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A goal programming model to study the impact of R&D expenditures on sustainability-related criteria: the case of Kazakhstan

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Abstract

Purpose – Most countries face important economic, social and environmental challenges and are strongly committed to invest in research and development (R&D) activities to help support the long-run economic sustainable growth. This paper aims to extend the previous research on macro-economic growth models and introduces endogenous variables to determine the amount of investments in R&D activities.

Design/methodology/approach – The model considers four different criteria and six economic sectors and aims at finding the optimal allocation of labor across different sectors. The model also endogenously determines the amount of investments in pollution abatement activities together with energy-related R&D efforts. The paper presents an application to the case of Kazakhstan, an emerging Asian country, that aims to become one of the top 30 most developed countries in the world by 2050.

Findings – The model shows the limits of the Kazakh agenda that identified too ambitious goals as the country has to go through a sociotechnical transition that involves a range of modifications in institutional structures, together with changes in user practices and the technological dimension. Kazakhstan should invest more in R&D activities able to develop sustainable energy sources to face the current electricity consumption demand and to reduce the greenhouse gas emission in the future.

Originality/value – The paper provides valuable knowledge for researchers and policy makers interested in the impact of R&D on the long-run economic sustainable growth.

Keywords Goal programming, R&D activities, Pollution abatements, Energy consumption

Paper type Research paper

1. Introduction

The 21st century has been marked by turbulent transformations caused by social, economic, political and technological changes. In recent years, there is an increased attention by government agencies, policy analysts, economists and organizations to develop suitable implementation plans able to achieve sustainable development goals (SDGs). SDGs were adopted in the year 2015 by UN member countries to achieve overall prosperity addressing significant global challenges in 17 broad areas, including better health, climate action, clean energy, industry, innovation and infrastructure (United Nations, 2015). In developing an implementation plan, decision makers have to balance various priorities integrating economic, social and

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environmental objectives and energy use, among other criteria, that are often conflicting and incommensurable. For example, if each country aims to achieve a certain gross domestic product (GDP) growth rate and exploits available resources in the pursuit, they might pollute more than permissible levels, leading to major health issues for their citizens. To remedy the effects will require investments in environmental abatement efforts evaluated in consideration with various criteria, such as economic effectiveness, technical feasibility and environmental regulations. The ideal plan for sustainable development should foster the use of available resources in an optimal way preserving their availability for future generations. Traditionally, decision makers have used the triple bottom line (TBL) approach (Slaper and Hall, 2011). While the TBL framework provides a way to aggregate the three criteria, namely, social, economic and environment, it explicitly lacks to address the growing importance of energy consumption and its effects. It is widely evident that demographic growth contributes significantly to increase greenhouse gas emissions fueled by increased energy consumption. Another important drawback is several decision models fail to accommodate the role of innovation and productivity in developing potential solutions to address sustainability-related challenges.

This increasing degree of complexity is forcing decision makers to look out for new approaches and methodologies that facilitate and support decision-making. Multi-criteria decision analysis (MCDA) offers effective techniques to provide potential solutions for successful achievement of SDGs. The mathematical tractability, spurt in modeling and computational ease have made goal programming (GP) a popular MCDA technique to study sustainability issues. Several GP techniques have been used to study applications spanning from quality control (Sengupta, 1981), manufacturing (Satoglu and Suresh, 2009), supply chains (Selim and Ozkarahan, 2008), renewable energy planning (San Cristóbal, 2012a), workforce planning (Bastian *et al.*, 2015) and others. We refer the readers to extensive reviews (Colapinto *et al.*, 2017a, b; Aouni and Kettani, 2001) and books (Barichard *et al.*, 2008; Jones and Tamiz, 2010) highlighting the role of GP models with applications.

The primary motivation of this paper is to develop a GP model to study the potential of achieving an SDG. To the best of our knowledge, no known approach has been used to study the effectiveness of research and development (R&D) investments and its influence in achieving sustainability-related goals. Our model has been validated using data from Republic of Kazakhstan. The global financial crisis of year 2008 and geopolitical changes have impacted the economy of Kazakhstan that was also challenged by the instability and decline in world oil prices. During the period 2000–2015, the commodity group "Mineral products" is the primary exported one and accounts for no less than 65.8 percent of the total exports. Kazakhstan has embraced a vision to become one of the world's most environmentally healthy countries, with sustainable energy at its foundation and diversified economic development as a key goal/objective. Kazakhstan 2050 development strategy (Linn, 2014) highlights a projected GDP growth of 3 percent, enabling the creation of 0.5 million jobs by transitioning to green economy. One effective and important step toward achieving an SDG related to the environmental objective is to increase the contribution of renewables in the energy mix, leading to efficient energy usage (Karatayev and Clarke, 2016). In addition, Kazakhstan aims at spend 3 percent of GDP for research, development and innovation in technology sectors (Mukhitdinova, 2015), preserving a steady employment, contributing to the social aspect of an SDG: this approach implies synergies and common goals between different stakeholders. Our paper adopts a broader approach with respect to previous research; past literature has concentrated mainly on energy policy and investments. MacGregor (2017) studied decision-making for electricity generation policy and investments in Kazakhstan and quantified the net present value of different policy options and suggested an alternative investment pathway. Ahmad *et al.* (2017) reviewed various potential local non-fossil fuel resources, including hydro, solar, wind, biomass and uranium, and established an assessment framework for prioritizing these resources via the analytic hierarchy process (AHP) based on expert opinion.

In this paper, we use a classical weighted GP (WGP) model to study the long-run sustainability of Kazakhstan toward achieving SDGs. We introduce the total amount of public investments in R&D as a constraint in the GP model considering investments in pollution abatement and energy consumption reduction. Our model is fully endogenous, and it allows to determine not only the optimal allocation of workforce in each economic sector but also the fraction of production to be devoted toward R&D investments, emission control and reduction in energy consumption. The original model presented in this paper enriches the work done by the same authors in previously (see Jayaraman *et al.*, 2017a, b).

The rest of the paper is organized as follows. In the next section, we briefly discuss the mathematical formulations of the GP and the WGP models. In Section 3, we discuss the relevant literature, Section 4 presents the model formulation. Section 5 details model implementation with empirical data on the Kazakhstan economy and numerical simulations. The conclusions and recommendations for decision makers are presented in Section 6.

2. A brief review of goal programming models

In a classical MCDA framework, the decision maker (DM) has to deal with several and conflicting criteria $F_1, F_2, \ldots, F_p$ that have to be maximized or minimized simultaneously. Within the GP formulation, the DM tries to minimize any possible deviation from the objective goals, either positive or negative. In fact, the GP model is a distance-function model in which the obtained optimal solution represents the best compromise between different objectives.

There are two broad approaches in a GP. First, the GP with non-preemptive, weighted structure shows roughly comparable importance among conflicting criteria. The other approach is preemptive GP, where the goals must be ranked from the highest important to the least important. One of the simplest formulation of the GP model was introduced by Charnes and Cooper (1961) and Charnes *et al.* (1955), which reads as:

$$\text{Min} \sum_{i=1}^{p} D_i^+ + D_i^-$$

Subject to:

$$F_i(X_1, X_2, \ldots, X_n) + D_i^- - D_i^+ = G_i,\ i = 1 \ldots p$$
$$X = (X_1, X_2, \ldots, X_n) \in \Omega$$
$$D_i^-, D_i^+ \geq 0,\ i = 1 \ldots p$$

where D_i^- and D_i^+ are, respectively, the negative and positive deviations with respect to the aspirational goal levels G_i, $i = 1, \ldots, p$ and Ω is the feasible set. Several different variants of this basic formulation have been introduced over the years (see Colapinto *et al.*, 2017a, b). Among them, the most popular one is the WGP, which reads as follows: Given a set of weights ω_i^-, ω_i^+ chosen by the DM, solve the following program:

$$\text{Min} \sum_{i=1}^{p} \omega_i^- D_i^- + \omega_i^+ D_i^+$$

Subject to:

$$F_i(X_1, X_2, \ldots, X_n) + D_i^- - D_i^+ = G_i,\ i = 1 \ldots p$$
$$X = (X_1, X_2, \ldots, X_n) \in \Omega$$
$$D_i^-, D_i^+ \geq 0,\ i = 1 \ldots p$$
$$X_j \geq 0 \text{ and integer},\ j = 1 \ldots n$$

The weights ω_i^-, ω_i^+ allow us to introduce a system of priorities among the objectives, with the result that those having more importance for the DM will have a higher weight. In the sequel, we will utilize the WGP approach to formulate our model. To conclude this section, it is worth to recall that other GP models and variants are available in the extant literature.

3. Background literature

Belton and Stewart (2002) acknowledged structuring complex decision problems well and integrating multiple criteria explicitly in decision-making lead to better, more informed decisions. In this perspective, GP models have gained increased attention among decision analysts and policy makers. The ability of GP models to simplify complex economic scenarios and determine the long-run sustainability of government and macroeconomic policies have fueled several recent studies across different countries, including Canada (Nechi *et al.*, 2019), Europe (Guijarro and Poyatos, 2018; Daim *et al.*, 2010b) and Asia (Gupta *et al.*, 2018). The application of GP models to social sciences, and in particular to economics, appears to start in the early 1970s, especially around the provision of public goods, and in special economic sectors. It has also been widely used to model environmental interactions (Linares and Romero, 2000) and macroeconomic policies (Colapinto *et al.*, 2017b). The wide applicability of GP models and mathematical tractability has enhanced the scope of applications. GP models have been used in supply chain optimization problem, as they permit imprecise demand and information (Selim and Ozkarahan, 2008; Tsai and Hung, 2009). Other applications range from vendor selection (Kumar *et al.*, 2004), production-distribution planning (Selim and Ozkarahan, 2008), manufacturing and production decision-making (Sheikhalishahi and Torabi, 2014; Taghizadeh *et al.*, 2011). In management science, GP has a direct correspondence with decision-making, because business managers are constantly solving complex decision problems involving costs, returns and risk. The increasing popularity of GP models is also evident by the diversity of applications (Ignizio, 1982) such as finance (Aouni *et al.*, 2014), marketing (Kwak *et al.*, 1991), capital budgeting (Kalu, 1999) tourism management (Blancas *et al.*, 2010) and others. GP models for R&D and project selection have been studied by several authors; some significant papers include: Keown *et al.* (1979) used a zero-one GP approach to allocation of R&D funds; Taylor *et al.* (1982) introduced a nonlinear integer GP for project selection and prioritizing the allocation of researchers, using both linear and nonlinear goal constraints; and Badri *et al.* (2001) developed a GP model for project selection incorporating R&D costs, capital budgeting and investment plans.

With respect to the aim of the current paper, we now focus on two major areas: problems relating to economic–energy–environmental (E^3) criteria, either individually or as a combination that are studied under the GP ambit, and papers on sustainability applications that integrate various social aspects.

One of the earliest works on energy resource allocation via the MCDA technique is the one by Ramanathan and Ganesh (1995) who presented an integrated AHP-GP model. Their model considered nine quantitative and three qualitative criteria and was applied to the household sector of Madras (India). Daim *et al.* (2010a) develop an Fuzzy GP (FGP) model to determine the optimal mix of renewable energy with application to Oregon (USA). San Cristóbal (2012a) developed a GP model to determine the optimal mix and location of renewable energy plants applied to north of Spain. Jayaraman *et al.* (2015a, b) developed a WGP model considering energy, economic and environmental criteria applied to year 2030 sustainability goals of the UAE. Extending their previous work, Jayaraman *et al.* (2017a) also developed an FGP model applied to the UAE, and Jayaraman *et al.* (2017b) studied a WGP model applied to various Gulf Cooperation Council (GCC) countries. Jones and Wall (2016) studied an application of GP model for off-shore wind farm site selection in the UK. Zografidou *et al.* (2017) developed a GP model for installing solar power plants in Greece considering financial and energy criteria.

Omrani *et al.* (2019) developed a WGP model for optimal workforce allocation in Iran considering economic, energy and environmental (greenhouse gas (GHG) emissions) criteria. Their results permit policy makers to develop suitable macroeconomic policies in planning for achieving year 2030 sustainability goals.

Models integrating social criteria emphasizing sustainability-related aspects due to climate change and adoption of SDGs have drawn significant attention among research and practice community in the past decade. Some significant works incorporating sustainability criteria using GP models include San Cristóbal (2012b) who developed a GP model combining economic, energy, social and environmental criteria to study sustainability-related goals for Spanish economy. His results provided insights on specific key economic sectors that needed significant attention to achieve sustainability-related goals. Zografidou *et al.* (2016) developed a data envelopment analysis and WGP model combining social, environmental and energy criteria to study the optimal renewable energy production toward meeting year 2020 EU mandated recommendations. Their results emphasized the allocation of more weightage to social and environmental aspects and reduced economic emphasis enables achieving maximum efficiency. Nomani *et al.* (2017) developed an FGP model to analyze the feasibility of achieving year 2030 environmental, energy and sustainability goals of India.

The growing body of literature concludes that altering energy mix with suitable substitutions from non-emitting renewable sources represents a viable option for meeting long-term energy sustainability. In addition, the focus on sustainability turns into developing well-diversified and robust economic policies that emphasize the need for innovation, entrepreneurship and R&D. This paper aims to bridge the gap from previous research by developing a fully endogenous model with explicit consideration of public investments in R&D as a constraint to determine: optimal allocation of workforce in each economic sector, fractions of production to be devoted toward R&D investments, pollution abatement and reduction in energy consumption. According to Johnstone *et al.* (2010), R&D expenditures and number of research personnel reflect the innovative capacity of a country, i.e. the resources available to develop new technologies.

We can conclude that a GP model has revealed useful insights on the performance and implementation of global sustainability policies involving multiple and conflicting objectives. Policy makers can use various sustainability assessment methods and multi-dimensional frameworks, based on the interactions and tradeoffs between economic, energy, environmental indicators and sustainability-related aspects.

4. Model formulation

In this section, we formulate our model and discuss its main properties. This is a macroeconomic model that considers simultaneously the following four criteria: F_1, F_2, F_3 and F_4. The first criterion, F_1, models the aggregate production function of the economy, and it describes how the real GD (in US$ m) in an economy depends on available inputs. The most important inputs are: physical capital (machines, production facilities), labor, human capital (skilled work force), knowledge, natural resources (oil, coal, agricultural and forest lands), social infrastructures and services. The second criterion, F_2, describes the GHG emissions expressed in equivalent Gg of CO_2 emissions. The third criterion, F_3, provides the amount of electricity consumption expressed in equivalent tons of oil (thousands). Lastly, F_4 represents the total amount of employed workers expressed in thousands. We suppose that the economy of a country depends on several key economic sectors, including agriculture, forestry and fishing, industry, constructions, trade, manufacturing, mining, oil, quarrying industry, general services, health, social services and others. If the economy is composed by "n" economic sectors, let us denote by X_j the amount of workers in the jth economic sector, $j = 1, \ldots, n$. In this paper, for simplicity, we suppose that there is no difference between skilled and raw labor and that there is no unemployment. We also denote by a_{ij} the per capita contribution of the jth economic sector toward the achievement of the objective $F_i, i = 1,\ldots, 4$. Each criterion F_i is linear with respect to the decision variable X_j and takes the following form:

$$F_1(X_1, X_2, \ldots, X_n) = a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n$$

$$F_2(X_1, X_2, \ldots, X_n) = a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n$$

$$F_3(X_1, X_2, \ldots, X_n) = a_{31}X_1 + a_{32}X_2 + \ldots + a_{3n}X_n$$

$$F_4(X_1, X_2, \ldots, X_n) = X_1 + X_2 + \ldots + X_n$$

If we denote by G_i the aspiration level of $F_i, i = 1,\ldots, 4$, and by C the average level of per capita consumption, the model we are interested in takes the following form:

$$\mathrm{Min}_{D_i^-, D_i^+, X_j, \Delta_s} \sum_{i=1}^{4} \omega_i^- D_i^- + \omega_i^+ D_i^+$$

Subject to:

$$F_1(X_1, X_2, \ldots, X_n) + D_1^- - D_1^+ = G_1$$

$$F_2(X_1, X_2, \ldots, X_n) - \Delta_2 G_1 + D_2^- - D_2^+ = G_2$$

$$F_3(X_1, X_2, \ldots, X_n) - \Delta_3 G_1 + D_3^- - D_3^+ = G_3$$

$$F_4(X_1, X_2, \ldots, X_n) + D_4^- - D_4^+ = G_4$$

$$(X_1 + X_2 + \ldots + X_n)C \leq \Delta_1 G_1$$

$$\Delta_1 = 1 - \Delta_2 - \Delta_3 \geq 0$$

$$0 \leq \Delta_s \leq 1, \quad s = 1..3$$

$$D_i^-, D_i^+ \geq 0, i = 1\ldots4$$

$$X_k \geq \Omega_k, \quad k = 1, 2, \ldots, n$$

$$X_k \text{ are integer variables for } k = 1, 2, \ldots, n$$

where the expressions $\Delta_2 G_1$ and by $\Delta_3 G_1$ denote, respectively, the amount of GDP invested in abatement activities and energy consumption reduction. The remaining fraction of GDP, $\Delta_1 G_1 = (1 - \Delta_2 - \Delta_3)G_1$ is then fully consumed.

The model is linear and endogenously determines the optimal levels of employment in each economic sector as well as the amount of investments in abatement activities and energy consumption reduction. The lower the values of the deviations are, the more the desired goals are aligned with the current trends and, as a consequence, the more sustainable the entire economy will be from a macroeconomic perspective. In the sequel, we illustrate the contribution of each constraint.

(1) The following set of constraints:

$$F_1(X_1, X_2, \ldots, X_n) + D_1^- - D_1^+ = G_1$$

$$F_2(X_1, X_2, \ldots, X_n) - \Delta_2 G_1 + D_2^- - D_2^+ = G_2$$

$$F_3(X_1, X_2, \ldots, X_n) - \Delta_3 G_1 + D_3^- - D_3^+ = G_3$$

$$F_4(X_1, X_2, \ldots, X_n) + D_4^- - D_4^+ = G_4$$

measure the distance between the achievement level of each criterion with respect to the corresponding goal $G_i, i = 1,\ldots, 4$. The second and third equations also include the effects due to investments in pollution abatement and energy consumption reduction.

(2) The inequality:

$$(X_1 + X_2 + \ldots + X_n)C \leq (1 - \Delta_2 - \Delta_3)G_1$$

states an upper bound for the total level of consumption. The total level of consumption is calculated by multiplying the total population for the average level of consumption (GDP per capita).

(3) The constraints:

$$\Delta_1 = 1 - \Delta_2 - \Delta_3 \geq 0$$

$$0 \leq \Delta_s \leq 1, \quad s = 1..3$$

$$D_i^-, D_i^+ \geq 0, i = 1 \ldots 4$$

$$X_k \geq \Omega_k, \quad k = 1, 2, \ldots, n$$

balance the willingness to preserve the total labor force in each economic sector and describe some sign constraints.

Finally, the objective function:

$$\sum_{i=1}^{4} \omega_i^- D_i^- + \omega_i^+ D_i^+$$

models the weighted sum of the deviations D_i^+, D_i^-, $i = 1, \ldots, 4$, between the achieved levels and the corresponding goals. In the next section, we validate the proposed model with an application to the Republic of Kazakhstan.

5. An empirical analysis: the case of Kazakhstan

Kazakhstan aims to become one of the top 30 most developed countries in the world by 2050, even if it is a quite young country. Indeed, Kazakhstan gained its independence in year 1991 from Union of Soviet Socialist Republics (USSR), when it also started its transition to market-based economy. For many years, Kazakhstan has heavily relied on extractive industries and has been attempting to diversify its economy. If we consider the past decade, we can observe that before the year 2013, economic growth in Kazakhstan was mainly supported by elevated oil prices. Over the period 2014–2016, it witnessed economic contraction: the real GDP growth rate decreased from 6 percent in year 2013 to 1.1 percent in year 2016. Since year 2016, the strategy of the Kazakh government has focused on shifting from a resource-based economy toward a free-market one. The government has started to put in place policies to guarantee economic diversification, to foster innovation and to develop the creation of an upper-level management (Jumadilova, 2012). Today, Kazakhstan is an upper-middle-income country, characterized by ambitious goals for the years to come. However, state-owned companies still dominate most of the economic sectors and import ready-to-use equipment and technologies from abroad. Indeed, small- and medium-sized enterprises have a low contribution to the national economy (around 20 percent) and engage little in innovation (OECD, 2018). The investments in R&D are mainly at the governmental level.

The recent expansion of the Kazakh economy has relied on high rates of energy use and has generated significant level of pollution emissions, also due to the presence of out-to-date infrastructure, technologies, standards and practices inherited from the Soviet past. Even if Kazakhstan is one of the most energy-intensive economies in the world, it is committed to national and international action to achieve ambitious environmental targets and a sustainable economic growth. Indeed, “Kazakhstan 2050” (Nazarbayev, 2012) is a strategic plan related to the sustainability and the long-run growth of the Kazakh economy. One of the objectives stated in this plan is the use of electricity generated from renewable and alternative sources and the creation of a “Green Economy.” Such efforts should be in parallel with other actions aimed at decreasing GHG emissions and improving the agricultural land usage and the waste management sectors. Kazakhstan aims at increase by roughly 4.5 times the GDP per capita, from the current US$13,000 to US$60,000 and become a country where the middle class makes up a predominant share of the population. This trend is in line with the projections for most fast-growing and developing countries and for Asia as well. Indeed, it is expected that by 2030, Asia might represent 66 percent of the world middle-class population (Kharas, 2017). Growing middle-class spending will undoubtedly have an effect on carbon emissions: This of course will depend on the government decisions concerning sustainable development and growth of urban agglomerations and the adoption of energy-efficient infrastructures and service transportation. Following the global trend, it is expected that the share of urban population will increase from the current 55 percent to roughly 70 percent. The main cities (Nursultan, Almaty, Symkent and Aktobe) and settlements of Kazakhstan will be connected by high-quality roads and high-speed transportation services (including railways, airports) that are currently under construction.

Kazakhstan has agreed to adopt the Kyoto Protocol and consequently reduce its carbon emissions by 15 percent by the year 2020 and 25 percent by the year 2050, compared to its emission levels in the year 1992. So, the projected goal for the year 2050 is to meet a value roughly equal to 151,000 Kt of CO_2 emissions.

The total available labor force comprises people ages 15 and older who meet the International Labor Organization definition of the economically active population, refers to all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed. While national practices vary in the treatment of such groups as the armed forces and seasonal or part-time workers, in general, the labor force includes the armed forces, the unemployed and first-time job-seekers, but excludes homemakers and other unpaid caregivers and workers in the informal sector. The main economic aggregated data for year 2014 are presented in Table 1. This information was obtained from various sources detailed in the references.

We refer to the six main sectors identified by the Kazakh government, and we retrieved our data mainly from the websites and the publications written by the Ministry of National Economy of the Republic of Kazakhstan Statistics committee, along with data downloaded from the Organization for Economic Co-operation and Development (OECD) and World Bank site (Table 2).

Using the data and the goals stated in the strategic plan "Kazakhstan 2050," we have estimated the following goals related to the criteria to be attained by the year 2050, given in Table 3.

Solving the model (using optimization software Lingo) clearly demonstrates that expected goals for 2050 cannot be achieved. In particular, the expected amount of GDP as well as the expected GDP per capita are not well aligned with the current population growth that is forecasted to attain the value of 22,447,000 people by 2050. The current estimations of the per capita contribution to each economic sector show that the current trend will not allow to achieve the projected GDP US$1,346,820,000,000 by 2050. Significant investments in each of the identified six economic sectors would be needed to considerably modify the per capita contribution of each economic activity toward the successful attainment of total GDP.

A more moderate estimate of the 2050 Kazakh GDP is the average between the forecasted value of year 2025 and 2050, namely, US$442,800,000,000. This estimate may be more

Total GDP	US$221,400,000,000
Total population	17,290,000
GDP per capita	US$12,805
Total work force	9,050 (in thousands)
Higher education (15% of population)	2,590 (in thousands)
Electricity consumption	96,820 Gwh
CO_2 emission	233,850 Kt
Total number of researchers in KZ = 0.196% of the workforce	17,702
Investment in R&D = 0.167% GDP	US$36,973,800,000

Table 1. Aggregated data for Kazakhstan

Variable	Sector	GDP per capita	Electricity consumption	GHG emissions	Amount of workforce (in thousands)
X_1	Agriculture, fishing, forestry	4,280	0.00023	0.0268	1,605
X_2	Industry	40,020	0.0208	0.0161	1,090
X_3	Construction	15,480	0.0221	0.0546	1,650
X_4	Trade	20,170	0.007	0.0066	1,833
X_5	Manufacturing, mining, oil, quarrying industry	49,130	0.0139	0.0431	879
X_6	Education, health, social services	28,000	0.005	0.0155	1,948

Table 2. GDP per capita (reference year 2014), electricity consumption per capita (in GWh, reference year 2014), GHG emissions per capita (Kt of CO2 equivalent reference year 2012) and the number of employees (reference year 2014) per economic sector

reasonable if one considers the high level of fluctuations of the Kazakh national currency, the Tenge.

With these adjusted forecasts of the 2050 GDP presented in Table 4, the model shows a successful attainment of sustainability related targets because of a reasonable effort. The results are presented in Table 5.

The results presented in Table 5 show very low levels for the deviation variables, and this combination of values shows a long-run sustainability of the identified goals. The model also allows to determine the investments in green energy and pollution reduction, which helps in achieving the long-run goals of macroeconomic policy.

6. Discussion and policy implication

The year 2013 "National Concept for Transition to a Green Economy by the year 2050" focuses on transitioning the economy and power sector toward sustainable development and aims to bring the share of renewable energy in electricity generation to 3 percent by 2020 rising to 30 percent by 2030 and 50 percent by 2050. While the government is adopting new legal frameworks to encourage the transition toward renewables, there are still significant barriers to address, including a lack of awareness of the opportunities associated with renewable energy, a lack of technical expertise and capacity, insufficient governmental support to overcome high initial financial and capital requirements and investment

Table 3. Estimated goals by the year 2050

Criteria	Year 2050 goals values (growth%) [1]
Expected GDP	US$1,346,820,000,000
Expected GDP per capita	US$60,000
Expected electricity consumption	151,000 GWh
Expected goal for GHG emissions	190,000 Kt (75% of 252,400 Kt in 1992)
Expected total population	22,447,000
Expected investments in R&D	3% of the 2050 GDP = US$40,404,600,000

Table 4. Feasible goals by the year 2050

Criteria	Year 2050 goals values (growth%) [2]
Expected GDP	US$442,800,000,000
Expected GDP per capita	US$19,720
Expected electricity consumption	151,000 GWh
Expected goal for GHG emissions	190,000 Kt (75% of 252,400 Kt in 1992)
Expected total population	22,447,000
Expected investments in R&D	3% of the 2050 GDP = US$13,284,000,000

Table 5. Results by the year 2050

Variable	Value	Variable	Value
D_1^-	0.000000	X_1	2,439,385
D_1^+	0.000000	X_2	1,090,000
D_2^-	0.000000	X_3	0.1641025E+08
D_2^+	0.000000	X_4	1,833,300
D_3^-	0.000000	X_5	879,000
D_3^+	0.000000	X_6	1,948,000
D_4^-	0.000000	Δ_2	0.6090579E-06
D_4^+	2152937	Δ_3	0.1962744E-05

disincentives due to subsidies of other energy sources (primarily fossil fuels). The financial barriers, including the low price of electricity in the country, uncertainties with the long-term power purchasing tariffs, difficulties in attracting foreign investment and a lack of access to credit for both consumers and investors, are currently acting against rapid adoption. Institutional barriers include the absence of a clear national program for renewable energy development, a lack of specific action plans and instruments, a lack of concrete competitive legislation and regulation relating to the newly developed renewable energy market. Given the increasing success of the oil and gas sector, Kazakhstan will require significant government leadership to meet its vision for 2050.

Our paper presents a methodological approach to the formulation of an effective and sustainable macroeconomic policy aimed at supporting the development of Kazakhstan. At the first glance, our model shows that the GDP goal is unsustainable and not realizable. If instead, a more cautious forecast of the 2050 GDP is adopted, namely, US$442,800,000,000, our model demonstrates the attainment of sustainability goals, together with the concrete possibility to attain the year 2050 goals. The model also provides the amount of investments in the energy sector as well as in pollution abatement activities, described by the variables Δ_2 and Δ_3.

Combining these two elements, Kazakhstan should invest more in developing sustainable energy sources to face the current electricity consumption demand and rapidly reduce the GHG emission in the future. Implicitly, even R&D investment and the evolution of skill labor demand have to be narrowed toward green sustainability. The country has to put R&D at the service of sustainable development. Our findings are in line with the previous literature about the relationship between innovation and environmental quality. Many studies at the country or firm level yield similar results, showing that R&D expenditures lead to a reduction in emissions (i.e. Garrone and Grilli, 2010; Wang *et al.*, 2009). And, the econometric model by Férnandez *et al.* (2018) proved that R&D spending can act as an engine of economic growth as well as a driver of sustainable development (lower CO_2 emissions).

The model shows the limits of the agenda that identified too ambitious goals, as the country has to go through a sociotechnical transition that involves a range of modifications in institutional structures, together with changes in user practices and the technological dimension. Sustainability transitions represent "*long-term multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption*" (Markard *et al.*, 2012). In favoring the year 2050 vision, it is evident that mixes of different policy instruments will perform better if all benefits and costs of complexity are taken into account. In Kazakhstan, we can observe an intrinsic complexity of the policy intervention that is highly context-dependent.

Further research should address and explore alternative criteria for the agenda-setting and the policy mixes; an estimation of the cost of single policy instrument implementation would also lead toward a more detailed efficiency analysis, taking into account also different energy policy options.

(1) http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

(2) http://www.escwa.un.org/popin/members/uae.pdf

(3) https://strategy2050.kz/en/multilanguage/

(4) http://www.stat.gov.kz/faces/wcnav_externalId/publicationsMonitoring?_afrLoop=4644604121093692#%40%3F_afrLoop%3D4644604121093692%26_adf.ctrl-state%3Dmwk4bqmtw_29

(5) https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=KAZAKHSTAN&product=ElectricityandHeat

(6) http://www.tradingeconomics.com/kazakhstan/total-greenhouse-gas-emissions-kt-of-co2-equivalent-wb-data.html

(7) http://stat.gov.kz/faces/homePage?c404=1&_afrLoop=5262549995809752#%40%3F_afrLoop%3D5262549995809752%26c404%3D1%26_adf.ctrl-state%3Dc45gfadfb_9

(8) https://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/kaz_ghg_profile.pdf

(9) http://scholar.dickinson.edu/cgi/viewcontent.cgi?article=1194&context=student_honors

(10) http://www.nationalbank.kz/cont/publish488539_24140.pdf

(11) http://www.oecd.org/education/school/CBR_Kazakhstan_english_final.pdf

(12) https://www.nap.edu/read/11808/chapter/2#4

(13) http://www.mfa.gov.kz/en/istanbul/content-view/kazakstan-2050-strategiasy-3

(14) http://www.oecd.org/eurasia/competitiveness-programme/central-asia/Kazakhstan-Monitoring-Skills-Development-through-Occupational-Standards-2019-EN.pdf

Notes

1. Goals data sources: http://scholar.dickinson.edu/cgi/viewcontent.cgi?article=1194&context=student_honors, http://www.nationalbank.kz/cont/publish488539_24140.pdf.
2. Goals data sources: http://scholar.dickinson.edu/cgi/viewcontent.cgi?article=1194&context=student_honors, http://www.nationalbank.kz/cont/publish488539_24140.pdf.

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