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ORCID
MA: 0000-0003-4953-2799
KL: 0000-0001-8449-5693
SGyP: 0000-0001-9289-7633

Impacts of fertilizer subsidy reform options in Iran: an assessment using a Regional Crop Programming model

Mona Aghabeygi[1,2,*], Kamel Louhichi[3], Sergio Gomez y Paloma[2]

[1] *Mona Aghabeygi, Università degli Studi di Parma, Parma, Italy*
[2] *European Commission, Joint Research Centre (JRC), Seville, Spain,*
[3] *Université Paris-Saclay, INRAE, UMR Economie publique, Thiverval-Grignon, France*
E-mail: monaaghabeygi17@gmail.com; Kamel.elouhichi@inrae.fr; Sergio.GOMEZ-Y-PALOMA@ec.europa.eu
*Corresponding author. E-mail: monaaghabeygi17@gmail.com

Abstract. The aim of this paper is to assess the potential impacts of different fertilizer subsidy reform options on the performance of the Iranian crops production sector. This is achieved using a Regional Crop Programming (RCP) model, based on Positive Mathematical Programming, which includes in total 14 crop activities and encompasses 31 administrative regions. The RCP model is a collection of micro-economic models, working with exogenous prices, each representing the optimal crop allocation at the regional level. The model is calibrated against observed data on crop acreage, yield responses to nitrogen application, and exogenous supply elasticities. Simulation results show that a total removal of nitrogen fertilizer subsidies would affect the competitiveness of crops with the highest nitrogen application rates and lead to a slight reduction of national agricultural income, at approximately 1%. This effect, which is more pronounced at the regional level, is driven by area reallocation rather than land productivity. The reallocation of nitrogen fertilizer subsidy to only strategic crops boost their production and income but increase disparity among regions and affects negatively welfare compared to the current universal fertilizer program. The transfer efficiency analysis shows that both target and universal simulated options are inefficient with an efficiency score below one.

Keywords: agricultural policy, fertilizer subsidy, land use effect, Regional Crop Model, Positive Mathematical Programing (PMP), Iran.
JEL codes: Q18, C13, C61.

1. INTRODUCTION

Iran is a country in Western Asia with 82 million inhabitants, standing at the world's 18th most populous country. Its territory spans 1,648,195 km2, making it the second largest country in the Middle east. In 2016, the Gross Domestic Product (GDP) was 1797 billion IRR, while the per capita GDP was about 219 million IRR, and the country is ranked as an upper-middle

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income economy by the World Bank (ICB, 2016). The agricultural sector plays an important role in the Iranian economy. In 2016, agriculture contributed up to 9.64 % of the GDP, provided up to 87% of the food supply, occupied around 10% of the land, and employed 19% of the labor force (IRICA, 2016; ICB, 2016; SCI, 2016). Smallholder farms with less than 25 acres (10 hectares) largely dominate the Iranian agricultural sector. They represent more than 70% of the country's agricultural producers and occupy more than 55 % of cropland (CSI, 2014). They are basically family-based and family-managed farms with an average size of 3 hectares, with 2 hectares under cultivation (IRNAGRIC, 2015). The crop sector is the most significant agricultural subsector in the country with 65.7% of agricultural' value added and 2.5 million agriculture production units. Field crops, mainly cereals, constitute the bulk of Iranian's crop production. In 2016, wheat makes up 50.39% of total cultivated land, followed by barley 14.95%, rice 5.07%, and corn 1.35%. However, in spite of input and output support policies, the yields of these crops remain below the world average (WB, 2016; IMAJ, 2016).

To boost productivity and foster national food security and agricultural self-reliance, Iran has deployed a multi-pronged program of subsidies. This includes guaranteed price floors for more than twenty crops, and which often results in producer prices that are well above world prices. In addition to this price floor, the Iranian Government provides support to farmers in the form of subsidized prices for fertilizer, pesticides, and improved seeds, as well as for equipment and basic inputs like water and energy (Hosseini and Shahnabati, 2015; Pakravan et al., 2016; Hosseini et al., 2017). Fertilizer subsidy is the most important of these subsidy programs. It started in the 1970s, but it focuses mostly on export crops and on training farmers in the proper use of fertilizers. However, as food security became a top priority with the explosion of population, fertilizer subsidy it was extended to staple crops (IC, 2016).

In 2016, mineral fertilizer subsidy represented around 10% of the public expenditure in agriculture. The subsidy was paid to the Iranian Petro-chemical industry, to permit it to sell fertilizers at reduced prices. Subsidized fertilizers were universally available to all farmers, regardless their specialization, size, geographical location, etc. (i.e., universal fertilizer program). However, due to the government's limited budget, not all farmers have access to subsidized fertilizer. In addition, given that subsidized fertilizers are often traded by intermediate dealers, they were sometimes sold to farmers at inflated prices or even smuggled out of the country. To address this issue, the "Agricultural Support Services Company (ASSC)", responsible for providing and distributing mineral fertilizers, has recently implemented a Smart Agricultural Input Distribution System (SAIDS) (SITO, 2016) that records detailed farmer information and monitors the transportation of fertilizer from petrochemical companies to the different regions (ASSC, 2016).

Although the introduction of fertilizer subsidy may contribute to enhancing food availability and food security, it has been subject to increasing criticism in recent years from both national and international players. In fact, several local experts argued that the use of input subsidies in Iran dates to the early 1970's, however agricultural productivity is still low, self-sufficiency is not achieved yet, and food safety and food security are still major concerns. As such, this instrument is seen as inefficient, given its high budget costs, and source of market distortions since it benefits only specific groups of farmers (e.g., farmers with ease access to input market). To this, one can add the new pressure coming from the World Trade Organization (WTO). In fact, the Iranian government is expecting to become member of WTO and such kind of subsidies are not allowed by this organization (Najafi and Dehghan, 2010; Alijani et al., 2012; Barikani and Shahbazi, 2016).

The debate on the 'efficiency' of fertilizer subsidy program is not new and not specific to Iran. According to the literature there are two types of subsidy programs depending on whether these are universally applied or targeted to a specific crop, category of farmers or region. Targeted subsidy programs include, for example, the five recent programs implemented in East and Southern Africa: Kenya, Malawi, Rwanda, Tanzania, and Zambia. These programs have in common their large scale in terms of number of beneficiaries (e.g., 2.5 million in Kenya), time frame (e.g., 10 years in Zambia), coverage (nation-wide), and implementation arrangements (voucher-based system). On the opposite, other countries such as Iran, India, and west African countries (Burkina Faso, Ghana, Mali, Nigeria, and Senegal) have adopted fertilizer subsidy programs, which seem to revert to universal (untargeted) price subsidies (Dorward, 2009; Praveen et al., 2017).

Both targeted and universal subsidies are highly discussed in the literature and two opposing views are generally identified. Those who sustain their effectiveness in bringing about green revolution (Gardner, 1992; Wright, 1995; Denning et al., 2009; Javdani, 2012) and those who considers them expensive, mainly benefit the wrong people, and distort agricultural markets (Holden and Tostensen, 2011; Chibwana et al., 2014).

The main objective of this paper is to contribute to this debate by assessing the economic effects of the fertilizer subsidy program currently implemented in Iran and to compare its performance with an alternative program based on targeting strategic crops. This is achieved using a Regional Crop Programming (RCP) model designed to simulate farms' responses to policy and market changes.

The paper is structured as follows: Section 2 describes the Regional Crop Programming (RCP) model and its major features. Section 3 presents and discusses the results of model simulation. Finally, section 4 draws the main conclusions and policy implications.

2. THE REGIONAL CROP PROGRAMMING (RCP) MODEL

2.1 Model features

RCP is a comparative static, regional, positive mathematical programming model, which includes in total 14 crop activities and encompasses 31 administrative regions. Positive means that the model aim to reproduces the real conditions as accurately as possible and to simulate "what is likely" to happen to this situation when changing external conditions (Howitt, 1995; Janssen and Van Ittersum, 2007). Regional signifies that the model operates at regional level and considers each region as one farm, as is often done in regional programming models (CAPRI (Britz and Witzke, 2014); REAP (Johansson, 2007); TASM (Eruygur and Cakman, 2008)). This implies that all farms within the region are assumed to be homogenous, have the same behavior and can perfectly exchange production factors. The use of a regional approach is motivated by the relative homogeneity[1] of arable farms in Iran as well as by the limited access to micro-data (i.e., farm data) for confidentiality reason.

Builds on regional data from the Iranian Agriculture Ministry-Jihad (IMAJ, 2016), the RCP model is a collection of 31 non-linear regional programming models, working with exogenous prices, each representing the optimal crop allocation at regional level. After being solved, the regional results of the regional models are aggregated to national level.

RCP is calibrated using positive mathematical programming (PMP) (Howitt, 1995) [2]. PMP is a methodology developed to exact calibrate programming models against observed economic behavior without the use of artificial flexibility constraints, while requiring minimal data. The PMP method is often preferred to linear mathematical programming as it avoids over specialization in crop production and yields smooth responses to policy changes. Because of these desirable characteristics, models calibrated using the PMP approach and its variants are popular in agricultural and environmental policy analysis. Existing agricultural supply models that rely on PMP principles include, among others, the European Common Agricultural Policy Regionalized Impact (CAPRI) modelling system (Britz and Witzke, 2014), the US Regional Environment and Agriculture Programming (REAP) model (Johansson et al., 2007), the Canadian Regionalized Agricultural Model (CRAM) (Horner et al., 1992), the Turkish Agricultural Sector Model (TASM) (Eruygur and Cakman, 2008), and the Dutch Regionalized Agricultural Model (DRAM) (Helming, 2005).

Over time, the literature on PMP has evolved and several variants have been developed to accurately calibrate programming models[3]. The more recent literature has focused on using supply elasticities and/or shadow prices for resources to reduce the under-determinacy of the model and increase the robustness of the parameter specification (Heckelei and Wolff, 2003; Mérel and Bucaram, 2010; Jansson and Heckelei, 2011; Mérel et al., 2011, Mérel et al., 2013; Britz and Witzke, 2014; Louhichi and Gomez y Paloma, 2014; Garnache et al., 2017; Louhichi et al., 2018; Henry de Frahan et al., 2019).

The PMP method used in this study builds upon this strand. It follows the variant proposed by Louhichi et al., (2018), which use cross-sectional data and prior information on supply elasticities and on dual values of land constraints, to calibrate the model to the base year condition. Supply elasticities are taken from the literature (Sabohi and Azadegan, 2014; Garshasbi et al., 2014; Jafari Lisar et al., 2017), while prior information on dual values of land constraints is derived from the Iranian Agriculture Ministry- Jihad (IMAJ) database.

RCP model relies on profit maximizing behavior and search for the optimal land allocation among production activities in each region taking into account land constraints. The regional profit (i.e., agricultural income) is defined as the sum of gross margin minus a nonlinear quadratic cost function for specific activity. The gross margin is equal to the total revenue from the sales of agricultural products plus fertilizer subsidies minus the accounting variable cost of production activities. The accounting costs include cost of seed, fertilizer,

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[1] If we exclude large-scale farms which represent less than 0.2% of agricultural holding (SCI, 2014), arable farms within the same region tend to be relatively homogeneous because the majority have small farm size and most of them are sharing the same technology and equipment (Ansari et al., 2020).

[2] Other methods have been developed to calibrate optimization models to observed allocations, although not perfectly. The well-known ones are the risk (Hazell and Norton, 1986) and the multi-attribute utility theory (Keeney and Raiffa, 1993) based methods.

[3] For a review of PMP models, see Heckelei et al., (2012) and Henry de Frahan (2019).

pesticides, hired labor, and water. The quadratic activity-specific function is a behavioral function introduced to calibrate the model to the observed land allocation of the base year, as is usually done in positive programming models. This function allows capturing the effects of factors that are not explicitly included in the model, such as capital and labor constraints, price expectations, risk-adverse behavior, and other unobserved costs (Heckelei and Wolff, 2003).

The crop yields and the nitrogen application rate are endogenously defined in our model to allow their adjustments under market and policy changes. This achieved thanks to a crop-specific quadratic[4] yield response function to nitrogen fertilizer (considered to be the most important nutrient), econometrically estimated and embedded in the model, under the assumption that yield is independent of the acreage planted.

The other fertilizer elements (P and K) are assumed to be applied in fixed proportion to nitrogen fertilizer and the remaining intermediate inputs such as seeds and pesticides are supposed to be independent to fertilizer and employed in fixed rate by hectare of each specific crop[5]. Intermediate inputs are also assumed to be independent on the (unknown) marginal costs that are captured by the quadratic behavioral function (Heckelei and Wolff, 2003).

The general mathematical formulation of profit maximization problem of region r = (1, 2, …, R) is as follows:

$$\begin{aligned}\operatorname*{Max}_{x\geq 0}\pi_r = \quad & \sum_i (p_{r,i}y_{r,i}x_{r,i}\text{-}w_{r,i}n_{r,i}x_{r,i}\text{+}s_{r,i}n_i x_{r,i}) \\ & -\sum_{i,k} C_{r,i,k}x_{r,i} - \sum_i d_{r,i}x_{r,i} - 0.5\sum_{i,i'} x_{r,i}Q_{r,i,i}{}'x_{r,i}{}'\end{aligned} \tag{1}$$

Subject to:

$$\sum_i A_{r,i,m}x_{r,i} \leq b_{r,m} \qquad [\varphi_{r,m}] \tag{2}$$

$$y=\alpha n+\beta n^2+\gamma \tag{3}$$

$$x\geq 0;\ y\geq 0;\ n\geq 0 \tag{4}$$

Where indices $i,i'=1,2,\dots,I$ denote the crop activity; $k=1,2,\dots,K$ the intermediate inputs (i.e., seed, pesticides, hired labor, water, etc.) and $m=1,2,\dots,M$ the resource constraints (only land is considered here).

π is the objective function value of region r, $x_{r,i}$ is the unknown level (hectares) of crop activity i, $p_{r,i}$ is the crop price (i.e. market price), $y_{r,i}$ is the crop yield, $w_{r,i}$ is the fertilizer price, $n_{r,i}$ (per hectares) is the fertilizer quantity, $s_{r,i}$ is the fertilizer subsidy (per hectares), and $C_{r,i,k}$ are accounting variable costs (per hectares) for each intermediate input k and crop i. $d_{r,i}$ is the linear term of the behavioral activity function and $Q_{r,i,i}{}'$ is the quadratic term of the behavioral activity function.

$A_{r,i,m}$ are the coefficients of resource (i.e., land) constraints, $b_{r,m}$ is the level of available resources and $\varphi_{r,m}$ are their corresponding shadow prices.

α,β and γ are the coefficients of the yield response function to nitrogen. The coefficients α and β are crop, seed variety, season, and agro-ecological zone specifics to take into account technological, soil and climate heterogeneity. γ is the intercept parameter whose position (value) can be shifted up or down in the calibration step to capture region specification.

By setting α and β at agro-ecological level we assumed that regions within the same agro-ecological zone have a common technology and, therefore, they have the same yield curve shapes but with different starting points (i.e., intercept γ is region specific). Five agro-ecological zones are defined for Iran, based on climatic conditions, soil characteristics and type of crops grown: Mountain Climate, Moist Climate, Hot and Dry Climate, Temperate Climate and Hot and Moist.

2.2 Model calibration

The aim of the calibration process is to ensure that, in each region, the observed crop allocation during the base year period is exactly reproduced by the optimal solution of the programming model, which relies on profit maximization. This implies that two key variables need to be calibrated: the regional crop yield and area. This is performed in two successive steps: first, we calibrate yield response to the applied nitrogen rate and then, the land allocation.

2.2.1 Calibrating yield response to nitrogen fertilizer

Calibrating yield response to nitrogen fertilizer consists of recovering the unknown crop specific nitrogen

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[4] We opted for a quadratic functional form because it keeps the model quadratic and simplifies the resolution of the optimization problem. More sophisticated specifications may consider exponential form (Godard et al., 2008; Mérel et al., 2011) or quadratic-plus-plateau form (similar to the conventional quadratic, but a plateau is imposed).

[5] This assumption lacks of rationalization given the strong relationship between fertilizer and other inputs. In fact, one could expect that an increase in fertilizer use would increase the risk of pest infestation (Rossing et al., 1997) and, as a consequence, the amount of pesticides applied (similar effects could be observed in other inputs). However, due to the lack of data to make a reliable estimate of this relationship and in order to avoid additional bias we have adopted this assumption following previous studies by Mérel et al., 2011; Mérel et al., 2013; Graveline and Mérel, 2014, Britz and Witzke, 2014, etc.

fertilizer prices w, the nitrogen response's intercept γ and the nitrogen fertilization rate n that allows reproducing exactly the observed yield y^0 assumed to be at the optimum level.

Mathematically, the above consists of solving the following model where the objective is assumed to be the maximization of the profit by unit of area with respect to nitrogen fertilization use (Godard et al., 2008; Louhichi et al, 2020):

$$\max \pi_{r,i} = p_{r,i} y(n) - w_{r,i} n_{r,i} + s_{r,i} n_{r,i} \tag{5}$$

Subject to:

$$y(n) = \alpha_i n_{r,i} + \beta_i n^2_{r,i} + \gamma_{r,i} \tag{6}$$

$$y(n) = y^0 \quad [\eta_{r,i}] \tag{7}$$

$$\eta_{r,i} \geq 0 \quad [\mu_{r,i}] \tag{8}$$

Where π is profit by unit of area, r is the region, i is the crop activity, y is the crop yield (kg ha^{-1}) and y^0 is its observed level in the base year (assumed to be optimal), p is the crop prices assumed to be known with exactitude, α,β and γ are the coefficients of the regression model, n is the nitrogen fertilizer quantity (kg ha^{-1}), w is the nitrogen fertilizer prices, $s_{r,i}$ is the fertilizer subsidy, η is the Lagrange multiplier related to the constrained yield level and μ is the Lagrange multiplier related to the non-negativity constraints for n,α and β are estimated by agro-ecological zone (more details are available in Louhichi et al., 2020).

2.2.2 Calibrating production activity levels

The calibration of activity levels consists of recovering the set of unknown parameters (d, Q and φ), so that the optimization model as described in equations (1) and (4) replicates exactly the observed activity levels (x^0) of the base year. This is performed using the results of the yield calibration step and a new variant of Positive Mathematical Programming (PMP) approach proposed by Louhichi et al., (2018). This variant relies on prior information on (i) supply elasticities ($\bar{\varepsilon}_{r,i,i}$), and on (ii) dual values of (irrigated and rainfed) land constraints ($\varphi_{r,m}$).

To perform the estimation, we derive the FOCs of the optimization model, equation (1) and (4) and then we apply the HPD method to estimate the unknown parameters $d_{r,i}$,$Q_{r,i,i}$' and $\varphi_{r,m}$.

The HPD model minimizes, in each region, the weighted sum of normalized square deviations of estimated national and agro-ecological zone own price(diagonal) supply elasticities and dual values of constraints from their prior subject to set of data consistency (FOC) constraints.

Following Louhichi et al., 2018, the general formulation of the corresponding HPD problem is the following:

$$\min HPD = \left[\sum_{i,i'} \frac{\left(\varepsilon_{i,i} - \bar{\varepsilon}_{i,i}\right)^2}{\sigma^{\varepsilon}_{i,i'}} + \sum_{z,i,i'} \omega_z \frac{\left(\varepsilon_{z,i,i} - \bar{\varepsilon}_{z,i,i}\right)^2}{\sigma^{\varepsilon}_{z,i,i'}} + \right.$$
$$\left. + \sum_{z,r,m} \omega_r \frac{\left(\varphi_{r,m} - \bar{\varphi}_{z,m}\right)^2}{\sigma^{\varphi}_{z,m}} \right] \tag{9}$$

Subject to:

$$gm_{r,i} - d_{r,i} - \sum_{i'} Q_{r,i,i'} x^0{}_{r,i'} - \sum_{m} A_{r,i,m} \varphi_{r,m} = 0 \tag{10}$$

$$b_{r,m} - \sum_{i} A_{r,i,m} x^0_{r,i} = 0 \tag{11}$$

$$\varepsilon_{r,i,i'} = \left[Q^{-1}_{r,i,i'} - \sum_{m} \left(\sum_{j} A_{r,j,m} Q^{-1}_{r,i,j} \left(\sum_{j,j} A_{r,j,m} Q^{-1}_{r,i,j} A_{r,j',m} \right)^{-1} \right.\right.$$
$$\left.\left. \sum_{j} A_{r,j,m} Q^{-1}_{r,j,i'} \right) \right] \frac{gm_{r,i}}{x^0_{r,i}} \tag{12}$$

$$\varepsilon_{z,i,i'} = \frac{\sum_r \omega_r x^0_r \varepsilon_{r,i,i'}}{\sum_r \omega_r x^0_{r,i}} \tag{13}$$

$$\varepsilon_{i,i'} = \frac{\sum_z \omega_z x^0_z \varepsilon_{z,i,i'}}{\sum_z \omega_z x^0_{z,i}} \tag{14}$$

$$B_{z,i,i}{}' = \textstyle\sum_j \mathrm{L}b_{z,i,j} \mathrm{L}b_{z,i}{}'_{,j};\ \mathrm{L}b_{z,i,i}{}' = 0 \quad \text{for } i' > \mathrm{i} \tag{15}$$

$$Q_{r,i,i'} = \sum_{z} \delta_{r,i} B_{z,i,i'} \delta_{r,i'} \tag{16}$$

$$\begin{aligned} &\sum Q_{r,i,i'} Q^{-1}_{r,i,i\prime} = 1 \quad \forall i = i \\ &\sum_{i} Q_{r,i,i'} Q^{-1}_{r,i,i\prime} = 0 \quad \forall i \neq i \end{aligned} \tag{17}$$

Where indices j,j'=1,2,…,I (similar to i,i') denote the crop activities; $gm_{r,i}$ is the gross margin for activity i (IRR/ha) with $gm_{r,i} = p_{r,i} y^0{}_{r,i} - w_{r,i} n^0{}_{h,i} + s_{r,i} - \sum_k C_{r,i,k}$. y^0 is the observed yield and w and n^0 are, respectively, the nitrogen fertilization price and quantity estimated in the yield calibration step.

$\overline{\varphi}_{z,m}$ and $\sigma^{\varphi}_{r,m}$ are, respectively, mean and standard deviation of the regional rental prices for irrigated and non-irrigated lands and $\bar{\varepsilon}_{i,i'}$,$\bar{\varepsilon}_{z,i,i'}$, $\sigma^{\varepsilon}_{i,i'}$ and $\sigma^{\varepsilon}_{z,i,i'}$ are mean and standard deviation of own price elasticities of supply at country and agro-ecologic zone levels used as prior (Jansson and Heckelei, 2011) and $\delta_{r,i}$ is a scaling factor with $\delta_{r,i}=\sqrt{1/x^0_{r,i}}$.

The normalized squared deviations of dual values and of agro-ecological zone supply elasticities are weighted (ω) with the inverse number of administrative regions (i.e., 1/31) and the inverse number of agro-ecological zones (i.e., 1/5), respectively, to obtain a comparable weight with the first component of the HPD objective function.

The prior for the own price supply elasticity at agro-ecological zone ($\bar{\varepsilon}_{z,i,i'}$) is defined as the own price supply elasticity at national level time the ratio of average production between agro-ecological zone and national level. This allow agro-ecological zone with low (high) average production to be more (less) elastic to price change compared to the national average.

The endogenous variables of HPD problem defined in equations (9)-(17) are: (i) the dual values of land constraints, $\varphi_{r,m}$, (ii) the own and cross price elasticities of supply at regional ($\varepsilon_{r,i,i}$'), agro-ecological zone ($\varepsilon_{z,i,i}$') and national ($\varepsilon_{i,i}$') levels, (iii) the elements of the lower triangular Cholesky decomposition related to $B_{z,i,i}$' parameters, $Lb_{z,i,i}$', and (iv) the regional-specific behavioral parameters $d_{r,i}$ and $Q_{r,i,i}$' (including the inverse matrix $Q^{-1}_{r,i,i'}$).

Equations (10) and (11) represent the FOC of the optimization model for crop activities and for land constraints, respectively. Equations (12), (13) and (14) compute supply elasticities at regional, agro-ecological zone and national levels, respectively. Equation (15) is the Cholesky decomposition which ensures appropriate curvature properties of the estimated quadratic cost function (i.e., convex in activity levels), Equation (16) calculates the region-specific quadratic parameters $Q_{r,i,i}$' and Equation (17) calculates its inverse $Q^{-1}_{r,i,i'}$.

2.3 Data

The primary data source used to parametrize RCP model are regional data from the Iranian Agriculture Ministry- Jihad (IMAJ, 2016) for the three-years average around 2015 (2014, 2015 and 2016). IMAJ publish annual report on crop area and production in each region obtained from the aggregation of individual farm data collected through face-to-face survey. The Information and Communication Technology Centre of Iranian Agriculture Ministry (ICTC- IMAJ) also use these individual farm data to derive input and output prices and quantities of crops in different regions as Cost Bank System (CBS).

The CBS and IMAJ database provide detailed regional information for the five groups of crops, namely cereals (wheat, barley, corn, and rice), legumes (pea and lentil), vegetables (onion, potato and tomato), fruit (melon and cucumber), and industrial crops (cotton, canola and sugar beet). Table 1 reports the statistical characteristics of the key variables for the 14 selected crops in RCP. These variables include total cultivated areas and total production for each crop as well as their yield, revenue, estimated fertilizer application rates, fertilizer subsidy, production costs (e.g., seed, pesticides, fertilizer, hired labor and water), gross income, estimated implicit costs/revenues and net income per unit of land, average across 31 regions and for the three-year average around 2015.

2.4 Scenarios: layout and implementation

As mentioned previously, apart from the pressure coming from the WTO, there is an intensive ongoing debate about the effectiveness of the input subsidies in Iran given their high, possibly unsustainable costs and the absence of credible empirical evidence on their impacts on agricultural productivity. Therefore, a reduction or a total removal of these subsidies or their reallocation to only specific farm groups or to specific crop sectors are among the reform options that are currently under discussion in the country.

In this regard, the aim of this paper is to simulate the impacts of two policy options: (i) a total removal of nitrogen fertilizer subsidy for all crops and all regions (ABOL scenario) and (ii) a reallocation of nitrogen fertilizer subsidy to only strategic crops (wheat, maize, and rice) while keeping the same subsidy budget (TARG scenario).

We are aware that this drastic scenario of a total removal of fertilizer subsidy is currently to a great extent unrealistic and cannot represent a prospective or even likely development; however, it might contribute to the on-going debate on their relevance and their legitimacy. Keeping the subsidies (or reallocating all of them) for only strategic crops seems to be more realistic due to the high attention given by the government to these crops for political, economic and food security reasons, particularly under the various international sanctions.

Both scenarios are implemented and compared to a baseline scenario representing the business as usual (i.e., the baseline scenario is used for the counterfactual comparison of the simulated scenarios).

3. RESULTS AND DISCUSSION

In this section we examine whether and how the simulated fertilizer subsidy reform options affect land

Table 1. Statistical characteristics of the key variables.

	Crops	Area under cultivation (1000ha)	Production (1000 ton)	Yield (ton)	Revenue (1000 IRR/ha)	Fertilizer use (kg/ha)	Fertilizer Subsidy (IRR/kg)	Nitrogen use (kg/ha)	Production Cost (IRR/ha)	Gross Income (1000IRR/ha)	Implicit costs/ revenues (1000IRR/ha)	Net Income (1000IRR/ha)
Cereals	Wheat	5894.07	12117.70	2.06	11815.04	302.02	277.76	194.46	20906.21	-8.81	42.73	33.92
	Barley	1739.84	3281.66	1.89	9246.78	171.97	135.86	110.06	19982.51	-10.60	44.43	33.83
	Maize	173.53	1249.70	7.20	73584.91	677.63	506.43	441.84	38678.80	35.41	36.13	71.54
	Rice	332.58	1737.17	5.22	92201.17	1127.29	1076.53	695.03	49732.81	43.54	-26.64	16.90
Legumes	Lentil	134.57	74.71	0.56	27663.63	5.13	2.91	3.36	7968.69	19.70	14.07	33.77
	Peas	492.56	236.67	0.48	7045.33	18.49	20.69	11.45	7924.71	-0.86	55.01	54.15
Vegetables	Tomato	118.76	4878.06	41.08	139039.97	676.35	961.94	427.57	88656.44	51.35	5.88	57.23
	Potato	148.45	4726.75	31.84	175494.44	620.01	794.18	371.17	110089.80	66.20	16.61	82.81
	Onion	50.16	1861.46	37.11	126122.08	1033.77	1853.98	629.38	98891.62	29.08	19.09	48.17
Fruit	Cucumber	46.25	1007.52	21.78	233610.84	307.87	271.12	209.55	73462.27	160.42	-53.94	106.48
	Melon	112.39	3099.80	27.58	100423.7	487.34	841.26	288.78	55581.61	45.68	-0.95	44.73
Industrial crops	Canola	60.01	93.63	1.56	21864.07	425.24	305.52	259.02	12638.04	9.53	24.93	34.47
	Sugar beet	100.66	5278.90	52.44	133050.2	587.20	467.32	350.48	71686.40	61.83	9.54	71.37
	Cotton	72.09	166.30	2.31	65600.89	132.61	86.32	81.20	45810.45	19.88	22.13	42.01
MIN	46.25	74.71	0.48	233610.84	5.13	2.91	3.36	7924.71	-10.60	-53.94	16.90	
MAX	5894.07	12117.70	52.44	7045.33	1127.29	1853.98	695.03	110089.80	160.42	55.01	106.48	
STDEV	1564.68	3248.38	18.14	69273.66	345.43	517.20	211.90	34388.40	43.18	28.70	23.86	

Source: ICTC- IMAJ. Three-years average around 2015 (2014, 2015 and 2016)

*Net income equals to the total revenue from the sales of agricultural products plus fertilizer subsidies minus the accounting variable cost of production activities plus implicit revenues/costs (i.e., PMP terms).

allocation, nitrogen fertilizer application rate, production, agricultural income, and government budget in Iran at both regional and national levels and compare their cost-effectiveness using the transfer efficiency index.

Before presenting simulation results it is important to notice that farmers may respond in three ways to a reduction or a removal of fertilizer subsidy: (i) extensive margin, that is, reallocation of acreage among crops by, for example, substituting more fertilizer-intensive crops with less fertilizer-intensive crops (i.e. acreage effects), (ii) intensive margin, that is, reducing fertilizer intensity per hectare for a given crop (i.e. yield effects), and (iii) land abandonment, that is, putting out of production land (i.e. land abandonment effects).

With our models we tried to capture only the first two adjustments which represent the main opportunities for farmers to respond to shocks. Land abandonment adjustment is excluded because agricultural utilized area is assumed to be fix in our model.

3.1 Acreage, fertilizer intensity and yield effects

3.1.1 ABOL scenario

The implementation of the ABOL scenario, based on a total removal of nitrogen fertilizer subsidy, would lead, as expected, to the reallocation of land from crop groups strongly dependent on fertilizer such as industrial crops, vegetables, and fruit to crop groups less dependent on fertilizer like legumes and cereals. As shown in Table 2, the acreage of industrial crops, vegetables and fruit decreased by -1.72%, -1.47%, and -1.16%, while the acreage of legumes and cereals increases by +0.93 and +0.06%, respectively. These results are also confirmed while looking to individual crops. The acreage of crops strongly dependent on fertilizer such as rice, tomato and maize decreased by -5.75%, -2.54% and -1.46%, respectively, whereas the acreage of crops less dependent on fertilizer such as barley, peas and lentil increase by +9.56%, +1.02% and +0.63%, respectively. This finding is explained by the fact that fertilizer-intensive crops become less competitive with the removal of subsidy and, therefore, lose some of their areas in favor of less fertilizer-intensive crops. Pishbahar and Khodabakhshi (2015) in a study focusing on farmers of Varamin area have found similar results showing a decrease in the acreage of maize and tomato with the removal of input subsidy. Kohansal and Ghorbani (2013) and Shirmahi et al., (2014) have revealed, using estimated price elasticity for nitrate fertilizer, that removing nitrate subsidy would cause a remarkable land reallocation among crops.

From this Table it also appears that all crops experience a reduction in their fertilizer application rates when the nitrogen price increase with the removal of subsidy. The average reduction of fertiliser application rate across all crops is around -9.16%, ranging between -0.7 % and -18%. Legumes are the most responsive to nitrogen price increase, in terms of fertiliser application rate. However, this response is small in absolute terms because legumes have relatively low fertiliser application rate in baseline. In the opposite, the response of fertiliser-intensive crop groups (e.g., industrial crops, vegetables, and fruit) is relatively low (less than 20%) but quite large in absolute terms. While comparing individual fertiliser-intensive crops (e.g., rice, onion, tomato, and maize), we found that their responses to nitrogen price increase are quite similar and close to -2.5%. The exception is maize where the percentage change in application rate seems to be very small (less than 1%), explained by the fact that the observed application rate for maize lies on the flatter proportion of the yield response curve.

Table II also shows that the reduction of nitrogen application causes relatively drastic yield losses in nitrogen-intensive crop groups than in less nitrogen-intensive crop groups. This clearly appears for legumes where a -48% decrease of fertiliser application rate causes a reduction of only -1.92% for yield, while a –1.84% decrease of fertiliser application rate for vegetable causes a reduction of its yield by -0.37%. However, given the relatively high yield of nitrogen-intensive crop groups their yield losses could be significant in absolute terms.

Appendix Table A1 reports the reallocated area in each region as a result of the ABOL scenario. From this Table it clearly appears that all regions seem to be affected by this scenario with different degree depending on their specialization. The largest reallocated area is observed in regions specialised in rice such as Mazandaran, those specialised in industrial crops (mainly canola) like Golestan and those specialised in vegetables (mainly tomato) like Fars. Golestan tend to be more affected because it is the first producer of canola with 14200 thousand hectares (around 25% of total canola area) and the second after Mazandaran in cultivating rice with 59060 thousand hectares (around 10% of total rice land). This result is expected, as these three crops have the highest fertilisation rates and, therefore, a reduction of fertilisation application cause drastic losses in their yields and, thus, in their performances. Regions specialised in maize such as Kurdistan seem to be able to maintain such specialisation although its dependency on fertiliser. This means that maize remains competitive in these regions even with an increase of nitrogen fertiliser price.

Table 2. Fertilizer application rate, acreage, production, yield, and income changes under ABOL and TARG scenarios (% change relative to baseline).

Crop/ group/ Scenario	Fertilization Application Rate		Acreage		Production		Yield		Average Net Income	
	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG
Wheat	-8.32	1.31	-2.38	0.90	-4.18	0.90	-1.94	0.00	-1.67	0.22
Barley	-18.15	3.65	9.56	-2.63	1.37	-1.06	-7.41	1.59	-0.51	-0.01
Maize	-0.72	0.15	-1.46	0.60	-1.73	0.67	-0.28	0.14	-0.39	0.10
Rice	-2.68	0.64	-5.75	0.76	-6.24	0.90	-0.38	0.19	10.51	-1.01
Cereals	**-4.02**	**0.81**	**0.06**	**0.13**	**-3.22**	**0.53**	**-1.34**	**0.31**	**0.49**	**-0.02**
Lentil	-11.61	-12.20	0.63	-0.38	0.26	-0.38	-1.79	0.00	1.27	-0.10
Peas	-58.60	-60.61	1.02	-0.16	-1.37	-2.40	-2.08	-2.08	-0.31	0.05
Legumes	**-47.94**	**-49.63**	**0.93**	**-0.20**	**-0.97**	**-1.92**	**-1.92**	**-0.96**	**0.30**	**-0.01**
Tomato	-1.86	-1.63	-2.54	-1.42	-2.79	-1.75	-0.27	-0.34	-0.47	-0.25
Potato	-0.97	-0.98	-0.71	-0.68	-0.79	-0.73	-0.06	-0.06	0.12	-1.80
Onion	-2.34	-2.33	-1.17	-1.39	-1.93	-2.03	-0.75	-0.65	-2.84	-1.41
Vegetables	**-1.84**	**-1.77**	**-1.47**	**-1.07**	**-1.83**	**-1.37**	**-0.37**	**-0.36**	**-0.90**	**-1.02**
Cucumber	-8.90	-8.72	-0.41	-0.38	-0.58	-0.51	-0.14	-0.09	-0.07	-0.16
Melon	-0.94	-0.95	-1.46	-1.72	-0.96	-1.03	0.51	0.69	8.05	-1.26
Fruit	**-4.29**	**-4.22**	**-1.16**	**-1.33**	**-0.87**	**-0.90**	**0.22**	**0.34**	**2.33**	**-0.49**
Canola	-1.78	-0.66	-3.44	-2.02	-3.69	-1.38	0.00	0.64	0.13	-0.39
Sugar beet	-2.25	-2.27	-0.87	-0.42	-0.85	-0.50	0.02	-0.08	0.39	-0.94
Cotton	-16.26	-14.10	-1.49	-3.19	-1.36	-3.40	0.00	-0.43	0.07	1.85
Industrial crops	**-3.72**	**-3.06**	**-1.72**	**-1.69**	**-0.91**	**-0.60**	**0.02**	**-0.07**	**0.18**	**0.12**
National	**-9.16**	**1.05**	**0.00**	**0.00**	**-2.61**	**-0.12**	**-0.23**	**-0.10**	**-076**	**-0.01**

Source: Model results.

3.1.2 TARG scenario

Paying nitrogen fertilizer subsidy to only strategic crops ("TARG scenario"), namely wheat, maize and rice boosts their areas at the expense of non-target groups. As shown in Table II, the area devoted to cereals group increase by 0.13%, whereas the area dedicated to all other groups' decline, reaching -1.69% for industrial crops. The percentage increase of strategic crops area is relatively small; however, measured in absolute terms, it is quite significant (about 57 thousand hectares) due to their large initial shares in the total area (Table 1).

Looking at fertilization application rate change under TARG scenario reported in Table II, we can see the same trend as for acreage change: an increase of fertiliser intensity for target crops and a decrease for the other crops. However, the magnitude of changes is quite different: the percentage change of fertiliser application is bigger than the percentage change of acreage, which is not surprising given that a large increase of crop area will be costlier due to rising marginal costs. The yield effect of the TARG scenario seems to be limited which means that reducing fertiliser price for target crops, which are nitrogen-intensive crops, boost only marginally their yield.

As predicted, the reallocation of fertiliser subsidies to only strategic crops stimulate their acreages in all regions (see Table A1). Regions specialised in target crops (i.e., with largest share of target crops) react relatively more rapidly to a nitrogen price decrease triggered by the TARG scenario, in comparison to the other ones. For example, in the East Azerbaijan, Fars and Kurdistan regions, where target crops area in baseline exceeds 70% of total cropland, the percentage increases are larger, in comparison to regions with small initial share (less than 30%). In these regions the land adjustment occurs, mainly at the expense of barley. For instance, in Fars, the acreage of barley declines by -20% under the TARG scenario and its share in total land drop down from 20% (121693 hectares) to 16% (97411 hectares).

3.2 Production effects

Table II shows the production effects of ABOL and TARG scenarios. As can be seen from this Table, the average production effects of ABOL and TARG scenarios are estimated to be around -2.61% and -0.12%, respectively. The main production effects under the ABOL scenario are (i) a decrease of production for nitrogen intensive crop groups (e.g., vegetable decrease by -1.83%, industrial by -0.91%, and fruit by -0.87%) and (ii) an increase of production for less nitrogen intensive crop groups (e.g., legumes). These trends are also confirmed while looking to individual crops. Production of crops less dependent on fertilizer such as barley and lentil increase whereas, whereas production of crops strongly dependent on fertilizer like rice, tomato and maize decrease ranging between -1% and -7%. These results are consistent with Rahmani et al., (2011) who also found that increasing fertilizer price led to a decrease in the production of maize by -1.28% and cotton by -1.62%.

Under the TARG scenario, the large positive effects in production are observed for the targeted crops, namely wheat, maize, and rice, ranging between +0.6% and +0.9%, while negative effects are experienced by less competitive crops such as cotton, tomato, and barley, with a production retraction of -3.4%, -2.4% and -1.06% respectively.

At regional level, Mazandaran by -31 %, Golestan by -26% and Kohkiloyeh by -20% show the highest decrease in production under the ABOL scenario. However, in the TARG scenario production increased in Mazandaran by +4% and Bushehr by +2% (see Table A2). As mentioned before, Mazandaran and Golestan are the most important regions in cultivation rice.

These production effects are driven either by land reallocation (i.e., land substitution between crop groups), land productivity (i.e., yield effect) or both. To better understand the contribution of each driver, we decomposed the production effects into two effects using the Logarithmic Mean DIVISIA Index (LMDI) approach (Ang, 2005): acreage effect (i.e., area) and yield effect (i.e., productivity):

$$production=\left(\frac{Production}{Area}\right)\times Area=Productivity\times Area \tag{18}$$

Where area stands for cultivated area, therefore, production impacts are decomposed into productivity and area effects in an additive form as follows:

$$\Delta production=\Delta productivity+\Delta Area \tag{19}$$

Where $\Delta x=x(scenario)+x(baseline)$. The LMDI approach is used to calculate the above individual contributions. For example, the area effect is calculated as follows:

$$\Delta Area=\frac{prod_{-s}-prod_{-B}}{\ln(prod_{-s})-\ln(prod_{-B})}\times ln\left(\frac{Area_{-s}}{Area_{-B}}\right) \tag{20}$$

Where $prod_{-s}$ and $prod_{-B}$ refer to production (in tons) under ABOL and TARG scenarios and baseline respectively, in stand natural logarithm and $Area_{-s}$ and $Area_{-B}$ denote the cultivated area under ABOL and TARG scenario and baseline, respectively.

Figure 1 reports the decomposition of production effects under ABOL and TARG scenarios. From Figure 1 it clearly appears that the acreage effect explains around 80% of production effect for vegetable, fruit, and industrial groups under both ABOL and TARG scenarios. As an example, the -1.83% decrease of vegetable production under ABOL scenario is assumed to be a combined effect of yield (-0.37%) and area (-1.47%). The acreage effect accounts for 80.33% of the total change in vegetable production, while the remaining 19.67% is attributed to yield effect. Given that the acreage effect explains most of the changes in production under ABOL and TARG scenario for these three crop groups, it is not surprising to observe that their production and acreage effects are strongly correlated. On the other hand, for cereal and legumes groups, production changes under both ABOL and TARG scenarios seem to be mainly driven by yield effect. For example, the 0.53% production increase of cereals is a result of a 75% yield change and 24 % of acreage change.

3.3 Agricultural income effects

The land and production effects presented previously dictate changes in agricultural income reported in Table II. Before interpreting these changes, it is important to notice that agricultural income is equal to the maximized value of the objective function presented in equation (1) and, therefore, it is inclusive of all shadow costs.

The impact of the removal of fertilizer subsidy (ABOL scenario) on agricultural income is rather small when aggregated at national level (less than 1% compared with the baseline), and the reallocation of fertilizer subsidy to only target crops has very limited effect on national agricultural income, compared to baseline. This is to say that due to the relatively low shares of subsided fertilizers in total fertilizer consumption and of fertilizer costs in total production costs, the removal or reallocation of fertilizer subsidy will not engender a large impact on agricultural income at national level. However, while looking deeper at the regional and crop levels the impact could be more pronounced and sometime with opposite sign.

As shown in Appendix Table A3, income change under ABOL scenario is negative for all regions, which

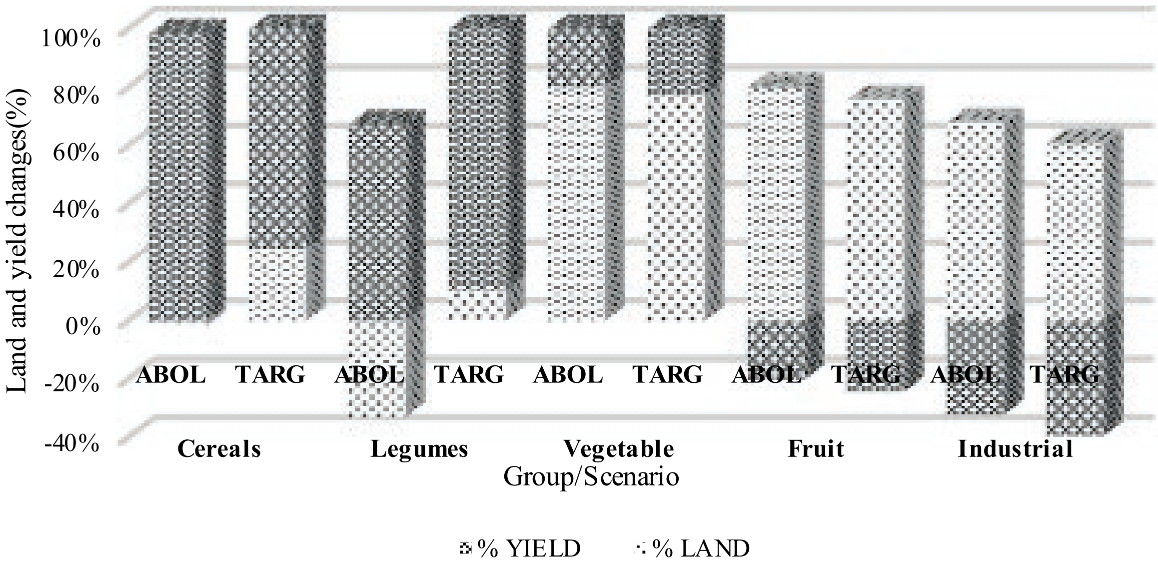

Figure 1. Production change decomposition under ABOL and TARG scenarios.

is not surprising, ranging between -0.35% and 5%. As expected, the most affected ones are those specialized in nitrogen-intensive crops such rice, tomato, and onion. This heterogeneous income effect is probably more noticeable when we go at lower levels such as sub-regional and farm levels.

Under TARG scenario (Table 6), the economic impact remains also small for the majority of the regions, ranging between -3% and 0.64%; nevertheless, there is an opposite effect: some regions loose and some regions gain from the reallocation of subsidy. Regions specialized in target crops (wheat, maize, and rice) such as Golestan gain from the reallocation, while other regions either they lose or almost no change compared to the current situation (i.e., Khorasan and, South Khorasan).

3.4 Policy efficiency

In this section we use the results of the RCP model to compare welfare implications of the two simulated policies: current (i.e., baseline) vs. target (i.e., TARG) fertiliser policies. For doing that, we use the ABOL scenario as counterfactual. In fact, the difference between the baseline and the ABOL scenario provides an estimation of the effect of the current policy (universal subsidies), while the difference between the TARG and the ABOL scenarios gives an estimation of the alternative policy (target subsidies).

From a cost/benefit perspective, the most efficient policy instrument is the one best at achieving the target benefit at lowest cost. Following Brooks et al., (2011), we use the transfer efficiency (TE) index to compare the relative efficiency of both policies. This index is calculated as follow:

$$TE = \left(\frac{increase\ in\ agricultural\ income}{total\ cost\ to\ taxpayers\ and\ consumers}\right) \qquad (21)$$

The implementation of the target fertiliser policy (TARG scenario) came at a total cost to taxpayers and consumers of about IRR 2.83 billion and generates an increase of agricultural income of IRR 2.64 billion, which means a TE of 0.93. Whereas the application of the universal fertiliser policy (baseline scenario) came at the total cost to taxpayers and consumers of IRR 2.83 billion and generates an increase of agricultural income of IRR 2.69 billion, which implies a TE of 0.94.

The main conclusion coming out from this comparison is that, first, the two policies are quite similar in terms of welfare implications and, second, both policies seem to be inefficient because their TE are lower than one, knowing that all the administrative costs related to the implementation of this policy are not considered in our analysis. These results are in line with the finding of Karimzadeh et al., (2006), Mosavi et al., (2009), Bakhshi et al., (2010) and Rahmani et al., (2011) who also reported that fertiliser subsidy in Iran has led to an inefficient use of nitrate fertilizer and, therefore, needs to be reviewed.

4. CONCLUSION

This paper presents the results of a comprehensive analysis aiming to assess the economic effects of the fertilizer subsidy programs currently implemented in Iran and to compare its performance with an alternative program based on targeting strategic crops. Two policy scenarios are simulated, and their results are compared to a baseline scenario representing the business as usual: a total removal of fertilizer subsidy "ABOL", and a reallocation of fertilizer subsidy to only strategic crops (wheat, corn, and rice) "TARG".

This analysis is done using a regional economic model which includes in total 14 crop activities and encompasses 31 administrative regions. This model is a collection of micro-economic models, working with exogenous prices, and calibrated against observed data on crop acreage, yields and exogenous supply elasticities.

From a methodological perspective, the novelty of this paper lies in the employ of detailed regional modelling approach that allow for an adjustment of both crop acreage and input intensities and, therefore, to infer the effects of policies that are likely to have effects at the extensive and intensive margins.

From a policy perspective, findings from this study reveal several exciting patterns. First, the effects of fertilizer subsidy removal are rather small at national level (less than 1%), although more pronounced at regional level, implying that a large share of farms do not use or use small quantity of fertilizer and, therefore, additional government efforts are needed to facilitate them access. Second, the reallocation of fertilizer subsidy to only strategic crops under TARG scenario boost their production and income, however, it increases disparity among regions and affects negatively national agricultural income and welfare compared to the current universal fertilizer policy. This imply that targeting strategic crops could not be the best solution and higher efficiency could be achieved by taking into consideration regional and farm heterogeneities. Policymakers may gain from be cognizant of heterogeneity among regions/farms and that one policy may not fit all regions/farms. Third, based on the result of the Transfer Efficiency (TE) analysis, both target and universal simulated options seem to be inefficient, as their TE indexes are lower than one, meaning that one IRR injected in the Iranian's agriculture sector generate less than one IRR. Such results tend to confirm previous studies in the literature showing low productivity of Iranian agriculture (Bakhshi et al., 2010; and Rahmani et al., 2011).

Our findings, however, need to be considered with some caution, on account of the model's assumptions. First, output market prices are assumed to be exogenous. This implies that market feedback (output price changes) is not taken into account in the model. This could be an issue mainly when production change is quite high such as for cereals under ABOL scenario. Accounting for price effects requires extending the supply model into a partial or a general equilibrium model which is clearly beyond the scope of the present paper. A relaxation of this assumption would dampen supply effects and partially offset the negative impacts of subsidy removal (ABOL scenario) given that a production decrease induced by higher fertilizer prices raises output prices which in turn enhances production. Similar trend would be observed for non-target crops under TARG scenario.

Second, due to data limitations the administrative costs related to the implementation of fertilizer policies are not considered. This may lead to an overestimation of the welfare impacts. A third potential caveat to our analysis is that we assume a fixed regional structure, implying that agricultural land extension/retraction (abandonment) in response to the simulated policies is not captured by the model. This may lead to an underestimation of the simulated impacts, mainly under ABOL scenario. A careful analysis of each of these limitations is, therefore, needed when examining simulation results.

Despite these limitations, our paper gives some insights on the potential role of fertilizer subsidy and provides useful recommendations to the policy making process aiming to enhance productivity and sustainability of the farming sector in Iran.

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Appendix Table A1. Regional acreage changes under ABOL and TARG scenarios (% change relative to baseline).

Region/Crop	Cereals		Legumes		Vegetables		Fruit		Industrial crops		Total	
	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG
Alborz	0.05	0.01	-	0.00	-0.55	-0.38	-	0.00	-1.60	0.19	0.00	0.00
Ardabil	0.06	0.03	-0.02	0.00	-0.60	-0.42	-0.20	-0.19	-1.40	-0.11	0.00	0.00
Boshehr	0.01	0.01	-	0.00	-0.68	-0.71	-0.37	-0.39	-	0.00	0.00	0.00
Chaharmahal	0.05	0.03	0.32	-0.10	-0.80	-0.36	-2.97	-0.84	-0.70	-0.06	0.00	0.00
East Azarbaijan	-0.43	0.10	4.86	-0.77	-1.28	-0.56	-14.15	2.13	-2.19	-0.54	0.00	0.00
Elam	0.03	0.01	0.48	-0.06	0.00	0.00	-0.75	-0.06	-1.46	-0.01	0.00	0.00
Esfahan	0.58	0.16	-8.97	-2.13	-2.51	-0.98	-4.42	-0.24	0.70	0.75	0.00	0.00
Fars	-0.70	0.31	29.08	-8.62	0.02	-0.80	1.56	-1.26	2.62	-1.40	0.00	0.00
Gilan	0.01	0.03	0.08	-0.13	-0.20	-0.55	-0.14	-0.26	-	0.00	0.00	0.00
Golestan	0.56	-0.02	-26.25	-4.72	-9.16	1.49	7.58	-2.82	-8.80	0.62	0.00	0.00
Hamedan	0.03	0.05	0.34	-0.04	-0.62	-0.63	-0.59	-0.52	-0.43	-0.16	0.00	0.00
Hormozgan	0.62	1.22	-	0.00	-0.53	-0.72	-0.05	-0.05	11.22	-23.83	0.00	0.00
Kohkiloyeh	0.33	0.02	-5.24	-0.39	-18.87	-0.99	-9.15	-0.60	-	0.00	0.00	0.00
Kerman	0.09	0.01	-1.91	-0.33	-0.60	-0.26	-0.18	-0.40	-1.57	1.02	0.00	0.00
Kordestan	0.09	0.03	-0.45	0.06	-1.21	-1.21	-0.34	-0.31	1.25	-5.49	0.00	0.00
Kermanshah	-0.04	0.08	0.09	0.12	1.57	-5.53	-	0.00	-0.66	0.30	0.00	0.00
Khouzestan	0.11	0.22	1.12	0.97	-0.87	-0.68	-0.51	-0.24	-2.61	-7.64	0.00	0.00
Lorestan	-0.02	0.03	0.14	-0.04	-0.39	-0.33	-0.16	-0.15	-0.41	-0.15	0.00	0.00
Markazi	-	0.01	0.59	-0.20	-0.10	-0.14	-	0.00	-2.81	0.33	0.00	0.00
Mazandaran	0.19	0.00	-	0.00	-1.49	-2.61	-31.24	3.77	-1.83	0.11	0.00	0.00
North Khorasan	0.14	0.12	1.53	0.02	-1.74	-1.75	7.11	-1.14	-4.33	-1.33	0.00	0.00
Qom	-0.01	0.00	-	0.00	-	0.00	-	0.00	0.08	-0.07	0.00	0.00
Qazvin	0.74	0.13	5.69	0.38	-9.34	-1.31	-19.03	-0.93	-12.41	-2.45	0.00	0.00
Razavi Khorasan	0.39	0.94	0.22	-0.42	-1.03	-3.81	-6.58	-9.25	-1.46	-4.72	0.00	0.00
Sistan	0.05	0.12	-0.45	-0.99	-0.40	-0.58	-0.13	-0.32	0.02	-1.07	0.00	0.00
South Khorasan	0.03	0.10	1.76	-8.69	-0.16	0.39	-0.65	-2.08	0.13	0.47	0.00	0.00
Semnan	0.06	0.05	-0.69	-0.32	-0.41	-0.54	-0.12	0.22	-0.04	-0.03	0.00	0.00
Tehran	0.03	0.01	-	0.00	-0.35	-0.16	-0.20	0.00	-	0.00	0.00	0.00
West Azarbaijan	-0.01	0.04	0.30	-0.04	-0.58	-0.51	-0.55	-0.30	-0.36	-0.22	0.00	0.00
Yazd	0.05	0.06	-	0.00	-1.17	-1.27	-0.01	-0.17	-	0.00	0.00	0.00
Zanjan	0.07	0.07	0.78	0.12	-2.10	-1.32	-1.79	-1.11	-3.93	-1.57	0.00	0.00
National	**0.06**	**0.13**	**0.93**	**-0.20**	**-1.47**	**-1.07**	**-1.16**	**-1.33**	**-1.72**	**-1.69**	**0.00**	**0.00**

Source: Model results.

Appendix Table A2. Regional production changes under ABOL and TARG scenarios (% change relative to baseline).

Region/Crop	Cereals		Legumes		Vegetables		Fruit		Industrial crops		Total	
	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG
Alborz	-1.39	0.26	0.00	-	-0.54	-0.40	0.00	-	-2.15	-0.26	-1.23	0.12
Ardabil	-3.38	0.60	0.01	0.01	-0.69	-0.51	-0.29	-0.27	-1.58	-0.21	-1.95	0.04
Boshehr	-9.84	1.94	0.00	-	-0.88	-0.92	-0.41	-0.42	0.00	-	-4.88	0.66
Chaharmahal	-3.21	0.47	-0.06	-0.34	-0.85	-0.40	-3.83	-1.72	-0.98	-0.35	-1.79	-0.06
East Azarbaijan	-6.04	0.79	3.08	-1.88	-1.37	-0.64	-8.76	1.06	-3.45	-1.82	-3.82	0.09
Elam	-3.32	0.55	0.48	-0.06	0.00	-	-0.88	-0.08	-8.94	0.17	-2.56	0.33
Esfahan	-3.76	0.03	-7.95	-2.65	-2.96	-1.22	-5.03	-0.30	-0.05	0.37	-3.16	-0.64
Fars	-2.41	0.25	14.92	-6.21	-0.39	-1.30	1.34	-1.46	1.68	-1.02	-0.56	-0.70
Gilan	-1.09	0.24	0.06	-0.15	-0.20	-0.55	-0.16	-0.26	0.00	-	-0.49	-0.09
Golestan	-3.47	0.75	-26.26	-4.73	-11.63	1.90	7.45	-2.94	-9.91	0.37	-4.91	0.87
Hamedan	-2.55	0.43	-2.51	-2.87	-0.69	-0.70	-0.91	-0.84	-0.57	-0.29	-1.35	-0.27
Hormozgan	-0.54	1.44	0.00	-	-1.15	-1.35	-0.82	-0.82	2.85	-29.57	-1.02	-1.01
Kohkiloyeh	-5.89	0.37	-5.21	-0.44	-19.72	-1.93	-11.91	-0.96	0.00	-	-7.10	0.10
Kerman	-1.79	0.32	-4.01	-1.72	-0.62	-0.28	-0.24	-0.44	-3.00	-0.07	-1.25	0.03
Kordestan	-1.77	0.35	-1.66	-1.20	-1.44	-1.44	-0.43	-0.40	0.36	-0.81	-1.54	-0.26
Kermanshah	-2.57	1.06	-2.14	-1.05	1.36	-6.03	0.00	-	-0.77	0.07	-1.22	-0.91
Khouzestan	-1.85	0.37	1.12	0.97	-1.25	-1.07	-0.63	-0.34	-1.51	-0.48	-1.49	-0.12
Lorestan	-2.73	0.50	-2.50	-2.68	-0.41	-0.35	-0.30	-0.27	-0.50	-0.25	-1.52	-0.05
Markazi	-2.22	0.39	-3.36	-3.87	-0.19	-0.17	0.00		-1.96	-0.17	-1.90	0.26
Mazandaran	-1.83	0.30	0.00	0.00	-5.79	0.13	-31.25	3.76	-1.90	0.04	-2.67	0.38
North Khorasan	-5.40	0.44	0.77	-0.73	-2.00	-2.06	6.79	-1.44	-5.03	-1.38	-4.13	-0.66
Qom	-0.84	0.16	0.00	-	0.00	-	0.00	-	0.09	-0.10	-0.79	0.15
Qazvin	-11.04	-0.73	4.07	-1.15	-8.76	-1.33	-19.09	-1.00	-16.72	-2.02	-10.41	-1.15
Razavi Khorasan	-4.60	1.45	-4.89	-5.55	-1.18	-4.06	-1.98	-4.77	-1.16	-1.46	-2.40	-1.46
Sistan	-5.66	1.19	-1.00	-1.69	-0.50	-0.70	-0.16	-0.36	-1.23	-2.31	-1.54	-0.05
South Khorasan	-3.98	1.23	1.76	-8.69	-6.08	-5.57	-1.06	-1.04	-0.51	-0.18	-2.53	0.16
Semnan	-2.28	0.46	-0.70	-0.32	-0.41	-0.49	-0.13	0.22	-0.31	-0.39	-0.97	-0.06
Tehran	-1.34	0.20	0.00	-	-0.40	-0.21	-0.25	-0.06	0.00	-	-0.91	0.03
West Azarbaijan	-3.47	0.62	-2.74	-3.08	-0.68	-0.62	-0.61	-0.30	-0.43	-0.29	-1.23	-0.13
Yazd	-1.27	0.33	0.00	-	-2.50	-2.57	-0.10	-0.26	0.00	-	-1.37	-0.59
Zanjan	-3.21	0.19	-0.56	-1.29	-2.24	-1.46	-1.85	-1.16	-4.09	-1.74	-2.53	-0.84
National	**-3.22**	**0.53**	**-0.97**	**-1.92**	**-1.83**	**-1.37**	**-0.87**	**-0.90**	**-0.91**	**-0.60**	**-2.61**	**-0.12**

Source: Model results.

Appendix Table A3. Regional agricultural income changes under ABOL and TARG scenarios (% change relative to baseline).

Region/Crop	Cereals		Legumes		Vegetables		Fruit		Industrial crops		Total	
	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG	ABOL	TARG
Alborz	-0.61	0.10	-	-	-12.95	-11.00	-	-	0.14	0.07	-0.60	0.06
Ardabil	-0.27	0.05	-0.03	-	-0.42	-0.40	-0.22	-0.20	-0.27	-0.24	-0.44	-0.02
Boshehr	-1.23	0.33	-	-	-1.01	-0.95	-0.42	-0.34	-	-	-0.29	-0.01
Chaharmahal	-0.30	0.10	-0.27	-0.06	-0.46	-0.38	0.05	0.04	-0.34	-0.25	-0.56	-0.02
East Azarbaijan	-0.12	-0.06	-0.06	-0.02	-0.63	-0.60	0.11	0.11	0.55	0.50	-0.40	-0.01
Elam	-0.34	0.08	-0.08	0.02	-	0.00	-0.22	-0.18	0.07	0.06	-0.49	0.06
Esfahan	5.19	-0.48	-29.76	-2.77	-3.28	-2.00	-1.45	-0.69	-0.68	-0.24	-1.43	-0.09
Fars	14.64	-23.26	-9.76	2.40	-1.69	-1.14	-0.78	-0.47	-0.69	-0.29	-1.57	-0.10
Gilan	-0.59	0.09	-0.55	0.05	-0.13	0.01	-0.75	-0.51	-	-	-0.66	-0.02
Golestan	-30.67	5.72	0.05	-	-0.48	-0.37	0.64	0.54	-2.97	0.64	-4.83	0.64
Hamedan	-0.56	0.07	-0.26	0.02	-0.84	-0.73	-0.40	-0.32	-0.35	-0.26	-0.52	-0.08
Hormozgan	-3.16	-1.78	-	-	-3.73	-3.43	-3.08	-2.67	-1.42	-1.17	-4.15	-3.65
Kohkiloyeh	-3.14	0.32	1.46	0.10	0.42	0.38	10.43	8.14	-	-	-1.58	0.22
Kerman	-0.86	0.16	-	-14.27	-0.53	-0.41	-0.15	-0.11	2.24	0.89	-0.69	0.04
Kordestan	-1.70	0.42	-0.13	0.03	-4.62	-4.03	-0.23	-0.15	-0.41	-0.28	-0.44	0.01
Kermanshah	-0.27	0.08	-0.14	-0.25	-0.46	-0.43	-	0.00	-0.34	-0.28	-0.35	0.02
Khouzestan	-0.53	0.04	-0.30	0.05	-0.75	-0.67	-0.26	-0.21	-0.61	-7.13	-0.67	0.01
Lorestan	-0.46	0.09	-0.11	0.02	-0.39	-0.32	-0.20	-0.14	-0.40	-0.31	-0.29	0.01
Markazi	-0.47	0.09	-0.52	0.05	-117.64	-89.64	-	-	0.11	0.07	-0.62	0.09
Mazandaran	0.37	-0.27	-	-	0.22	0.08	0.16	0.05	-4.00	-0.11	-2.03	0.38
North Khorasan	-0.41	0.18	-0.32	0.06	-2.53	-2.09	-0.40	-0.23	-1.14	-0.62	-0.80	0.02
Qom	-0.49	0.09	-	-	-	-	-	-	2.58	0.89	-0.47	0.07
Qazvin	0.36	0.20	-0.33	-	-1.02	-0.88	-0.32	-0.18	-0.45	-0.30	-1.08	-0.02
Razavi Khorasan	-0.69	-0.04	-0.38	-0.19	-15.75	-14.54	2.26	2.33	-0.93	-0.73	-0.70	-0.08
Sistan	0.70	-0.05	-1.54	-0.52	-1.26	-0.84	-0.45	-0.23	-0.79	-0.28	-1.53	-0.28
South Khorasan	-1.01	-0.05	-22.51	-20.38	-0.31	-0.29	-3.56	-2.27	-0.55	-0.52	-0.90	-0.08
Semnan	-0.83	0.15	-0.28	0.03	-0.52	-0.32	-0.30	-0.12	-0.39	-0.15	-0.85	-0.01
Tehran	-0.71	0.10	-	-	-0.60	-0.41	-0.24	-0.12	-	-	-0.72	0.04
West Azarbaijan	-0.85	0.13	0.51	-0.07	-0.55	-0.52	-0.26	-0.23	-0.23	-0.20	-0.38	-0.03
Yazd	-1.12	0.03	-	-	-3.34	-2.78	-1.19	-0.82	-	-	-1.49	-0.20
Zanjan	-1.94	-0.02	-0.08	0.01	-0.65	-0.60	-0.27	-0.22	-0.34	-0.28	-0.50	-0.03
National	**0.49**	**-0.02**	**0.30**	**-0.01**	**-0.90**	**-1.02**	**2.33**	-	**0.18**	**0.12**	**-076**	**-0.01**

Source: Model results.

Appendix Table A4. Regional agricultural cultivated area (1000 ha) and production (1000 T).

Region/Crop	Cereals		Legumes		Vegetables		Fruit		Industrial crops		Total	
	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod
Alborz	18.96	85.65	-	-	0.64	21.30	-	-	0.39	1.06	20.01	108.02
Ardabil	469.41	863.32	33.16	19.42	25.61	840.94	2.48	77.50	7.43	15.70	538.11	1816.90
Boshehr	121.69	125.82	-	-	0.79	18.31	3.14	123.35	-	-	125.64	267.49
Chaharmahal	94.8	173.49	2.78	2.44	6.15	219.08	0.03	1.29	1.2	47.69	104.98	444.02
East Azarbaijan	510.51	828.19	58.51	36.87	19.26	741.71	2.45	47.21	1.97	2.98	592.72	1656.98
Elam	195.78	376.31	9.86	6.48	0	0.00	7.12	190.12	3.55	8.28	216.32	581.20
Esfahan	138.94	466.83	3.18	1.90	18.76	696.11	1.8	52.41	3.9	80.13	166.6	1297.41
Fars	536.92	1706.22	9.51	8.20	29.87	1327.49	18.48	733.72	27.5	620.26	622.31	4395.91
Gilan	16.77	21.08	0.82	0.57	0.05	1.16	1.64	35.66	-	-	19.3	58.48
Golestan	529.17	1583.54	0.78	0.66	12.62	393.84	6.62	49.78	24.1	44.58	573.31	2072.42
Hamedan	490.24	841.32	20.84	10.64	29.25	1110.40	4.41	143.18	8.59	305.26	553.35	2410.82
Hormozgan	18.54	81.69	-	-	24.66	719.85	12.11	250.88	0.18	0.10	55.51	1052.53
Kohkiloyeh	155.67	221.24	6.4	5.68	0.24	4.98	1.44	44.77	-	-	163.78	276.68
Kerman	79.96	325.08	0.88	1.15	3.43	101.87	4.28	122.91	1.74	3.47	90.31	554.50
Kordestan	603.16	831.53	98.28	30.30	11.87	374.73	2.4	45.87	1.57	53.26	717.29	1335.71
Kermanshah	603.46	1264.86	135.54	60.41	11.91	592.79	0	0.00	14.27	549.71	765.19	2467.78
Khouzestan	628.27	1975.09	1.1	0.77	23.52	776.63	21.4	599.42	15.56	263.93	689.87	3615.86
Lorestan	363.75	619.61	110.34	64.58	7.58	227.68	11.33	264.32	6.51	242.27	499.52	1418.47
Markazi	258.48	539.49	8.04	3.61	3.71	104.73	-	-	1.47	26.48	271.71	674.32
Mazandaran	309.01	1418.05	0	0.00	1.92	43.55	1.52	37.15	4.74	6.31	317.21	1505.07
North Khorasan	211.6	354.23	13.98	6.76	6.37	207.13	0.57	8.19	10.04	125.75	242.58	702.09
Qom	31.76	104.67	-	-	-	-	-	-	2.19	5.11	33.95	109.79
Qazvin	200.95	493.04	7.55	3.56	12.56	669.46	1.16	25.01	4.27	99.98	226.51	1291.06
Razavi Khorasan	477.59	1069.87	9.81	3.44	22.8	823.85	15.28	290.13	45.59	994.63	571.1	3181.95
Sistan	105.9	236.45	0.43	0.47	6.73	172.76	22.98	573.91	1.27	1.83	137.32	985.43
South Khorasan	43.17	103.39	0.08	0.02	0.33	5.64	3.71	52.41	9.1	46.74	56.41	208.22
Semnan	56.08	149.93	1.47	0.65	5.1	120.91	2.33	59.94	4.75	119.35	69.75	450.81
Tehran	77.35	310.64	-	-	5.28	200.21	2.04	50.08	0	0.00	84.68	560.94
West Azarbaijan	426.04	739.55	68.44	34.19	9.52	317.49	2.37	65.32	30.4	1873.51	536.79	3030.09
Yazd	20.95	68.39	-	-	0.93	36.57	0.99	27.51	-	-	22.88	132.48
Zanjan	344.96	407.51	25.24	8.50	15.77	594.95	4.4	135.16	0.35	0.33	390.74	1146.48
National	8139.84	18386.08	627.02	311.27	317.23	11466.12	158.48	4107.2	232.63	5539	9475.75	39809.91

Source: ICTC- IMAJ. Three-years average around 2015 (2014, 2015 and 2016).