurgy and chemical industries, using local resources.

However, the value-added and economic rents of resource-processing sectors are modest and vulnerable to global price shocks. Moreover, full-fledged technological modernization and diversification may be too slow or impossible to realize, thus relying on processing industries only. In parallel to natural resource-based industrial upgrading, AKT should therefore set up new, higher value manufacturing industries based on a careful assessment of global competition, export markets and other risks. Kyrgyzstan can revive its agro-machinery and heavy-machinery building sectors on the basis of the former Bishkek Heavy Machinery Plant, Bishkek Agricultural Machinery Plant, and Defence Enterprise Dastan. Kyrgyzstan can also enter the renewable (e.g. solar) energy and new materials sectors, drawing on its rare earth metals endowments. Tajikistan can establish an advanced manufacturing industry, e.g. producing parts for aerospace and electronics sectors, based on its Aluminium plant.

Similarly, Afghanistan can launch local material-based manufacturing and chemical sectors concurrently with developing its abundant mineral resources, e.g. oil, natural gas, iron and rare earths. As a first step, Afghanistan should engage into global value chains to perform assembly, e.g. manufacture of electronics, and then gradually move to the assembly of more technology-intensive components. Yet, unlike Kyrgyzstan and Tajikistan, to exploit its natural resources, Afghanistan first needs to build a basic infrastructure of roads, power generation and transmission.

Ideally, commodity exports should generate income for AKT to finance their higher value-added, knowledge-intensive industries. In turn, the higher value industries should trigger the expansion and technological modernization of the natural resource-processing industries. Just as private firms, AKT governments need to choose a portfolio of industries so as to diversify risks and secure sufficient return on investment. Indeed, the comparative advantage and the infant industry approaches are not mutually exclusive but rather complementary. This is in line with Lin's (2012) modified neoclassical theory of comparative advantage. This theory argues that developing countries should anticipate their future comparative advantage using international benchmarking, i.e. looking at specializations of more developed countries with similar starting conditions. Yet this theory does not seem to be applicable to AKT as it is hard to come up with benchmark countries, especially for the post-Soviet states of Kyrgyzstan and Tajikistan.

In the case of Kyrgyzstan and Tajikistan, it seems more natural to benchmark against their past Soviet-level industrial performance: first, they need to restore their previous productive capacity in some selective manufacturing industries, and then, to move onto adjacent technologically-intensive sectors. As for Afghanistan, it needs to build a basic infrastructure in parallel to developing its mining and agricultural sectors, and once certain minimal productive capabilities are built, move to manufacturing industries.

Having identified the priority sectors, the countries need to decide on the scale of enterprises in these sectors. Mass production, capital-intensive sectors, such as chemical, metallurgy and machine-building, typically call for large production scales to achieve international competitiveness, while small batch, differentiated product industries such as apparel, agro-processing, and software, require smaller and more flexible firms.

Technologies for small batch, differentiated products (e.g. food, apparel, software) can be imitated, reverse engineered or developed locally. If needed, required technologies could also be licensed, but care must be taken to avoid outmoded or excessively expensive technologies. In these sectors, more competition and market segmentation, through SME promotion, should be allowed in order to stimulate quality improvements and rapid technological progress.

In contrast, technologies for capital-intensive sectors are difficult to imitate or develop locally and should therefore be either licensed or purchased on a turn-key (off-the-shelve) basis from foreign corporations. Alternatively, the countries can form joint ventures with transnational corporations to access the required technologies. To the extent possible, the states must seek to retain at least a 51 percent equity stake in the strategic capital-intensive sectors.[30] AKT can circumvent WTO restrictions by ingeniously crafting entry conditions for foreign companies.

As a matter of fact, if countries kept a certain sector unbound, they are free to impose limits on foreign equity ownership and mandate joint ventures in this sector. For instance, the Afghan Law on Private Investment is very liberal with respect to foreign investments, presently allowing 100 percent foreign ownership and full repatriation of profits in most of its economic sectors. As an LDC, Afghanistan is free to impose restrictions in certain strategic industries.

5.1.2. Technology Transfer Policies

In general, technologies can be acquired through technology licencing, FDI or the purchase of related machinery. Moreover, some mature technologies can be obtained without large financial investments through informal mechanisms such as hiring foreign experts and learning from open sources. Each of these methods has its own advantages and disadvantages.

In the case of FDI or technology licencing, foreign companies – technology or FDI suppliers – would naturally be reluctant to transfer state-of-the-art technologies, offering instead obsolete, lower-quality technologies. Even if a developing country secures an advanced technology, it would often lack the domestic expertise and skills to adapt and utilize it, thus becoming dependent on a foreign counterpart. For these reasons, developing countries tend to import cheaper, outdated technologies instead of core technologies. The purchase of machinery or turn-key plants is more

[30] Generally, local ownership requirements are now prohibited under WTO's TRIM Agreements.

difficult and expensive but prompts the country to develop local technological capabilities to use, adapt and improve the technology.

To tackle all these issues, the AKT governments need to devise a smart regulatory framework for FDI and technology importation. First, mandatory technology transfer requirements can be incorporated into the FDI regulations. Such requirements are generally not prohibited under WTO rules, and should be actively used by all three countries. Second, the sectoral composition of FDI and imported technologies can be screened and controlled by the AKT governments through preferential treatment of FDI going into their priority industries. As in the cases of Japan, South Korea and China, both domestic firms and foreign subsidiaries may be mandated to obtain government approval for technology licensing, in order to prevent imports of obsolete, low-quality technologies or inflated licensing fees.

Further, although banned under WTO Trades Related Investment Measures (TRIM), export requirements, i.e. selling the output overseas, can also be imposed on FDI.[31] Typically, exports entail higher quality standards and force foreign companies to bring in more advanced technologies. R&D requirements may also be incorporated in the FDI regulations.

Moreover, each FDI arrangement with TNCs should be carefully negotiated and crafted to maximize the transfer of technologies and the building of local technical expertise. To this end, the formation of joint ventures of AKT state-owned enterprises with TNCs appears to be an effective strategy. Through joint ventures, AKT can retain control over enterprises and gain better access to technologies. The quality and quantity of technologies as well as the related technical assistance, R&D and local personnel training should be clearly stipulated in each case. A more comprehensive list of such requirements, known as local content policies, is discussed in the following section.

To incentivise technology transfer by TNCs, AKT can employ a variety of policies, including R&D subsides, tax holidays, guarantees on repatriation of profits and so on. Strategic and careful courting of FDI, rather than their blind and unconditional pursuit, would thus maximize technological and knowledge transfers.

Technologies may come not only from overseas; the countries can (and should strive to) generate indigenous technologies, especially in agricultural, agro-processing, and textile industries in which they already possess some productive capabilities. International design, branding and marketing practices can be imitated and adapted by the AKT apparel industries without formal technology transfers. To support indigenous technology transfers, AKT governments can set up state agencies to finance pilot firms that develop, adapt and spread innovative technologies across the country. Funding must be conditional on firms demonstrating the feasibility and applicability of their technologies as well as on training other firms in the application of these technologies.

Generally, it seems reasonable for AKT, in their earlier stages of industrialization, to import more mature manufacturing technologies for standardized products that are easier to use and to adapt by local personnel. However, as the domestic human and financial capitals accumulate, the countries should undertake their own R&D and develop indigenous technology in the strategic sectors.

5.1.3. Financing Mechanisms

The AKT governments can channel low cost financial capital to their strategic industries either through existing or new, special-purpose state banks. For example, Kyrgyzstan's state-owned

[31] Challenging in a WTO dispute is a long and difficult process. The challenging member has to collect evidence and go through numerous panels and committees before the verdict is passed and countervailing measures are taken. The WTO procedural timeline thus gives developing countries considerable leeway.

Ayil (Agricultural) Bank is already providing low (half of the market rate) interest loans to agro-businesses. As in the cases of Japan, South Korea and China, all three countries need to set up state-owned development banks and export banks to supply low interest loans for the purchase of machinery and technologies to their export-oriented firms. The funding for these banks can come from domestic savings or can be raised through import levies.

Instead of looking for foreign loans, the AKT governments should seek to mobilize domestic funding for their strategic industrial projects. One option is to accumulate export proceeds from extractive industries in a sovereign fund. Another option is to introduce forced saving contributions both by employers and workers to government pension funds, as Singapore did in the 1980s. The government can also issue special purpose sovereign bonds to finance strategic projects. For instance, to fund the construction of the Rogun Dam, Tajikistan recently raised US$1.8 billion by selling sovereign bonds to its population. This experience should be emulated by Kyrgyzstan and Afghanistan in their efforts to modernize their energy sectors and infrastructure.

Commercial banks should also be incentivised by the AKT central banks to issue low interest loans to export-oriented firms. More generally, the AKT governments should enhance the financial intermediation capacity of domestic banks, including their capacity to mobilize domestic savings, to extend lending to rural areas, and to improve availability of and access to financial information. Strategic enterprises should be exempt from collateral requirements and backed by government guarantees. Moreover, they need to be provided with accelerated depreciation on capital investments, and other indirect capital subsidies.

The AKT governments can also develop markets for equipment leasing, i.e. obtaining the use of machinery on a rental basis, by putting in place a proper legislative framework and encouraging domestic banks to lease equipment to firms on concessional terms. The advantages of leasing over the purchase of equipment include conserving working capital and avoiding cash-devouring down payments as well as tax benefits and lower monthly payments. For example, the Kyrgyz government is currently implementing a government-funded agricultural machinery (e.g. tractors, combines, fork-lifters) leasing programme through Ayil Bank. Since 2014, the equipment leasing transactions have totalled one and half billion soms (about $23 million).

To finance infrastructural projects and export-oriented firms, the AKT governments should also avail themselves of concessional funding offered by regional or interstate cooperation mechanisms, e.g. the Russian-Kyrgyz Fund, the Chinese Belt & Road Initiative. Concessional loans should be issued only to export-oriented firms in the strategic sectors, and not to retail trading businesses, e.g. Asia Mall, as recently happened in Kyrgyzstan.

Furthermore, public-private partnerships should be fostered. AKT governments can set up co-investment funds to leverage private investment into high-risk start-ups. Typically, private sector co-financing is a signalling mechanism that an investment passes a market test and a real demand exists for the product. These funds would provide seed money to innovative technology-based firms that lack access to funding or face prohibitive financing costs. Government co-investment funds would structure the domestic investment market, enhance local businesses' deal-making capacity and help them attract foreign investors.

Finally, all three states can act as venture capitalists and incubate high-technology firms in their strategic sectors, e.g. set up ICT incubators. The AKT governments can establish National Investment Funds with 100% public capitalization, which, like venture funds, would make long-term investments in the strategic manufacturing and high-tech industries such as ICT, bio- and nano-technologies.

5.1.4. Infant Industry Protection under WTO Regulations

Opponents of the infant industry approach claim that past protectionist industrial policies of developed countries cannot be followed by today's developing countries because of the changed rules of the game in the international arena, including increasingly stringent WTO regulations and harsh intellectual property rights laws – the phenomenon dubbed as 'shrinking industrial policy space'. However, on closer inspection, there still remains ample room under WTO regulations for developing member countries to conduct industrial.

First, the WTO's General Agreement in Tariffs and Services (GATS) does not rule out import tariffs *per se* but requires a member state to bind its tariff rate on a product-by-product basis, i.e. to set and commit to an upper tariff limit. A country's applied tariff rates may be well below its bound rates, thus providing the country with latitude to legally raise tariffs within the limit to further their industrial policy goals. For instance, Kyrgyzstan's average applied rate was 4.4%, well below the average bound rate of 7.7%, and Tajikistan's average applied tariff rate was 5.16% while its average bound rate stood at 8.0% in 2016. Afghanistan has the lowest tariff rates in the Central Asian region, e.g. 2.5% tax on imported machinery and only 1% tax on imported raw materials.[32] Moreover, as a least developed country (LDC), Afghanistan enjoys exemptions from some export restrictions. For example, it may use export subsidies to protect its infant industries from foreign competition.[33] Afghanistan should exercise care to grant such privileges only to selected strategic industries, e.g. manufacturing and agro-processing, but not mining, to avoid becoming trapped in low value extractive industries.

Second, GATS does not prohibit export taxes and regulates loosely many types of services. AKT can use export taxes to stimulate local processing and value addition to domestic raw materials, e.g. metal ores and crude oil. The countries kept themselves unbound in a number of service sectors, such as ICT services, healthcare and entertainment, and are therefore free to protect these sectors.

Third, there are a lot of grey areas in the interpretation and application of the WTO's subsidy regulations. While sector-specific subsidies are banned, subsides for R&D, 'green' technologies and disadvantaged regions, though considered as 'actionable',[34] are not strictly enforced and used widely by developed countries. For the most part, export-oriented extractive industries in AKT are located in remote mountainous areas, so the countries can easily resort to the 'disadvantaged region' argument to introduce subsides in these industries. New manufacturing plants can also be built in economically distressed regions, e.g. gem stone and chemical plants in the Gorno-Badakhshan Autonomous Region of Tajikistan and Badakhshan Region of Afghanistan.

Next, AKT can also support their strategic sectors through direct and indirect R&D subsides. For example, the governments may compensate firms' R&D spending up to a certain limit from a special fund, or firms may be allowed to deduct their R&D expenditure from their taxable incomes. Some production subsides can also be disguised as R&D subsides. Furthermore, other subsidies such as financial incentives, credit finance and infrastructure financing are also permitted.

Last, an array of non-tariff protection measures for infant industries (e.g. government procurement, R&D and worker training requirements for large firms) is largely exercised by countries at various stages of development, including WTO member states. For the most part, these are so-called local content policies. In view of their importance and widespread use, we discuss them in more detail in the next section.

In conclusion, the AKT governments would be well-advised to exercise caution when entering into any bilateral or regional trade agreements, including free trade agreements and preferential trade agreements with developed countries, as these agreements tend to be even more restrictive than WTO regulations.

32 Afghanistan's Customs Department, http://mof.gov.af/en/documents/category/customs-documents

33 http://ecdpm.org/wp-content/uploads/DP205-Local-Content-Trade-Investment-Ramdoo-December-2016.pdf

34 In the WTO parlance, a subsidy is actionable if other WTO members may challenge it as adversely impacting their economies. The burden of proof lies on the member that feels adversely affected. If injury is proven, the country may be subjected to countervailing measures.

5.1.5. Local Content Policies

Local content policies aim at maximizing the benefits that accrue to the domestic economy from a production activity. Despite their formal ban under WTO rules, local content policies, in one form or another, remain widely used throughout the world. They typically require a producer to source its inputs from the domestic economy, including both labour and raw materials, thus generating backward linkages with upstream/supplier industries. As such, these measures restrain the volume of imports and foreign labour brought in the country by foreign companies. For instance, metallurgical or chemical firms may be forced to use local raw materials or even to buy and operate related local mines.

Local content policies may also mandate the producer to sell a certain share of its output to domestic industries, thus stimulating forward linkages with downstream industries. For example, mining companies may be required to supply ore to domestic refineries and metallurgical plants; or metallurgical plant may be required to take ownership of and to operate a domestic deposit.

Consequently, local content policies contribute to economic integration through promoting strong forward and backward linkages. Such policies are especially relevant to extractive industries in developing countries, which tend to be isolated from the rest of the economy, forming so-called enclave-economies. Depending on the type of linkages, local content policies can be classified into two groups: (i) measures that promote upstream linkages, i.e. local sourcing of inputs; and (ii) measures that foster downstream linkages, i.e. local value addition to outputs.

Afghanistan, Kyrgyzstan and Tajikistan should make smart use of both types of policies. Some of these measures, e.g. import restrictions, are prohibited under WTO rules, but some are not, e.g. R&D requirements. Their legality and appropriateness need to be determined on a case-by-case basis. To a large extent, these would depend on the country's circumstances and whether numerical (volume or value) obligations and corresponding enforcement mechanisms, e.g. penalties for non-compliance, are specified. Numerical targets may trigger WTO complaints and disputes, and their compliance may be difficult to monitor and to enforce. On the other hand, if no numerical targets are specified, the measures may be ineffective. Both 'sticks' and 'carrots' can be employed to enforce local content requirements. Yet given the lack of AKT governments' monitoring capacity, the 'carrots' approach should be favoured. For example, the use of local content should be taken into account in the granting of tax exemptions and profit repatriation privileges to foreign companies.

As all three countries are WTO members, it seems more appropriate for them not to legislate formal local content regulations, but instead to negotiate these requirements with foreign companies on a case-by-case basis, taking into account the industry, investment and production volumes, and other specific circumstances.

The first group of policies can be applied both to the AKT's existing extractive and future manufacturing industries. These policies may take the form of procurement requirements, employment and training requirements, R&D spending requirements, and ownership requirements. For instance, foreign investors in manufacturing sectors can be required to purchase local raw materials (e.g. oil, metals, cement, wood), services (e.g. local subcontractors) as well as to hire and to train local personnel in order to safeguard demand for local products and to establish an integrated higher-value domestic value chain. Local employment, training and R&D requirements are another important class of industrial policies that should be actively pursued to build local productive capabilities in technologically-intensive sectors. In particular, numerical R&D spending targets need to be introduced. Typically, R&D and training requirements are not prohibited by WTO regulations. AKT governments should therefore make full use of these instruments and encourage foreign companies to employ and train certain percentages of the local workforce, especially in higher-skills positions, e.g. engineers, technicians etc., with a view of ensuring transfer of technologies and know-how.

The second class of policies should be mainly geared towards the existing AKT extractive industries with the dual goals of (i) developing export-oriented manufacturing industries (e.g. machinery, chemicals) that would add value to unprocessed minerals and would export higher-value products; and (ii) import-substitution of critical imported products (e.g. petroleum products, fertilizers). Specific measures include domestic market obligations, captive mining practices, export quotas and taxes (which are not prohibited by the WTO), export licensing, price floors for exports, and limiting the right to export unprocessed minerals to specific firms. For instance, domestic market obligations obligate mining companies to sell a certain share of their output to domestic firms, while captive mining may involve awarding mining rights on the condition that the mineral in question will be used only in domestic production.

In fact, Tajikistan has already in place some domestic market requirements with respect to a number of minerals mined on its territory, including iron, copper, nickel, lead, tin, zinc, molybdenum, magnesium, cobalt, cadmium, titanium, zirconium, aluminium and their scrap. Afghanistan and Kyrgyzstan should follow Tajikistan's suit. Particularly, export taxes and licensing should be applied to strategic rare earth elements in all three countries to induce their local processing and development of REE-based manufacturing. Furthermore, instead of exporting its unprocessed oil, iron, copper and other non-ferrous ores, Afghanistan should set up smelters, refineries and beneficiation plants to export refined metals and petroleum products. Kyrgyzstan possesses a number of refineries and smelters, e.g. Kara Balta Refinery, Orlovka Combine, Kadamjay Antimony and Haydarkan Mercury Processing Plants, but they are either shutdown or operating on the brink of being shut down because of outmoded technology or raw material shortages. As discussed earlier, these plants need to be modernized, if necessary re-profiled, and supplied with local ore. In particular, gold mining companies in Kyrgyzstan should be obligated to sell their gold ore to domestic refineries.

To sum up, local content policies are the key industrial policy instrument for forging linkages among industries and firms. Another policy option for building and strengthening inter-industry linkages is the promotion of industrial clusters.

5.1.6. Industrial zones or clusters

An industrial cluster is a group of interrelated industries or firms that are concentrated in one geographic area and are linked to each other through common flows of goods, services, labour and technologies. Clusters differ from industries or sectors in that they have stronger ties across firms and may encompass entire value chains from raw materials to end products, including infrastructure and support services. Ruhr Region in early-twentieth-century Germany or Silicon Valley in the USA today are examples of industrial clusters.

The benefits from establishing industrial clusters in AKT are fourfold. First, clusters would allow AKT to exploit economies of scale and inter-sectoral strategic complementarities through sharing inputs (raw materials, labour), support services (marketing, sales) and infrastructure (storage, distribution, transportation). This allows unit costs to be cut, productivity to be enhanced and thereby international competitiveness to be attained.

Second, clusters would allow AKT to overcome both horizontal fragmentation (among producers of the same good) and vertical fragmentation (among producers of different inputs along a chain) through founding producer cooperatives and vertical input-output chains. Instead of competing with each other, farmers within a cluster could organize themselves into cooperatives, pool resources and enhance their joint sales position. Or instead of importing mineral ore (e.g. alumina) from abroad, processing plants can use ore mined from local deposits and supply their output to local manufacturing plants.

Third, clusters may serve as vehicles of technology transfer and innovation. Geographic concentration leads to the development of specialized skills that catalyse the emergence of new technologies and the accumulation of knowledge, which then would spill over across the whole cluster. Finally, geographic concentration also gives rise to various research institutions, business associations and networks that further strengthen the cluster by providing organizational and co-ordinational advantages.

As the AKT economies are mostly concentrated in natural resources industries which do not generate strong linkages to other sectors, industrial clusters built upon natural resource industries may prove effective in tackling economic fragmentation and backwardness. For instance, food-processing (fruits, vegetables, nuts) clusters can be founded in Helmand Province of Afghanistan, Sughd oblast of Tajikistan and Issyk-Kul and Batken oblasts of Kyrgyzstan; cotton textile-garment clusters can be set up in Sughd and Khatlon provinces of Tajikistan, and a textile-garment cluster – in Bishkek. Furthermore, mineral-based industrial clusters can be created in all three countries: an aluminium cluster in the western Regar District of Tajikistan, a rare-earth-nonferrous-metals manufacturing cluster in Chui oblast of Kyrgyzstan, a construction cluster in Kabul and a petrochemical cluster in Takhar and Jawzjan provinces of Afghanistan.

Agroprocessing clusters in Helmand, Sughd, Issyk-Kul and Batken could produce juice concentrates, canned and dried fruits (e.g. apricots, grapes, apples, plums) and vegetables (e.g. tomatoes, cucumbers, beans), organic honey and bee products, processed nuts, pistachios, etc., which have high export potential in the markets of Russia, Kazakhstan and China. These clusters need to design a regional brand and a common marketing strategy to attract foreign investment.

Non-ferrous-metallurgy-centred clusters in the Chui and Regar regions of Kyrgyzstan and Tajikistan, respectively, could encompass the complete cycle production of high-value manufacturing products. For example, the Tajik aluminium cluster could comprise all stages of production from bauxite mining through aluminium refining and production (casting, extrusion, forging, plating, etc.) to parts for aerospace and automotive industries (e.g. wings, fuselages, tires, cables). The Kyrgyz rare-earth cluster could embrace a full production cycle ranging from extraction and processing to manufacturing high precision optical instruments, lasers and superconductors.

The reconstruction and rehabilitation of Afghanistan will not be possible without a stable supply of critical petrochemical products such as diesel, benzine, fertilizers, and construction materials such as cement, bricks, gravel, steel, sand glass and tiles, currently imported from China, Pakistan and Iran. All these materials can be made from local raw materials within potential petrochemical and construction clusters, in northern and north-western Afghan provinces.

Clearly, governments cannot arbitrarily force industrial clusters upon different regions; some initial conditions such as resource endowments and prior history of regional specialization must be met. However, once emerged, industrial clusters may not be able to organise themselves into cohesive and stable structures. This is especially true for larger clusters linking more diverse industries and firms of varying size, ownership and maturity.

The AKT governments can support their clusters by crafting fiscal and financial incentives (e.g. tax rebates, exemptions, low cost loans), improving infrastructure (e.g. roads, electric power supply), providing micro-credits to small producers, introducing international product quality control systems (e.g. labs), enforcing standardisation and certification, organizing research (e.g. technological innovation parks) and personnel training. For example, in agribusiness clusters, the main focus of government intervention should be on the provision of technical assistance to SMEs to comply with strict sanitary, environmental and quality standards imposed by global agricultural value chains. Such policies are especially effective if implemented at the cluster level because of the benefits of agglomeration.

More importantly, governments should put in place adequate legal, regulatory and institutional frameworks ensuring a level playing field for all cluster participants as well as promote dialogue between them. In particular, the AKT governments need to encourage regional research and educational institutions to participate in clusters. In metallurgical, chemical and manufacturing chains, research and innovation typically belong to leaders of the chain, i.e. large technologically-intensive firms. The governments should disseminate their innovations to SMEs and induce them to collaborate with leaders' research centres. Finally, the AKT governments could help their clusters establish contacts in export markets, and in particular, link them up with the country's diaspora residing abroad who can supply their funds, knowledge, skills and overseas business connections.

5.1.7. Industrial Planning, Monitoring and Evaluation

All industrial measures discussed above will not be successful without proper planning, execution and monitoring. As in the cases of Japan, Korea, Malaysia and a number of other newly-industrialized nations, careful industrial planning with clearly set quantitative and qualitative targets (performance indicators) as well as precisely delineated accountability measures (including rewards and penalties) may prove effective.

Industrial planning can be implemented through Five-Year Plans or other industrialization programmes. Ideally, the governments should draft and publish annual plans by product, industry and region to set targets against which the performance of state-owned enterprises in strategic industries is measured. In particular, clear criteria for success, accountability, and sunset clauses must be engineered. Performance evaluations should be conducted in a transparent way by independent committees comprising all stakeholders, and not by government agencies; good performers should be rewarded, e.g. through preferential access to loans, technologies, government contracts etc., bad performers – penalized by withdrawal of all subsides and other benefits.

Furthermore, a special government agency, e.g. Ministry of Industry and International Trade, should be instituted or designated among the existing ones to oversee and to coordinate the implementation of the country's industrial programme. In particular, this agency should coordinate both complementary investments, i.e. investments to complementary industries, and competing investments in the same industry (to avoid duplication and waste of resources) through entry regulations and relocation of resources. As practice demonstrates, coordination externalities cannot be handled by private actors. This government agency should be required to report regularly (e.g. monthly or quarterly) on export performance, production and technology adoption in strategic industries, as well as on global market conditions with a view of anticipating problems and devising their solutions. Such regular meetings are to introduce discipline and secure attention from top leadership.

Next, stakeholder advisory committees can be set up to identify key technologies and development strategies for each strategic sector through public-private consultations. For each of its nine strategic sectors, the Dutch government, for example, put together a team consisting of a technology expert, an innovative SME entrepreneur, a government official and a representative of research institutions to draw up an action plan for the sectoral development.

5.2. Horizontal Policies

Despite their importance, industrial policies alone are insufficient for the success of technological modernization and industrialization of nations. To be effective, they must be complemented with comprehensive and fine-tuned horizontal policies, including R&D, education, SME and infrastructure policies.

5.2.1. R&D Policies

The AKT governments can promote technological R&D both directly and indirectly. Direct government interventions in the past involved deploying special-purpose government research institutions (GRI), science and techno-parks to spearhead R&D in the priority technological areas. South Korea is a case in point, as it set up GRIs to assist domestic firms in the transfer of foreign technologies. The mismatch in the goals and culture of academia and industry prevented meaningful participation of Korean academic institutions in the early industrialization process. Besides, technology adaptations needed to be implemented within tight schedules and demanded specialized skills that academia was unable to deliver.

Kyrgyzstan and Tajikistan are likely to confront similar challenges as their existing academic and research institutions, on the one hand, and industries, on the other, are largely misaligned. Therefore, they should either establish new or re-organize their Soviet-era public research institutions into special-purpose, integrated GRIs, where they would concentrate both financial and human capital with a view of achieving rapid technological adaptations, and later, breakthroughs. The funding of GRIs can be raised through taxes on mining companies' profits, set, say, at 3 percent.

At the beginning, the focus of GRIs should be on the absorption, assimilation and adaptation of imported technologies. GRIs should provide technical assistance to domestic firms and produce experienced researchers. Since it takes time to build up local technological capabilities, GRIs should not be expected to obtain patents and deliver results right away. However, once a critical mass of knowledge and skills is accumulated, GRIs should generate and disseminate indigenous technology across industries. At this stage, clear performance targets (e.g. patents) need to be specified, and GRIs need to be held accountable to them.

For instance, Kyrgyzstan can re-profile its animal breeding, plant breeding and irrigation institutes as well as other ailing research institutes under the National Academy of Sciences into bio- and nano-technological research centres and laboratories to engineer new variety of crops, plant and animal breeding, land management and irrigation practices as well as new materials for smart food packaging, e.g. polymers and nanostructured materials.

Likewise, Tajikistan can re-organize its metallurgical and chemical research institutions under the National Academy of Sciences into GRIs tasked with the adoption (and, in the future, development) of technologies for its aluminium and chemical industries. War-torn Afghanistan will have to set up GRIs from scratch. Given its comparative advantages, GRIs specializing in mining, metallurgy and agriculture may be particularly relevant for Afghanistan. Finally, all three countries should also institute ICT academies to train ICT specialists and to design smart sensors, remote-control and other electronic equipment for their mining, energy and manufacturing industries.

Indirect support to R&D can take the form of R&D requirements and tax credits. The AKT governments can mandate large firms in technologically intensive sectors to spend a certain minimum percentage of their annual revenue on R&D. For example, China requires its high-tech companies to devote at least 5% of their annual sales to R&D activities; for example, Huawei spends on average 10% of its revenue on R&D.

To incentivise firms, the AKT governments can allow them to deduct R&D expenditure from their taxable income. In strategic sectors, such as ICT, bio- and nano-technologies, the deductions may be as high as 300% of the R&D expenditure. Furthermore, direct R&D tax credits can also be granted, especially to SMEs and start-ups in high risk industries and service sectors, e.g. pharmaceutical and software firms. These companies face greater risks and lack a financial cushion, and therefore, need immediate cash refunds, e.g. as reimbursements for payroll taxes on R&D related salaries. When designing R&D tax credit policies, the AKT governments should also differentiate among different types of innovations, e.g. incremental vs. radical, long-term vs. short-term R&D projects, and fine-tune their policies accordingly.

Next, the AKT government should promote multi-firm research consortia and collaboration between firms and academic institutions. Collaboration helps to avoid duplicative research and reduce R&D costs while stimulating synergies and knowledge spillovers across firms and academia. In particular, the governments need to encourage academia-industry networks in industrial clusters.

Finally, academic research in all three countries is grossly neglected by the governments. Faculty members are underpaid and have to work multiple jobs. There is lack of research grants, laboratories and access to scientific literature. The AKT governments should partner with the private sector and foreign donors to fund university R&D projects. Research grants should be performance-based and directed at highest priority technological areas, such as metallurgy, machine-building, biotechnologies and ICT. The governments should also promote commercialization of university R&D. In this regard, technology-holding companies set up and run by Korean universities present an interesting commercialization modality to emulate.

5.2.2. Vocational Training and Education Policies

The quantity and quality of a country's human capital are the main determinants of its ability to bridge the technological gap and to catch up with more advanced nations. And effective education policies are essential for building human capital adequate to the needs of technological modernization.

Afghanistan has one the lowest (36%) literacy rates in the world; the gross secondary and tertiary education enrolment rates are also dismal, standing at 55% and 8.5%, respectively. Some 3.3 million children (about 32 percent of the school-age population) – 75% of them girls – are still out of school, and there is an acute shortage of teachers, especially in rural areas. Given such low starting conditions, Afghanistan needs to expand and improve the quality of education at all levels: primary, secondary, vocational and university.

A bulk of the country's physical educational infrastructure lies in rubble and needs to be rebuilt. Nearly a half of all schools do not have a building[35] whose classes are held outdoors or in private houses. International organizations and donors have been financing the reconstruction of schools; however, with the withdrawal of the American troops in 2014, the amount of international aid has dwindled. Therefore, first and foremost, the Afghan government has to mobilize and deploy domestic resources to restore and strengthen its educational infrastructure.

Second, there is serious inequity in educational access across different socio-demographic groups and regions in Afghanistan. Particularly pronounced are gender (e.g. only 71 girls per 100 boys enrolled in primary education) and rural-urban disparities (e.g. most schools are located in cities and northern regions). When formulating educational policies, the Afghan government should therefore place special emphasis on providing access to quality primary and secondary education to disadvantaged and marginalized groups, including women and youth in remote mountainous regions.

Third, under the Taliban regime the curricula of secondary and high schools were shifted towards Islamic theological teachings, and since its collapse, no systematic effort to overhaul the curricula was made. The Afghan government needs therefore to initiate a substantive review and reform of the primary and secondary education systems, beginning with the development of modernized and standardized curricula along with clearly stated learning outcomes. The curricula must be shaped in such a way as to provide students with a solid background in math and sciences, as they are fundamental for modern industries. Specialized fast-track teacher training and re-training in these fields should be carried out throughout the country with a centre at the Helmand Institute of Teacher Training. To systemically monitor the progress, outcomes, and ef-

[35] "Afghanistan's education plan NESP-III focused on Quality, Access and effective management". IIEP-UNESCO. February 12, 2018.

ficiency of education programmes, the Afghan government should set up a national evaluation system. Lastly, policy options for the vocational and higher education spheres of Afghanistan are similar to those for Kyrgyzstan and Tajikistan, discussed below.

Since Kyrgyzstan and Tajikistan already have relatively high primary, secondary and tertiary education enrolment rates,[36] they need to focus more on the profile (i.e. specialties) and quality of education rather than its quantity. Just like their industrial systems, the Kyrgyz and Tajik educational systems are compositionally-skewed and misaligned with their labour markets. These countries are currently experiencing a skill mismatch between their vocational school and university graduates and the needs of their industries. There is a dearth of engineers, scientists and programmers, while there is a surplus of lawyers, managers and economists who are struggling to find jobs.

Many skilled workers and technicians trained during the Soviet times are now approaching retirement. The current vocational and higher education systems in these countries are unfit to meet the labour force replacement needs in technical specialties (some experts estimate the deficit at 400%). For instance, in Kyrgyzstan, the technical science graduates from higher education institutions accounted only for 9%, and the vocational school graduates in technical specialties[37] made up only 4% of total graduates in their respective pools in 2014.[38] Compounding the problem, many skilled workers, especially youth, are migrating abroad, having failed to find suitable jobs or unable to realize their professional potentials at home.

The low quality of available higher education is another concern for Kyrgyzstan and Tajikistan. The Tajik government spends about $215 per student per year, and the Kyrgyz government – $400 per student per year in higher educational institutions, constraining the ability of the higher education sector, which remains largely state-funded, to offer quality education. The low quality of professional technical and higher education hampers labour productivity and the overall technological progress in these countries.

Against this backdrop, the Kyrgyz and Tajik governments need to take a more differentiated and focused approach than Afghanistan, by upgrading their technical, vocational and higher education systems and creating decent career opportunities in the fields where they are experiencing shortage: mathematics, engineering, natural and technical sciences. They need to come up with effective mechanisms to ensure close collaboration between academic institutions and firms in the curricula design, internships, on-the-job training, attestation and guaranteed employment by sponsoring firms. Industry engagement is critical for enhancing quality and aligning educational programmes with the labour market needs. Additionally, professional re-training programmes in high-demand jobs such as programmers, web designers and telecom operators should be offered to the unemployed or workers in declining sectors or occupational groups.

Furthermore, all three countries need to strengthen technical and vocational training in the job categories that are critical for their strategic industries, including programmers, electricians, metalworkers, blacksmiths, welders, and turners. The governments need to establish a network of vocational schools and technical colleges spanning the whole country and put their students through mandatory on-the-job training and attestation at domestic mining and manufacturing firms before professional education certificates are issued.

Finally, the Afghan, Kyrgyz and Tajik governments should make the utmost effort to bring home their expatriate scientists, engineers, doctors and businessmen. Their numbers are particularly high for Afghanistan. These successful people are the core of the countries' professional elite,

36 Kyrgyzstan's secondary and tertiary enrolment rates are 93% and 47%, respectively, and Tajikistan's – 87% and 30%, respectively. Both countries have almost 100% literacy rates.

37 In the following fields: electronics, machinery, metalworking and computer sciences.

38 National Statistical Committee of the Kyrgyz Republic. Education and Science in the Kyrgyz Republic. Statistical Bulletin. Bishkek, 2014

holding the expertise and experience needed for industrialization and technological modernization. They would bring with them not only formal knowledge but also tacit knowledge and know-how, unwritten in books and manuals. Moreover, Kyrgyz and Tajik expatriates currently employed in Russian industries have gained the skills and know-how particularly relevant for the technological modernization of the Kyrgyz and Tajik economies since Russia possesses more advanced technologies, and the same time, shares a similar industrial structure.

5.2.3. SME Policies

If building technological and productive capabilities of large SOEs is a time-consuming, costly and risky process, it is all the more so for SMEs as technological capability accumulation requires indivisible and expensive inputs such as technology, machinery, R&D, worker training, product design and marketing – all of which are typically beyond SME capacities. At the same time, given their agility, flexibility and penchant for innovation, SMEs are increasingly becoming the main conduits for ICT-led technological innovation. Moreover, small and medium enterprises are key job creators in AKT. For these reasons, targeted government support to SMEs is essential in the current technological cycle.

Government policies in support of SMEs are no different from general industrial policies discussed earlier (low cost financing, export subsides, R&D and training subsides, local content requirements); indeed, perhaps they need to be more nuanced and focused. In addition, governments need to address informational asymmetries between entrepreneurs and investors.

The AKT governments need to encourage SMEs to adopt and assimilate new technologies for producing higher value-added products and services, for example, organic food, tourist services, software, Internet content and games. For this purpose, the governments need to provide start-ups and SMEs with product or export market information and advice as well as to connect them with potential investors and relevant research institutions. They also need to engage technology-oriented SMEs as subcontractors to government-funded projects in the strategic industries. This would expose SMEs to advanced technologies, and enable skill accumulation and 'learning-by-doing'. For example, SMEs should be actively involved in e-governance programmes such as Taza Koom.

Access to low cost financing is another serious constraint for SMEs. The AKT governments should extend micro-credit schemes to SMEs in high-tech and strategic industries. The most promising projects or firms should be provided with concessional loans and/or backed with government guarantees. Clearly, strict and transparent evaluation criteria need be applied in granting such loans and guarantees. In addition to low cost financing, the AKT governments can directly 'incubate' high-tech start-ups and SMEs.

Co-financing funds and venture capital funds appear to be more effective financing mechanisms for start-ups and SMEs because of their built-in market signalling mechanisms. Another novel financing modality is crowdfunding, which is gaining popularity in developed countries. Crowdfunding is the practice of funding a project by raising small amounts from large numbers of people through the Internet, social networks and other media. Over $34 billion was raised globally through crowdfunding in 2015.

Moreover, the AKT governments need to shape a legal and administrative framework for voluntary cooperative arrangements (e.g. business associations) among SMEs, especially farmers and small agri-businesses. Such cooperatives would allow SMEs to pool and use their resources more efficiently. Perhaps, more controversially, the AKT governments could also exempt SMEs from certain taxes and restrictions on forming export cartels, for example, in agro-processing and apparel industries. Such measures are generally not prohibited by the WTO. The AKT governments also need to promote SME participation in industrial clusters by forming associations, and providing technical assistance and government procurement contracts.

Next, R&D tax credit policies should be tailored to SME needs. Conventional R&D tax policies, permitting firms to deduct one-time their R&D expenditure from taxable income generally benefit large incumbent firms, and not small new entrants. R&D tax policies for SMEs and start-ups should contain provisions for carry-over across years, and allow for cash refunds and automatic reimbursement of payroll taxes, since start-ups do not have a financial cushion and most of their R&D is intertwined with regular work done by salaried personnel, and hence cannot be separated from wages, e.g. software, content or game design firms. Start-ups and technologically-oriented SMEs should also be provided with tax relief on investment, capital gains and losses, e.g. write-offs of losses and carry-over of profits to future periods.

Further, the protection of intellectual property rights and patents issued by SMEs should be strengthened. SMEs should be permitted to sell or lease their intellectual property or patents to large corporations, including foreign ones, and the AKT governments should provide legal assistance in this regard.

Finally, conventional policies and regulations concerning registration, conduct of business (e.g. permits, licences), taxation and closure of SMEs should be further simplified and streamlined in all three countries.

5.2.4. Infrastructural Policies

(a) Transport

Extensive and quality transportation infrastructure is indispensable for technological modernization. Not only does it facilitate trade by allowing fast and smooth movement of people and goods, but it is also one of the leading demanders and enablers for advanced technologies. Unfortunately, Afghanistan, Kyrgyzstan and Tajikistan all suffer from poor transportation infrastructure. Afghanistan's transport infrastructure has largely been destroyed over the decades of war. Moreover, because of their geographic isolation and mountainous terrains, the AKT countries have the highest transport costs in the world, which severely constrains international trade.

Roads are the main mode of passenger transport and freight; approximately 95% of passenger and about half of freight traffic are carried by road in all three countries. Despite the AKT governments' efforts and aid of international donors (e.g. USAID, ADB, World Bank, China) to construct and rehabilitate roads, the AKT road networks remain sparse, disintegrated and of poor quality (only 30 to 40% of roads are paved), consisting of 35,000 km (16,854 km paved), 14,000 km (4,000 km paved) and 42,150 km (12,350 km paved) in Kyrgyzstan, Tajikistan and Afghanistan, respectively. For example, the majority of roads in Afghanistan, outside the Ring Road, are unpaved; connectivity between the northern and southern parts of the country is limited. Roads in all three countries are routinely eroded by extreme temperatures, landslides, earthquakes, and, in Afghanistan, by periodic damages inflicted by militant groups. The poor state of roads is the leading cause of accidents and non-battle human casualties.

The countries do not have adequate railway systems to compensate and complement their poor road infrastructure. Kyrgyzstan's railway system is almost non-existent with a mere 424 km of railway tracks linking the country with neighbouring Kazakhstan (322.7 km-long Northern line) and Uzbekistan (101.2km-long Southern line).

Similarly, Afghanistan's railway infrastructure is limited in coverage and length: a 75 km-long rail line between Mazar-e-Sharif and Uzbekistan, a total of 13.5 km of railroads connecting to Turkmenistan, and a 60-km rail line from Herat to Iran. There are also plans to lay a rail link to Pakistan. Currently, there are no rail connections between Afghanistan, China and Tajikistan. Afghanistan's limited railroad connectivity can be explained by historical reasons, namely, by Afghanistan's desire to prevent the intervention of the Russian and Britain Empires in the past. However, a different set of factors are hindering the construction of railroads in today's Afghanistan, including incessant insecurity, lack of funds and gauge-width differences with its neighbours.

Of the three countries, Tajikistan has perhaps the most extensive railway system, consisting of 960.6 km of track, connecting it with Uzbekistan. However, it is in poor condition and susceptible to blockades by Uzbekistan. In fact, Tajikistan is heavily dependent on Uzbekistan for transit of its goods – mainly, aluminium and cotton – to the world markets. Transit has been disrupted by Uzbekistan on numerous occasions related to border and water disputes.

To secure an alternative corridor to global markets, the construction of a 635 km-long Turkmenistan-Afghanistan-Tajikistan (TAT) railway, with an estimated cost of $2 billion, was launched in June 2013. Turkmenistan completed its section linking to Afghanistan in November 2016, but the construction of the Afghan leg of the railroad has halted due the deteriorating security situation in northern Afghanistan. Tajikistan, in turn, decided not to begin work on its section until Afghanistan does so. If completed, the TAT railway would provide the Central Asian states with vital access to the Indian Ocean and significantly boost their trade, making Afghanistan a land bridge integrating the Central Asian region with global markets.

Air transport does not play an important role in commercial freight in all three countries; it is mainly used for passenger and military transportation. There are four international airports, and seven domestic airports in Kyrgyzstan, of which the largest one – Manas Airport in Bishkek – can handle heavy military aircrafts and hosted an American airbase till 2014. Tajikistan has four airports, of which only two (Dushanbe and Khujand airports) can handle international flights. There are a total of 43 airports in Afghanistan, of which four are international. Despite such a large number, only 25 have paved runways, most of which are used for military purposes.

Evidently, such a deplorable state of infrastructure represents a serious impediment to the technological and industrial modernization of the countries, calling for urgent action of their governments. Aside from the construction of new and the rehabilitation of existing roads, railways and airports (which are already underway), the AKT governments should also address the problems related to maintenance and effective management of their transport infrastructure. In doing so, they need to explore new, innovative technology-based solutions. The following policies could aid them in this process.

First, the AKT governments should take inventory of their ground roads and design a computer-based road management system. Such a system would collect real-time data and allow the governments to anticipate damages and carry out repairs in a timely manner. It would also help mitigate rampant corruption in road construction and maintenance through surveillance, detailed record keeping, cost accounting and quality control. In addition, the governments should involve civil society and the private sector in the process of contract awards, quality inspections and final work acceptance. Public hotlines for reporting malpractices and fraud in road construction or rehabilitation may prove effective in combatting corruption and improving the quality of roads.

Second, the AKT governments should look for new materials and technologies for the construction of durable roads, capable of withstanding harsh mountainous climatic conditions. For instance, instead of asphalt, concrete or new composite materials with stronger bonding properties should be used to pave roads. In fact, AKT have sufficient stocks of minerals to produce such construction materials locally; their construction industries just need to acquire the relevant technologies.

Third, expanding international railroad connectivity and, in particular, gaining access to the Indian Ocean via South Asia, must be the paramount priority for AKT, which are currently dependent on their neighbours for transit. Afghanistan and Tajikistan should complete the construction of their segments of the TAT railway, and Kyrgyzstan should first connect its northern and southern regions (Bishkek-Osh) with a domestic rail line, and then further link it to Tajikistan. This way, Kyrgyzstan and Tajikistan would be able to interlink with each other and to secure an alternative route to global markets, bypassing Uzbekistan and Kazakhstan.

Fourth, the AKT governments should modernize railway equipment, including coaches, locomotives, and freight wagons. To effectively manage railway infrastructure, they also need to set up a computerized database, containing data on the condition of railway tracks, inventory of locomotives, wagons, cargo and passenger traffic data, and cost-accounting information.

Finally, the existing airports should be upgraded and equipped with new automated freight-handling equipment, refrigerators (to store perishable goods) and modern warehouses. The AKT governments also need to integrate all transport facilities into one intermodal transport system and draw up optimized logistics plans and itineraries for international freight.

(b) Energy

The state of AKT energy infrastructure is discussed in Section 2.5. The existing AKT energy infrastructures are inadequate to meet the growing demands of their populations and industries. This problem is particularly acute in Afghanistan, which has the lowest level per capita of energy consumption in the world - 70 percent of the population still have no regular access to electricity. Electricity blackouts are also frequent in Tajikistan and Kyrgyzstan, especially during the winter months. Construction of new hydropower stations and transmission lines is hampered by the lack of financing in the case of Kyrgyzstan, and both the lack of financing and security in the case of Afghanistan. Tajikistan has resolved this problem by raising the required funding from its population. Moreover, inefficient exploitation of the existing energy infrastructure and considerable losses and theft further exacerbate the energy deficit in these countries.

The AKT governments can tackle all these issues through the following measures.

First, Kyrgyzstan should secure the required funding and complete the construction of the Kambarata Hydropower Plant, and Afghanistan should conduct feasibility studies and attract foreign investments for building new hydropower stations on its mountainous rivers.

Second, Tajikistan and Kyrgyzstan should comply with their obligations and begin the construction of the CASA 1000 transmission lines in 2018 to ensure timely electricity imports to Afghanistan and Pakistan in accordance with the agreed schedule.

Third, AKT need to undertake comprehensive rehabilitation of their existing transmission and distribution networks to cut losses and to prevent accidents and further degradation of the networks.

Fourth, all three countries should explore alternative, renewable energy sources to increase and diversify their energy supply. Solar energy and micro-hydropower plants seem to be promising technologies for all three countries, while Afghanistan has also wind power potential. Micro hydropower stations can improve access to electricity in remote mountainous areas, where it is difficult to build transmission lines.

Finally, to achieve energy efficiency, the AKT governments should implement a comprehensive energy-saving programme, encompassing the rehabilitation of heating plants and distribution systems, the installation of smart meters and energy-saving insulation both in industrial buildings and residences, the rationalization and simplification of electricity tariffs, and the measures to prevent theft and corruption at state-run infrastructural units.

(c) Telecommunications

The current states of the AKT telecommunication infrastructure and connectivity are examined in Section 2.5. The analysis has revealed a number of obstacles to the penetration and adoption of ICT technologies, and in particular to Internet access, in the three countries. The AKT governments can address these constraints through the following measures.

First, with the help of international financial institutions, the AKT governments should expand and diversify their international broadband connectivity by building a new fibre route along the CASA 1000 power lines, from Kyrgyzstan and Tajikistan to Afghanistan and Pakistan. This regional route, known as Digital CASA, would reach the submarine cable landing stations in Pakistan's port of Gwadar, and thus diversify the region's Internet connectivity. The benefits of this for AKT are numerous: reduced broadband costs for end-users, higher Internet adoption rates, more reliable and faster Internet connectivity, and greater revenue for the governments and ICT companies – all which would be further amplified through the demand-supply multiplier effects and propagate across other sectors.

Second, the Kyrgyz government should curb the existing prohibitive transit prices at the Kazakh border and encourage its Internet providers to cut accordingly the transit prices at the Tajik border. The Tajik government could, in turn, purchase wholesale capacity across the Kyrgyz border at a discount and then transfer that discount to its Internet providers.

Third, to enhance domestic connectivity, the AKT governments should lay additional fibre optic cables along their existing or planned roads, railways and electricity transmission lines. For example, Kyrgyzstan should build additional fibre optic cables along the Bishkek-Osh highway, Tajikistan needs to roll out fibre cables in its eastern Gorno-Badakhshan Autonomous Region, while Afghanistan needs to connect the remaining nine provinces to its Ring Road fibre backbone. In addition, towers, back-haul and radio access networks should be deployed across rural and mountainous regions, where the construction of fibre cables is costly.

Fourth, to increase efficiency in the use of available capacities, the AKT government should promote the establishment of Internet Exchange Points (IXPs) in major cities and encourage participation of Internet providers in IXPs. IXPs help to offload congested traffic, and lower costs and latency by exchanging traffic between providers. International operators should be permitted to peer at domestic IXPs.

Fifth, the AKT governments should also promote the development and hosting of local content to expand demand for Internet services to uncovered population groups and industries. As discussed in the previous sections, one option is to support domestic start-ups and SMEs engaged in software and Internet content development.

Sixth, the AKT governments can directly participate in the creation of local content by implementing national e-governance programmes and by offering education programmes to increase digital literacy among their populations. AKT can emulate best practices in e-governance from Kazakhstan, which is the regional leader in this area.

Last but not least, the AKT government need to step up Internet security by implementing internationally recognized cybersecurity standards and putting in place cyber-attack surveillance and prevention systems.

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