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Spice Price Spikes:
Simulating Gendered Impacts of a Saffron Boom and Bust in Rural Morocco

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Abstract.

Access to international markets provides smallholders with unprecedented opportunities, but also exposes them to market whims of unprecedented amplitude and can trigger substantial changes in the local economy. In Morocco's mountainous Taliouine-Taznakht region, saffron production drives the local economy and is the major source of female employment. The global market for saffron has been excessively volatile lately. We use a local economy-wide impact evaluation (LEWIE) approach to reveal how saffron price shocks reverberate through the local economy, with a particular focus on gender impacts. We find that saffron price shocks dramatically affect saffron production and labor demand, particularly for female harvest labor. Investments in yield-enhancing technologies create harvest labor bottlenecks that disproportionately affect women. Using Monte Carlo methods show that variability in female wage income is especially sensitive to variability in global saffron prices. Appreciating local inter-linkages is critical to understand household and regional impacts of export price volatility.

Keywords: Impact evaluation, price shocks, price volatility, agricultural household, gender, saffron, Morocco.

JEL codes: **D58, O13**

1 Introduction

The international market for high value boutique food products has exploded in recent years. Innovations in certification programs (e.g., fair trade, organic), policy emphasis on value chain approaches to growth in agro-food sectors, widespread NGO support for interventions to improve smallholder profitability, and aggressive marketing by both general and specialty retail chains have combined to create an unprecedented proliferation of differentiated and specialized products from around the world in European and North American markets. Entire aisles in many supermarkets are now dedicated to these boutique food products, which can often be traced to development efforts linking smallholder producers to high value international markets. Integration with specialty export markets opens up new economic opportunities, but it also exposes producers and the economies of which they are part to the whims of international markets and price volatility. In this paper, we study the impacts of global saffron prices and price volatility on a saffron-producing economy in Morocco, using unique household data and local economy-wide modeling methods.

Saffron, the dearest spice in the world, is produced by cultivating saffron crocus flowers (*crocus sativus*), painstakingly removing their stigmas, and carefully drying them. In the mountainous region of Taliouine-Taznakht in Morocco, cultivation is a male-dominated activity, while women are almost exclusively responsible for the tedious process of harvesting the flowers and delicately removing the crocus stigmas – work that must be accomplished in a very compressed and intense timespan of a few weeks. Our model captures this unique production structure and gender-based division of labor to examine the impacts of saffron price changes on different types of rural households and different labor groups.

Recent fluctuations in the price of saffron have been vertiginous. From 2006 to 2009, the international saffron price more than tripled then collapsed back to its historical average faster than it had risen – a pattern mirrored in saffron prices in rural Morocco. While food prices spiked worldwide during this same period, the factors driving the saffron market are distinct from those driving general food markets. Iran produces the vast majority of the world's saffron, and Spanish wholesalers control much of the international saffron trade. Together, this market power at the production and wholesale levels shapes the international saffron market. Poor production in Iran in the late 2000s appears to be the main cause of the saffron price spike (Dubois 2010).

A boom and bust of unprecedented magnitude has potentially far-reaching consequences for rural livelihoods in saffron-producing regions. A pronounced and rapid appreciation of saffron prices for three consecutive years likely triggers sizeable production responses, investments, and restructuring of the economy towards saffron production. One would expect a price collapse to have the opposite effect. Meanwhile, local economy-wide linkages transmit the impacts of the price boom/bust from saffron-producing households to others within the local economy, and inter-temporal linkages transmit impacts across seasons.

Because of the structure and gender division of labor in traditional saffron production, international market shocks impact gender and intra-household dynamics. A high demand for female wage labor at harvest time may divert women from the non-market activities they traditionally perform, including child rearing and housework. The demand for female labor in these "reproduction" activities, in turn, may constrain the saffron-supply response to higher world prices, in much the same way that missing product markets limit market supply response in agricultural household models.[1]

Pronounced and rapid appreciation (depreciation) of saffron prices has potentially far-reaching impacts in a region that depends so much on saffron production for cash income. Combined, the rapid succession of a boom and bust of unprecedented amplitude represent a dizzying shift in incentives for the local economy and raise the question of how changes in the distribution (not just level) of prices impact an agricultural export economy.

[1] E.g., de (De Janvry et al. 1991) and (Taylor and Adelman 2003). The term "non-productive" is sometimes used in this context. We prefer "reproductive" (i.e., involved with reproducing the household) for reasons that any parent would understand. "Non-monetized", "care economy", "social reproduction" are other terms used in the literature. For further reading see Waring (1990) .

We use a local economy-wide impact evaluation (LEWIE) model to uncover the impacts of the saffron price boom-and-bust on the rural economy of Taliouine-Taznakht. Our model is tailored to the specificities of the saffron production process, in particular, a highly seasonal and gender-biased labor demand. It also incorporates the non-monetized economy, which represents a substantial burden on the time use of women in the region. We use the model to evaluate the transmission of impacts of the saffron-price boom and bust through the local economy, across seasons and households, and between genders. The findings highlight ways in which local general equilibrium adjustments mediate between global shocks and local outcomes. To our knowledge, this is the first attempt to formally model the local economy-wide impacts of an agricultural export price boom and the first to capture seasonal linkages in a LEWIE model. We simulate the impacts of three types of shocks to the economy observed in recent years in Taliouine-Taznakht: (1) a saffron price shock (increase or decrease), (2) investments in saffron production-enhancing technology, and (3) an increase in the variance of the saffron price distribution.

Our simulation findings reveal that an increase in the global price of saffron leads to a significant reallocation of labor to saffron production in both the cultivation and harvest seasons. It stimulates the labor market, as larger producers hire workers from smallholder households. Workers of both genders are put to work, but males are disproportionately affected in the cultivation season and females at harvest time. Women's time devoted to childcare and other reproduction activities falls at harvest time and increases in the cultivation period. Increases in flower yields create labor bottlenecks at harvest time, resulting in a high demand for female labor to process flowers. While land area in saffron expands, raising total flower production, harvesting technology does not change, and the removal of saffron stigma remains a female-dominated activity. Increasing volatility of saffron prices has different impacts on the variability of factor use, production, and incomes. Households are able to buffer the extent to which saffron-price variability translates into income variability, but with high amplitudes in factor-use and production responses. Price variability exacerbates variability in both saffron production and labor demand at harvest time. Wage incomes of females are much more sensitive to saffron price variability than wage incomes for males.

2 Background and Data

The saffron crocus can grow under a relatively wide range of climates; however, production of good quality saffron requires specific conditions: soils cannot be too humid or too fertile, rain cannot fall during the flowering season, and temperatures must remain high (Madan, Kapur, and Gupta 1966). The region of Taliouine has been producing saffron for centuries, but saffron is a more recent crop for the neighboring region of Taznakht. The two regions, respectively, planted 565 and 105 hectares in saffron in 2010 (Aboudrare, Aw-Hassan, and Lybbert 2014). Compared to worldwide saffron production, the production in this region is relatively modest. Most of the world supply of saffron comes from Iran, 80% to 95% depending on the year and source (Ghorbani 2006; Kafi et al. 2006). In addition to the Taliouine-Taznakht region of Morocco, which accounts for about 1.5% of world supply (Dubois 2010), other producers include Greece and the Kashmir region of India.

Saffron is a highly labor-intensive crop. It is traditionally grown in small, flat plots that can be flood irrigated several times a year. Farmers plant crocus bulbs in these small plots. Bulbs produce flowers for up to seven years, with peak harvests in the third and fourth years. Plots are thus rotated and replanted every 5 to 7 years, with plantation beginning in September. Flowers appear after a few irrigation cycles. The harvest lasts less than a month, from the end of October to mid-November, but it mobilizes about 60% of the total labor input to the activity (Dubois 2010). Groups of workers – predominantly women and girls – pick flowers very early in the morning before the sun withers the stigmas. They then spend the rest of the day extracting stigmas from the harvested flowers. In most households, family labor is exclusively engaged in saffron production during this intense harvest period. Households that produce substantial saffron rely heavily on a thriving local labor market for female workers during harvest. Figure

1 illustrates the important role of female labor in saffron production in the Taliouine-Taznakht region, particularly in the harvest season.

Because saffron production provides one of the only wage labor opportunities for females, it is instrumental to women's ability to secure cash income, with potentially important consequences for family dynamics. The high demand for female wage labor may create a strain on women's time, possibly diverting women from other activities they traditionally perform, such as child rearing or housework. As those activities are not directly income-generating, they usually are overlooked in modeling the impacts of market shocks in rural economies. The female labor market is highly seasonal; it exists only at harvest time, with very little wage-work available to women the rest of the year.

Until recently, most of the saffron produced in the Taliouine-Taznakht region was sold in local markets. Under the proper conditions, saffron can be stored for several months without losing its potency, so many households would stagger their saffron sales over the course of nearly a year as needs for cash arose. Since 2008, there have been efforts to organize producers into cooperatives, improve the production and marketing of saffron in the region, and directly link smallholder producers with high-value international saffron markets.

Even before these efforts, prices in local saffron markets closely tracked international markets because of the activities of Spanish traders (see Figure 2). Beginning in 1991, the average real saffron price in local markets in Taliouine was about 4,000 Moroccan Dirhams (MAD) per kilogram (~$40/kg). Beginning in 2007, however, these prices rapidly increased more than threefold. After peaking at 14,000 MAD/kg in 2009 ($750/kg), the price collapsed back to just above its historical average of about 6,000 MAD/kg.[2]

Our model is calibrated using household data from the region of Taliouine-Taznakht, which we collected with the help of ICARDA, USAID and ORMVAO (see acknowledgements). Data were collected from

[2] The MAD/US$ exchange rate varied from 7.2 to 9.2 between 2007 and 2010.

264 households from 6 rural districts in the region, chosen to be representative of the region. Two to four villages (or "douar") were randomly selected within each district (a total of 17 douar); households were randomly chosen within each *douar* in numbers proportional to population weights. Two questionnaires were administered: one for males and one for females. In households with married heads, both the household head and spouse were interviewed separately. Respondents were interviewed in their local language (*Amazigh).*

Table 1 provides a description of our data by rural district. The survey sites span a range of agro-ecological conditions due to their varied altitudes, from 1500m to more than 2000m above sea-level. Some have been producing saffron for centuries and others started as late as in the 1980s. The total number of households in the districts at the time of data collection was 945, of which 28% are included in our sample.

Saffron cultivation takes place on very small plots. The average saffron plot size varies from 536m^2 to 1645 m^2 (0.16 hectares). Only 22% percent of this area is irrigated. The average production volume per cultivating household doubled between 1999 and 2009, from 235 grams to 450 grams. Saffron represents a very high share of total income, up to 50.2% in Sidi Hssain, the district with most ancient saffron cultivating history. In all districts, saffron accounts for more than half of total agricultural income.

The region is generally poor – in both absolute terms and relative to much of the rest of Morocco – and has high income inequality. Gini coefficients all exceed 0.48. However, there are indications that inequality has tended to recede with the expansion of saffron cultivation (Aboudrare et al. 2014). Saffron production creates local spillovers because of its labor intensity; landless households benefit from wage work opportunities in saffron production as well as potentially in linked activities. This underscores the importance of understanding impact channels in the local economy.

3 A LEWIE Model with Seasonality and Gendered Labor Markets

A LEWIE model is an applied general equilibrium (GE) model with a local twist: it is a system of equations describing the functioning of a local or regional economy, accounting for all commodity and factor markets (hence "general" as opposed to "partial" models focusing on a single market). It includes production and consumption functions for all commodities and services, balanced by market clearing equations that define prices for all tradable commodities and factors (hence "equilibrium") and net trade for tradables. LEWIE models, in contrast to the majority of applied and computable general equilibrium (CGE) models, are implemented on a relatively small scale (a local economy, which can be a village, region, island, etc.). They are rooted in the tradition of agricultural household models (Singh, Squire, and Strauss 1986) and village models (Taylor & Adelman, 1996), disaggregating local activities, actors and markets and constructed using local data, usually at the household level (Taylor & Filipski, 2014; Taylor & Thome, 2012; Thome *et al*, 2013). The Saffron LEWIE model is an economywide model at a regional scale. It portrays the economic behavior of households in the Taliouine-Taznakht region: what the households produce, how they produce it, how they trade with each other and with the rest of the world, how they earn money in the labor market, and how they spend their income. The full model appears in Appendix 1.

GE modeling has been a popular tool to analyze ways in which macroeconomic shocks ripple through economies ever since Leontief laid the groundwork for input-output analysis (Leontief 1951). They have been used frequently to highlight the complex and interrelated impacts of economic shocks, ranging from trade liberalization (Sadoulet, Janvry, and De Janvry 1992)(de Melo 1988)(Hinojosa-Ojeda, Robinson, and Lewis 1995), to tax policy (Berck and Dabalen 1995; Vellinga 2011), to migration flows (Brücker & Kohlhaas 2004; Sussangkarn 1996;Taylor and Dyer 2009), to cite a few examples. In many cases, GE models are able to provide answers where other economic methods are impractical or infeasible.

The questions we ask in this paper (relating to saffron price shocks and local labor markets) are of the kind best answered through a GE lens on a local scale. A price shock enters the economy via saffron producers, who immediately transmit it to others in the economy, from the hired laborers who work their fields to the shopkeepers who sell them groceries. The economy of Taliouine-Taznakht is land-constrained and relatively isolated from the rest of the world when it comes to labor markets, so any shifts in demand or supply of factors are likely be reflected in local wages and rents; these potentially alter incentives for everyone in the region. Concentrating productive resources into the saffron activity requires shifting resources away from other activities. A local GE framework is uniquely suited to highlighting these trade-offs. Identifying the impacts of saffron price shocks with econometric methods would require data that do not exist. A randomized controlled trial is not feasible, and time-series data from household surveys spanning the length of the price boom are not available.

The flexibility of the LEWIE framework allows us to tailor our modeling to the specificities of the saffron economy, including the gendered nature of the production process and seasonality of production activities and labor demand.

3.1 Gender and Seasonality

The stark division of labor between males and females is a defining characteristic of saffron production and central to our analysis. Understanding the labor impacts of the saffron boom thus necessitates distinguishing female from male labor. In addition, the saffron harvest competes with the care economy for female time. “Engendering” the model requires modifying the standard LEWIE approach in two ways: first, by treating male and female labor as separate inputs in production activities; and second, by featuring household reproduction activities explicitly.

General equilibrium models with gendered features were pioneered by (Fontana and Wood 2000) and have since been applied in multiple studies (Fofana et al. 2005; Fontana 2002, 2004; Sinha and Sangeeta 2003; Terra, Bucheli, and Estrades 2009). Filipski et al. (2011), which focuses on rural activities and time allocation in the Dominican Republic, uses a model that shares some of the features of the saffron LEWIE presented in this paper. It also provides a review of the gendered CGE literature.

While a gender division of labor in agriculture is not uncommon, saffron presents two specificities. First, the saffron gendered division of labor is by task, not by crop or plot. This contrasts with the frequently observed situation in which females are in charge of growing food crops and males cash crops (Doss 2002), or where females and males control different plots (Udry 1996). Second, the seasonal flash market for female wage workers is a unique consequence of the female-labor-intensive nature of the saffron harvest. Therefore, the seasonality of saffron production is directly linked to a gender disaggregation of labor.

Our model distinguishes the saffron harvest season from the cultivation season. We are not aware of CGE models with seasonality, but from a mathematical point of view, incorporating seasonality into the model is not much different from distinguishing between regions, which is not unusual. We treat the two seasons as sequential production stages (Antle 1983). In the cultivation season, households produce flowers. In the harvest period, the flowers, along with labor, are the key inputs into the production of saffron. Flowers, then, represent a constraint on saffron production: no more saffron can be produced than is available from the stigma of flowers grown in the first period. The price of flowers is a shadow price, determined by the marginal value product of flowers in second-period saffron production. It links the two periods in our model. The market price of saffron, which is exogenous, influences the shadow price of flowers—a temporal analogue to the way in which market prices influence shadow prices of subsistence crops (Dyer, Boucher, and Taylor 2006).

3.2 Modeling Specifics

The building blocks of LEWIE are agricultural household models describing the economic behavior of households in the economy (Singh et al. 1986). Households allocate their resources to equate marginal value products of inputs across production and reproduction activities. On the consumption side, they allocate income to equate marginal rates of substitution (MRS) with corresponding price (or in the case of household non-tradables, shadow-price) ratios. First-order conditions determine input demands as well as output. Factor incomes, together with any exogenous income, set the budget constraint on household consumption. Households maximize utility subject to this budget constraint; this determines consumption demands. The difference between output and consumption determines marketed surplus. In these respects, household models in our LEWIE for Taliouine-Taznakht are similar to any generalized household-farm model with multiple production and income activities, as in de Janvry *et al* (1991).

The model equations and variable definitions appear in the Appendices. There are five blocks of equations: (1) a price block, which determines a "value-added" price by taking the market or shadow price and netting out costs of intermediate inputs; (2) a production block, which determines output and input demands using first-order conditions for profit maximization; (3) an income and consumption block, which gathers together each household's income from all sources and allocates it to different consumption goods, based on constrained-utility maximization; (4) a market-clearing block for factors and intermediate inputs, which determines prices at the household (fixed factors) or regional (locally tradable factors) level or, in the case of intermediate inputs, net trade with markets outside the region; and (5) a market-clearing block for commodities, which determines regional prices for locally tradable goods (crocus flowers) and household-specific prices for Becker z-goods (care and leisure).

3.2.1 Actors. Village households are grouped into three categories, based on their labor trading status for saffron production in the year of the survey (hire in, rely on household labor, or hire out). Table 2 describes those three groups. Each group has its own set of behavioral equations in the model; both production and consumption behavior are household-group-specific.

3.2.2 Activities. We model saffron production as two linked activities: the production of saffron crocus flowers (*crocus sativus*), and the harvest of stigmas out of the flowers. In addition, we distinguish three types of non-saffron activities: agriculture, livestock, and all non-agricultural activities (services, crafts, etc.). Finally, in each of the two seasons we model two reproductive activities, care and leisure, where care refers to household chores, cooking, child rearing, and home improvement (reproductive activities).

3.2.3 Production. Production activities require factors and intermediate inputs. Factors in the model include land, capital, commercial inputs, and four types of labor distinguished by gender and season. Intermediate inputs are produced by one activity and used by another, such as feed for cattle or, most notably, crocus flowers used in the saffron harvest. The different activities and the factors and inputs they use are listed in Table 3.

Factors and intermediate inputs are treated differently in the production function. Factors create value added (via a Cobb-Douglas process). Intermediate inputs do not create value added but must be used in fixed proportion to output. Intermediate inputs follow a Leontief process because, unlike factors, they are not substitutable. This specification is particularly appropriate to model two seasons with respect to the saffron activity: crocus flowers (produced in the cultivation season) are intermediate inputs into saffron production (the harvest season). One can farm the same plot of land more intensively and produce more crocus flowers (i.e., substitute land for labor); however, one cannot harvest the same flower more intensively to obtain more saffron out of it (i.e., substitute labor for flowers).

We distinguish between labor in the harvest season and in the rest of the year (which we call the cultivation season). With the added gender distinction, the model features four pools of laborers: males in the harvest season, females in the harvest season, males in the cultivation season, and females in the cultivation season. Some activities draw labor from all four pools (for instance, livestock production, which requires year-round attention); others use only one type of labor or another (the saffron harvest only uses harvest-season workers, male and female). This allows the model to simulate labor-market outcomes, including labor shortages that may occur at harvest time or the choice females face between wage work and care activities.

Table 3 provides insight into how we treat seasonal activities and "non-productive" activities. We divide saffron production into a "flower production" activity (cultivation) and a "saffron production" (harvest), each of which only uses labor in the corresponding season. The flower production activity combines labor with land, capital, and purchased inputs to grow crocus flowers. The saffron harvest is similar to a pure resource extraction activity: it only uses labor to get saffron out of the existing flowers.

Agriculture, livestock, and non-agricultural activities are not seasonal, at least in the sense of the seasons in our model, as households may have some flexibility in allocating time to them. It is conceivable that a household can choose to till the soil or apply fertilizer at a time that does not overlap with the saffron harvest. Leisure and care activities, on the other hand, are separated by season to reflect the fact that activities such as resting, preparing meals, or helping children with their homework are not readily fungible across time. They use no land, capital, or inputs; they simply compete with other activities for limited family time. Males and females allocate time to leisure, but our data indicate clearly that only females contribute to the care activity as we define it.

3.2.4 Consumption. Households spend income on goods and services produced by village activities and an additional category of items supplied by outside markets. Care and leisure are non-tradable: they can only be "consumed" in the household that "produces" them, much like a Becker z-good (Becker 1965). They are valued at the opportunity cost of time put into them, valued at market wages, which vary between genders and across seasons. Household utility functions follow a Stone-Geary schedule with consumption minima for leisure and care.

3.2.5 Markets and closure rules. The model links households through markets, which permit intra-regional trade in commodities and labor. However, not all goods and factors are tradable in all markets. For each good and factor, closure rules determine where markets clear and prices or wages are determined. Table 4 summarizes those assumptions.

We distinguish among three possible levels for commodity trade: non-tradable, tradable within regional markets, and tradable outside the region. A non-tradable commodity is a subsistence good: the household must produce it in order to satisfy its own demand, and, once produced, it cannot be sold. Leisure and care are subsistence goods by definition: one cannot pay a neighbor to take a nap on one's behalf, cook a home-cooked meal, or provide motherly care to children (purchased meals and foster care services do enter the model in the "non-agricultural activities" category; they are imperfectly substitutable for care as depicted by the Cobb-Douglas utility function).

Regional markets clear locally. Households can sell local nontradable goods in the village, but they cannot export them from the village; the prices of these goods depend on local supply and demand. Only saffron flowers are treated in this way: a crocus patch cannot be transported out of the village for harvest, but a labor-constrained household might sell its patch at harvest time (though our data indicate that it is more likely to hire workers and supervise their work).

Commodities traded in integrated markets can be imported or exported outside the region at a fixed, exogenously determined price. Agricultural production, livestock, non-agricultural production, saffron, and imported goods in our model are all traded in integrated markets.

There are also three levels of market closure for factors: the household (fixed factors), regional markets, and integrated markets. Fixed factors are not only non-tradable; they are activity-specific. Land and capital are fixed factors in the model, with a household-level "shadow price." Labor is treated as regionally tradable with a local wage, reflecting poor integration of local labor markets with the rest of Morocco. Soaring wages at harvest time are an indication of poor labor-market integration. Purchased inputs are traded on an integrated market; thus, they have a fixed price in the model.

3.3 Model calibration

Unlike most GE applications, our saffron model is not calibrated from a social accounting matrix (SAM). Model parameters were estimated using household survey data, as in Thome et al. (2013). The survey provides data on inputs, production volumes, incomes, demands, and prices. Factor shares for the saffron activity were estimated from a log-log regression of saffron output value per unit of land on labor and purchased input values and a fertilizer dummy. We find that labor accounts for 62% of the value of output, while purchased inputs and fertilizer account for 13% (though this share was not statistically significant in the regression). The residual 25% is attributed to land. These results highlight the labor-intensity of the saffron production process. We further use precise labor input data in labor hours available from the survey to obtain the contribution of each labor type to value added (cultivation and harvest, female and male).

Although the survey provides detailed data on saffron production, there are some data gaps with regard to other activities. Factor shares in other productive activities were not available; they had to be approximated with information from other studies.[3] Data on households' weekly allocation of time in each season provide care-to-labor time-use ratios for females and leisure-to-labor time-use ratios for males (who do not contribute time to the care economy, according to our data). The data are weakest on leisure. Reliable time-use data by gender, including leisure, are rare. In this model, females are assumed to enjoy half as much leisure as males in harvest season and a quarter as much in the cultivation season.[4] Sensitivity analysis reveals that the findings presented below are not particularly sensitive to these parameters.

Expenditure shares from the survey were used to calibrate the consumption function parameters along with subsistence production valued at locally observed prices. For leisure and care, consumption is equal to production (the value of time inputs). The total value of hired labor used in production is distributed to households based on their reported wage income. The survey data also provide information on income from exogenous sources such as remittances or gifts.

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[3] Brooks et al. report estimated factor shares for family labor in two other African countries range from 0.26 to 0.96 in staple activities, 0.29 to 0.79 for livestock, and 0.24 to 0.75 in other crop activities(Brooks et al. 2010). The shares we use fall within these ranges, and can be found in appendix 2.

[4] We use different ratios at cultivation and harvest time because the inequality in females' access to leisure tends to worsen when they enter the labor force (and/or become mothers) (Bruce 1989). Females of rural low-income households enjoy about half as much (47%) leisure as males in Fontana's gendered SAM of Zambia, where females seldom work out of their homes (Fontana 2002). They enjoy about a quarter as much (0.26%) leisure as males in a gendered SAM of Bangladesh, where women are heavily engaged in wage work in the textile industry (Fontana and Wobst 2001).

For households without a marketed surplus, prices were imputed using median prices observed at the village or regional level. The baseline values and parameters for the model were arranged in a table (Appendix 2) that inputs directly into the LEWIE model, which was programmed in GAMS.

4 LEWIE Simulations & Results

The set of calibration values for variables and parameters constitutes a base solution to the system of equations constituting the model. Simulations with this model involve altering parameters in the system of equations then re-solving to obtain a new equilibrium. Observing how model variables adjust to keep the economy in equilibrium gives us insight into how real shocks might affect the economy. We use our LEWIE model to simulate three types of shocks to the saffron economy: (1) a shock to saffron price levels, (2) a change in production technology, and (3) an increase in the variance of the price distribution. All three simulations are inspired by the recent events observed in Taliouine-Taznakht.

4.1 Price Simulations

We simulate a 10% increase in the price of saffron, so as to keep first order approximations realistic. At the height of the spike, prices increased by as much as 80% in a given twelve month period (between October 2007 and October 2008). The shock we model is positive and evokes the rapid and pronounced saffron price boom, but a similar exercise can be performed with a negative price shock (in the spirit of the bust that followed) and would essentially produce a symmetric response. The results of the price simulations are summarized in Table 5.

The top panel of Table 5 reports the reallocation of labor between activities in each season. Households allocate more time to the newly-profitable saffron activity. In the harvest season, they increase their labor input into saffron harvesting (by 93.5 million MAD). This means increasing output of crocus flowers in the cultivation season (by 85 million MAD). The stimulus to flower production reflects the inter-temporal linkages at work in this model. Higher labor demand pushes up wages in both seasons, creating negative impacts on the production of tradables (Ag, Livestock, and Non-Ag). While the levels of labor reallocations to saffron activities are roughly equal in both seasons, they represent less of a strain during the flower cultivation period, which lasts much longer than the harvest period. The pressure on labor resources at harvest time is reflected in the large percentage reduction in labor inputs to all other activities, both tradables and non-tradables. In the cultivation period, increasing labor supply by 15% requires reducing labor inputs to other activities by not more than 6%, but in the harvest period, the reduction ranges from 12% to 19%, depending on the activity.

The impact on household non-tradables (care and leisure) is ambiguous and season-dependent. In the harvest season, households neglect leisure in favor of saffron. However, households *increase* leisure in the non-harvest season, by a larger net amount. This is due to the income effect of dearer saffron. By demanding more of the leisure activities, households shift time away from tradables production (agriculture, livestock, and non-agricultural goods). Still, a high shadow value of time discourages them from increasing leisure at harvest time. This simulation displays a "catching up on lost sleep after the harvest" effect, an inter-temporal shift in leisure. As for the care activity, it is neglected during the harvest season, but unlike leisure it is hardly compensated for in the cultivation season. This reflects the female-labor intensity of the care activity.

The bottom panel of Table 5 reports changes in labor demand for the three household groups, by gender and season. Recall that household groups are defined according to their labor surplus status in saffron production: group 1 hires laborers on their saffron plots, group 2 does not hire any labor in or out as far as saffron production is concerned, and group 3 hires saffron workers out (to group 1). This is the situation in the base model, but nothing in the model prevents households from departing from their original labor market participation status once a shock is simulated. The results in Table 5 reveal that the price increase stimulates the labor market for both genders and in both seasons. Most reallocation of male labor occurs in the cultivation season, while the opposite is the case for female labor. Since males are not usually hired for harvesting, the harvest-time reallocation of labor represents a larger change in percentage terms for males. The case of group 2 household females is most interesting: while they did not participate in the labor market in the base model, the high saffron prices pull them into the labor market. This illustrates the opportunities embodied in the saffron boom.

4.2 Technological Change Simulations

The Taliouine-Taznakht region is fairly arid and unfit for many crops. Water is an important constraint. Saffron yields depend critically on the type of irrigation and the amount of water available. Drip irrigation can increase crocus flower yields while reducing water use but is not widely used because of high fixed costs and scale economies The saffron boom stimulated technological change, including the adoption of drip irrigation. Unfortunately, there are no comprehensive data available to track irrigated area over the price-spike period. However, in the field we observed that irrigation technology was a hot topic of conversation among Taliouine-Taznakht farmers during the price-boom years

We used the model to simulate a 10% increase in productivity in the cultivation season resulting from irrigation or other measures. The two-season structure of the model allows us to highlight the notion of bottleneck. This is inspired by the introduction of drip technology, which dramatically increases yields in the cultivation period but does not alter harvesting efficiency. Formally, we implement this simulation by increasing the shift parameter on the Cobb-Douglas production function for crocus flowers by 10%.

Table 6 shows the impact on labor allocation patterns across all activities in both seasons. Even though the technological change occurs in the cultivation season, the magnitude of its impacts is much greater in the harvest season. Households are able to reduce their allocation of labor to growing saffron flowers (reduction of 15 million MAD worth of labor) and still produce higher crocus yields, which require harvesting. With harvesting technology unchanged, the higher flower productivity creates a labor bottleneck at harvest time. This leads to large labor reallocations at harvest (85.4 million MAD worth of labor reallocated). Labor reallocations by household group (bottom of table) reaffirm that the technological change in the cultivation season disproportionately impacts labor markets in the harvest season.

These findings shed light on labor-market tensions created by the saffron price boom. High saffron prices stimulate an increase in saffron production and a shift towards high-yielding crocus flower-production technologies. Yet harvesting crocus stigma remains a painstaking, meticulous, labor-intensive task. Further increasing productivity in the cultivation season is likely to increase labor-market pressures (and bid up wages in the harvest season) further.

From a gender perspective, enhancing flower-production technologies creates a serious female-labor bottleneck at harvest time, inducing women to shift their time out of care and leisure activities. Woman are able to increase their labor input into care more than in the saffron price increase scenario because of higher labor productivity in saffron, but not enough to compensate fully for the harvest-time decrease. Given the female labor intensities of both care and harvest activities, higher saffron production comes at a potentially high domestic cost.

If new technologies raised productivity in the saffron harvesting and processing stage, harvest-stage bottlenecks could be ameliorated; however, impacts would be felt in both cultivation and harvest activities. We are not aware of technologies on the shelf to increase productivity in saffron harvesting and processing. Simulations of the likely impacts of such an innovation (available on request) show that the major impacts of harvest-stage technological change would be felt in the cultivation period. Higher labor productivity at harvest raises the shadow price of crocus flowers, and this induces households to increase their production of flowers. Improved harvest technology creates a cultivation-labor bottleneck. Improving harvesting technology depresses the harvest-time labor market, as group 1 households reduce their demand for labor and group 3 households keep more of their labor at home.

4.3 Price variability simulations

Our simulations show how sensitive labor markets are to saffron price shocks, a direct consequence of the labor-intensive nature of this activity. When variations in saffron prices reach the magnitude observed in the past decade, this sensitivity can amplify the vulnerability of some households. How does volatility in global saffron prices translate into variability in local outcomes? Do general equilibrium adjustments in the local economy buffer households from global price swings?

We use our LEWIE model with Monte Carlo simulations of global price variability to study the consequences of a mean-preserving spread in saffron prices for labor demand, production, incomes, and wages. This entails running two sets of simulation loops, one with a low price variance (s_l^2) and the other with a high price variance (s_h^2). In the first loop, we perform 1000 price-shock simulations just like those analyzed above but with a different price shock each time. Each shock is drawn from a normal saffron price distribution.[5] The distribution of prices is normalized to mean 1.0 and variance 0.05, which corresponds to the variance of the series of world saffron prices before the year 2000 (Figure 2). We record the values of all variables for each simulation and use these to construct a distribution of impacts for each variable in the model.

We then perform a second loop of 1000 simulations, this time drawing from a normal distribution with variance 0.17 (corresponding to the variance of the price series after 2000) and recording all values for each simulation. This gives us a distribution of impacts for each variable in the model under a scenario of more variable saffron prices. Comparing the percentage change in variance of a given outcome *i* under the high price variance ($s_{i,h}^2$) and low price variance ($s_{i,l}^2$) scenarios to the percentage change in price variance, that is:

$$\frac{(s_{i,h}^2 - s_{i,l}^2) / s_{i,l}^2}{(s_h^2 - s_l^2) / s_l^2} \qquad (1)$$

[5] 1000 was chosen as an arbitrarily high number of iterations, large enough that we have no doubts about our variance calculations.

reveals the extent to which the variance of the outcome increases with the variance of the saffron price.[6] This can be thought of as the elasticity of the variance of an outcome with respect to the price variance.[7]

Figure 3 compares the outcome-to-price variance elasticities calculated using equation (1) for wage income by gender, as well as for saffron production and real incomes by household. The top bar (hashed) represents the increase in saffron price variance, which we normalized to one. (It is in fact a 220% increase in variance, from 0.053 to 0.172). Bars longer than the hashed one correspond to variables whose variance increases more than the saffron price variance (darker). Bars shorter than the hashed one indicate the opposite, that is, variables for which GE effects buffer households from saffron price volatility.

All bars except female wage income are shorter than the price bar, meaning that GE effects mostly buffer the economy from some of the price variability. In terms of saffron production, about 70% of the price variation translates into output variation. Group 2 households experience the greatest variability.

The variability in production volumes reflects variability in labor inputs, which are similarly buffered from the price variability at around 70% (not in figure). However, while variability in total input demand follows production volumes, only part of that labor is hired, and consequently the demand for hired labor may still be highly variable. The two central bars show a dramatic difference between male and female labor markets and opportunities for earning cash income. The male wage income varies little compared to saffron prices, because males have outside opportunities on the labor market. Females on the other hand have no alternative options for remunerative work: the variability in their wage income is 33% higher than the price variability. The variance in wage income of females is exacerbated compared to saffron price variation.

[6] Similar results are obtained if we construct the measure using standard deviation, coefficient of variation, index of dispersion, etc.

[7] This is not to be confused with the elasticity of an outcome with respect to the price. The two measures are not equal in a non-linear model such as LEWIE.

The three bottom bars show the household income variance elasticities. In real terms, income variability is partially buffered: there is between a 0.86% and 0.92% transmission of variability from price to income. This reflects the central role of saffron in this economy. The income transmission of saffron price shocks varies across households. Transmission is greatest for Group 3, which controls few productive resources and is most dependent on wages. Achieving partial income buffering requires sizeable adjustments in production and labor allocations, which are the principal means by which households maintain income in the face of price shocks. This adjustment comes at the cost of unstable labor markets and, especially for females, highly unstable wage income.

5. Conclusion & Discussion

The surge in global saffron prices provided the isolated and resource-constrained region of Taliouine-Taznakht with a unique opportunity for significant growth. Our LEWIE model helps dissect the local response to these price incentives by distinguishing among heterogeneous household responses and explicitly capturing the seasonality and gendered nature of saffron production. In the wake of the price bust, the model also sheds light on how this small export economy responds to exogenous price volatility, and what it means for men, women and different types of rural households in the region.

Our price simulations reveal that an increase in the price of saffron leads to significant reallocation of labor to saffron production, both in harvest and cultivation seasons. It stimulates the labor market, as relatively large producers hire workers from less capital-endowed households. Workers of both genders are put to work, but males are disproportionately affected in the cultivation season while females are disproportionately affected in the harvest season. The saffron boom draws female labor into harvesting activities at the expense of other female-dominated activities, including domestic care.

Technological change leading to increased productivity of saffron flowers also has a profound, gender-differentiated impact on labor markets. The Taliouine-Taznakht region is currently expanding land area in saffron and raising flower yields with investments in drip irrigation, the cost of which is 100% subsidized by the Ministry of Agriculture.. Meanwhile, the harvesting technology remains female labor-intensive in hand-picking flowers and processing their stigmas. The adoption of yield-increasing technologies thus creates a sharp increase in the demand for female labor. Our results highlight ways in which seasonal bottlenecks in the production process can shape gender-specific labor-market pressures. The unique opportunity for females to earn wage income in saffron processing conflicts with women's responsibilities in the non-monetized economy during the harvest season, although our findings reveal some substitutability of domestic work between seasons.

The saffron price boom did not last: it was followed by an almost symmetric bust. Our simulations suggest that GE effects partially buffer local incomes from global price volatility, but at a cost of even greater volatility in wage earning opportunities for females. The transmission of price variability to incomes is greatest for the households that depend most heavily on wage earnings.

A number of questions arise from these gendered simulation results. Increased female labor-market participation in response to higher saffron prices and increases in flower productivity has significant repercussions inside the household. It conflicts with reproductive activities such as child-rearing. The tension between care and harvesting, given the labor intensity of both, makes the cash-crop supply response lower than it otherwise would be. It also raises questions about the long-term impacts of seasonal shifts in care intensity on child outcomes.

The saffron boom may have other repercussions on households and gender roles that are beyond the purview of our model. If young girls are drawn in to fill labor-demand gaps, female school enrollment rates could decrease. In the longer run, however, rising opportunities for females can lead to lower birth rates and smaller families (Becker 1992). Rising cash incomes for females can alter utility weights in intra-household decision making, with possible repercussions on outcomes ranging from household consumption patterns to child nutrition, school enrollment, or family planning. In our price increase simulations, the share of total wage income earned by females increases from 29% to 37%, but this share is extremely volatile in the presence of saffron-price variability. Unpredictable economic opportunities for females may shape intrahousehold bargaining and interactions along with broader economic and social dynamics differently than predictable and permanent changes.

If harvesting technology becomes a crippling bottleneck, the regional labor market is likely to adapt by pulling on untapped sources of labor. Men could increase their participation to the harvest activity; harvest could increasingly call on child labor, as children allegedly have harvesting abilities comparable to women; or seasonal female laborers from outside the region could begin migrating to the Taliouine-Taznakht saffron harvest—currently an uncommon phenomenon in rural Morocco. The repercussions of such evolutions in local livelihood strategies and rural Moroccan society run deep.

The saffron price-boom only lasted three years. Even though prices have now returned to their historical trend, the peak has taught us (as well as saffron producers) how volatile the price of a global specialty crop can be. Aware of this, the government of Morocco is running ad campaigns to boost national demand for saffron and other local products. It is likely that the three year saffron boom was sufficiently long to have impacted the economy and society in durable and perhaps irreversible ways. Our model highlights the need to further analyze these evolutions and labor dynamics. While LEWIE cannot tell us how production dynamics have impacted social interactions in Taliouine-Taznakht, it does highlight the spillover effects of saffron prices across activities, genders, and seasons, and it demonstrates the ways in which technical and economic constraints shape impacts of global shocks in local economies. This is a potentially insightful point of departure for exploring and ultimately modeling broader follow-on dynamics in the local economy. For example, new female labor opportunities in the region could emerge endogenously as a response to these gender-differentiated labor market impacts, although local religious and cultural norms may shape opportunities as much as local prices and profits do.

At a general level, our simulations highlight a conundrum in linking smallholders to international markets, particularly in the case of niche markets subject to consumer fads and volatile prices. On one hand, a precipitous rise in saffron prices generated unprecedented incomes for Taliouine-Taznakht households, not only for saffron producers but also for the workers they hire and for the producers of local nontradables. It dynamized labor markets, in particular for female workers with few other opportunities for cash income. On the other hand, it left in its wake a tradeoff between poor households' access to high windfall incomes and economic stability.

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Table 1: Data description by rural district

	District						
	Askaoune	**Siroua**	**Assais**	**Agadir Melloul**	**Sidi Hssain**	**Iznaguene**	**Total Sample**
Characteristics							
Altitude	Over 2000m		1700m-1800m		1500m-1600m		
History of Saffron Production[a]	Recent	Recent	Ancient	Ancient	Ancient	Recent	
Population (# households)	266	176	109	74	212	108	**945**
Sampled households (#)	62	43	41	20	56	42	**264**
Descriptive Statistics (Averages)							
Household size (#)	8.4	9.0	7.0	7.7	6.6	9.2	**8.0**
Number of Children (<16 years old)	2.8	2.9	1.7	2.3	1.8	2.0	**2.3**
Age of household head	57	53	62	55	56	56	**56**
Area in saffron (m^2)	903.2	1436.4	749.4	536.5	749.3	1645.5	**813.9**
Share of saffron irrigated (%)	33.7%	37.4%	32.0%	14.0%	41.0%	11.2%	**22.1%**
Saffron production per household 1999 (kg)	0.108	0.398	0.216	0.093	0.347	0.448	**0.235**
Saffron production per household 2009 (kg)	0.448	0.722	0.303	0.360	0.615	0.662	**0.450**
Household revenue from saffron (MAD)	6919.4	13696.1	3223.7	7199.0	9175.3	10647.4	**7054.6**
Share of total income from Saffron (%)	39.6%	34.7%	34.2%	40.8%	50.2%	41.4%	**40.1%**
Share of agricultural income from Saffron (%)	79.3%	51.1%	67.9%	72.3%	79.8%	55.4%	**71.5%**
Gini coefficient for 2009 incomes	0.48	0.49	0.52	0.48	0.61	0.50	**0.56**

Source: Aboudrare *et al.*, 2014; [a] Ancient refers to several centuries, Recent to less than 50 years.

Table 2: Description of household groups in the model

HH group	Labor trading status for saffron activity	Sample size	Proportions (weighted)	Represented population
1	Hire labor in	109	41.00%	2945
2	Self-reliant	113	45.00%	3232
3	Hire labor out	42	14.00%	1005
Total		264	100.00%	7182

Table 3: Activities in the model and input or factor use

	Activities								
	Flower	Saffron	Ag	Livestock	Non-Ag	Care in harvest season	Leisure in harvest season	Care in cultivation season	Leisure in cultivation season
Inputs into each activity									
Commodities									
Flower		x							
Saffron									
Ag				x					
Livestock									
Non-ag									
Factors									
Land	x		x	x					
Capital	x		x	x	x				
Male Labor – harvest season		x	x	x	x		x		
Female Labor – harvest season		x	x	x	x	x	x		
Male Labor – cultivation season	x		x	x	x				x
Female Labor – cultivation season	x		x	x	x			x	x
Purchased inputs	x		x	x	x				
Total Value of Production*	**1,601,687**	**2,731,097**	**2,308,370**	**5,257,764**	**505,361**	**137,295**	**16,475**	**1,473,635**	**921,022**

X marks which factors or inputs are used by each activity. *: for care and leisure value = opportunity cost of time.

Table 4: Market Closure for Commodities and Factors

	Market Closure		
Commodities	Non-Tradable	Regional market	Integrated Market
Flower		x	
Saffron			x
Ag			x
Livestock			x
Non-ag			x
Imported goods			x
Care in harvest season	x		
Leisure in harvest season	x		
Care in preharvest season	x		
Leisure in preharvest season	x		
Factors	Fixed factor	Regional market	Integrated Market
Land	x		
Capital	x		
Male Labor – harvest season		x	
Female Labor – harvest season		x	
Male Labor – preharvest season		x	
Female Labor – preharvest season		x	
Purchased input			x

Table 5: Impact of a 10% increase in the price of saffron.

A- Labor reallocation - by activity						
	Cultivation			Harvest		
	level	delta	pct change	level	delta	pct change
Flower	577.23	85.63	14.8%	na	na	na
Saffron	na	na	na	1,129.41	93.60	8.3%
Agriculture	1,429.41	-70.94	-5.0%	186.45	-32.84	-17.6%
Livestock	1,652.93	-24.70	-1.5%	215.60	-31.40	-14.6%
Non-Ag	312.94	-19.20	-6.1%	40.82	-7.60	-18.6%
Care	1,473.64	4.72	0.3%	137.30	-19.71	-14.4%
Leisure	921.02	24.49	2.7%	16.48	-2.05	-12.4%
B- Labor market participation - by household						
	Cultivation			Harvest		
	level	delta	pct change	level	delta	pct change
Males						
hh1	174.35	-12.73	-7.3%	8.13	-7.21	-88.7%
hh2	-178.77	9.38	-5.2%	-13.29	4.20	-31.6%
hh3	4.42	3.35	75.8%	5.16	3.01	58.3%
Females						
hh1	-18.05	-4.29	23.8%	-61.30	-8.10	13.2%
hh2	0.00	3.10		0.00	5.01	
hh3	18.05	1.19	6.6%	61.30	3.08	5.0%

Note: Amounts expressed in thousands of MAD worth of labor before wage readjustment. “Delta” refers to the level difference from base. “na” to non-available. Source: LEWIE simulations

Table 6: Impact of a 10% increase in harvesting technology

A- Labor reallocation - by activity						
	Cultivation			Harvest		
	level	delta	pct change	level	delta	pct change
Flower	577.23	-15.28	-2.6%	na	na	na
Saffron	na	na	na	1,129.41	85.41	7.6%
Agriculture	1,429.41	-19.41	-1.4%	186.45	-28.10	-15.1%
Livestock	1,652.93	5.06	0.3%	215.60	-29.34	-13.6%
Non-Ag	312.94	-6.00	-1.9%	40.82	-6.35	-15.6%
Care	1,473.64	13.11	0.9%	137.30	-19.43	-14.2%
Leisure	921.02	22.53	2.4%	16.48	-2.19	-13.3%
B- Labor market participation - by household						
	Cultivation			Harvest		
	level	delta	pct change	level	delta	pct change
Males						
hh1	174.35	-2.21	-1.3%	8.13	-9.22	-113.4%
hh2	-178.77	2.70	-1.5%	-13.29	5.47	-41.2%
hh3	4.42	-0.49	-11.0%	5.16	3.75	72.6%
Females						
hh1	-18.05	-1.93	10.7%	-61.30	-9.91	16.2%
hh2	0.00	1.87	na	0.00	6.21	na
hh3	18.05	0.06	0.3%	61.30	3.70	6.0%

Note: Amounts expressed in MAD worth of labor before wage readjustment. Source: simulations

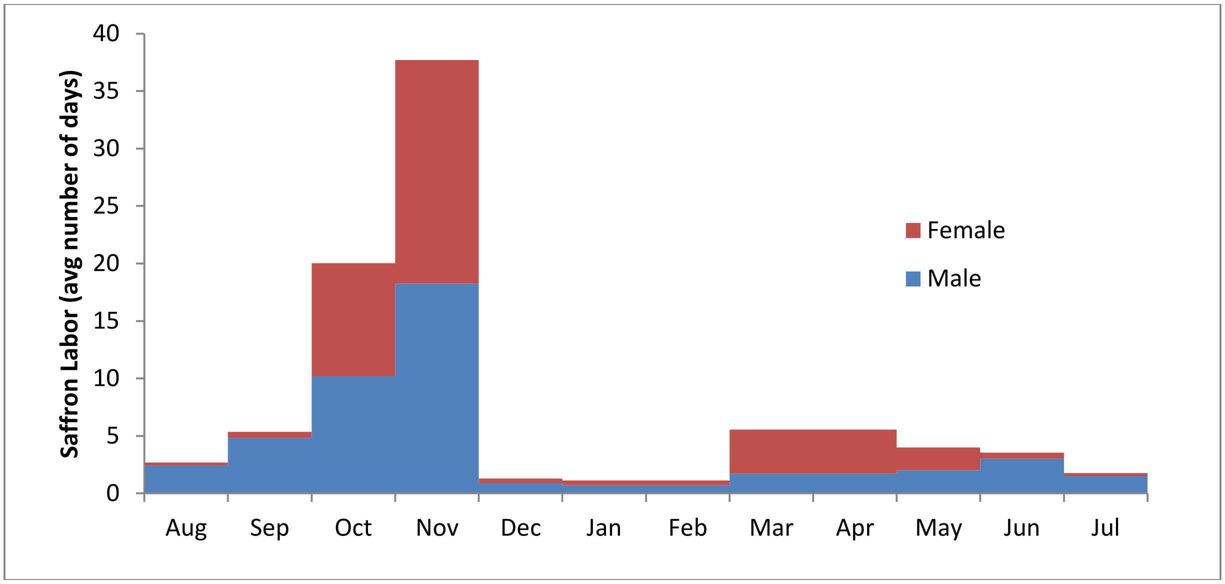


Figure 1 Saffron labor inputs by month and by gender in the Taliouine-Taznakht region of Morocco (Source: Aboudrare et al. 2014)

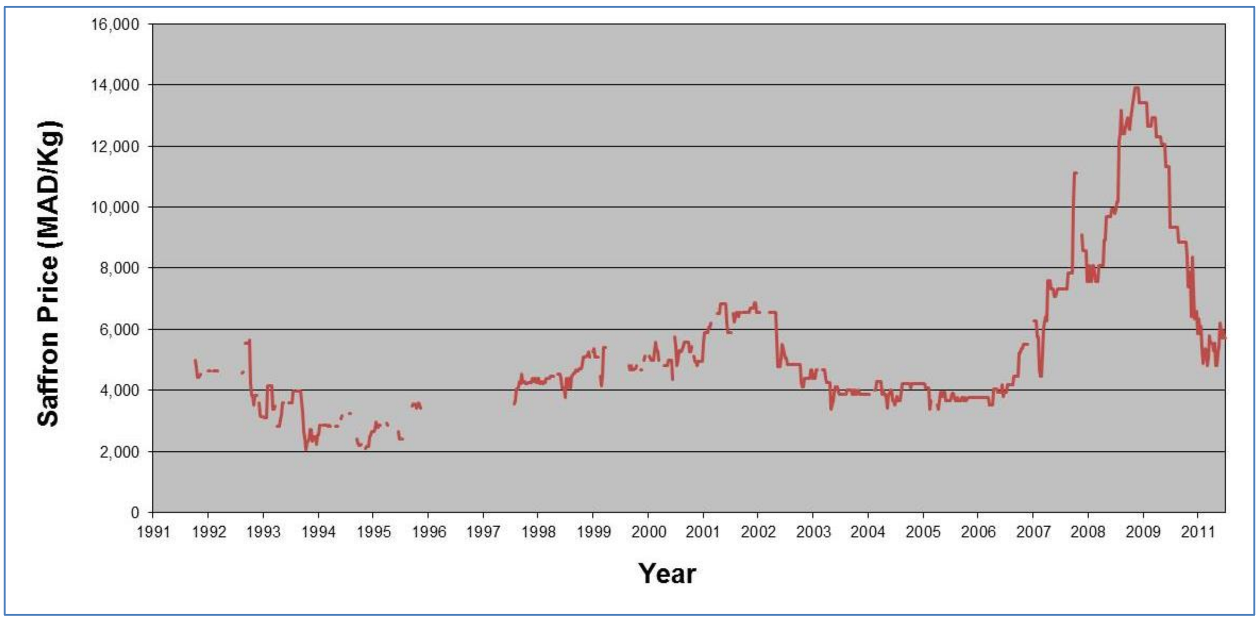
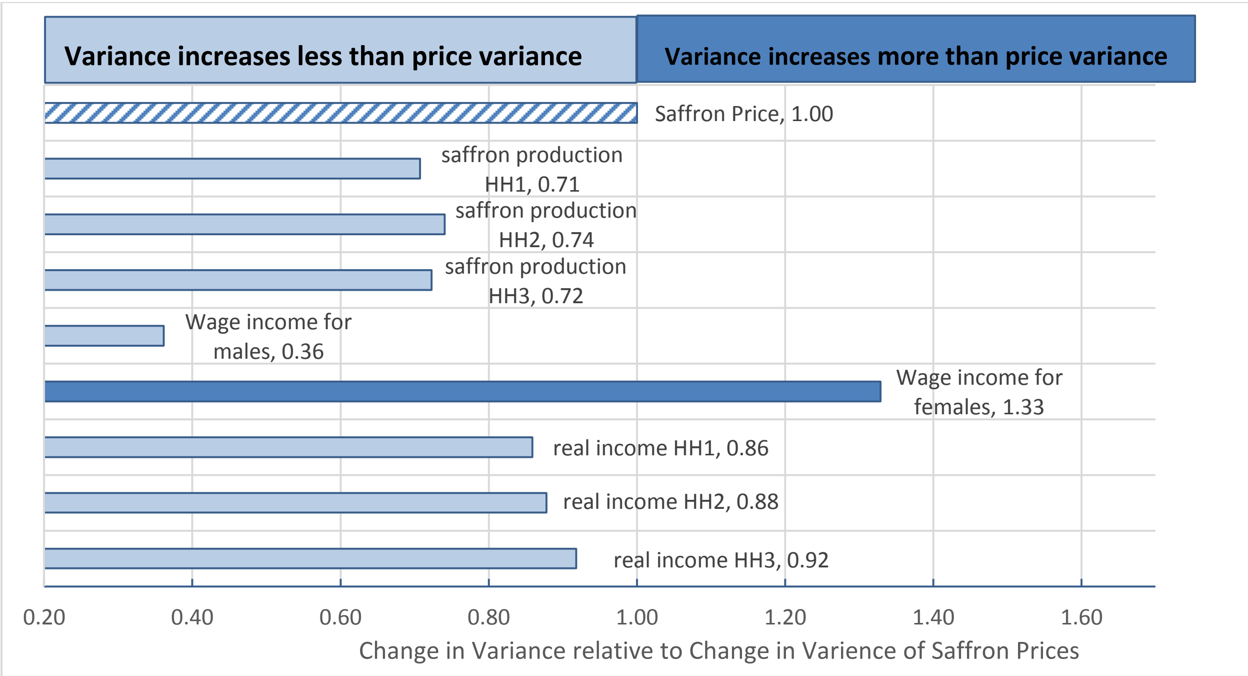


Figure 2 Evolution of real (1989) saffron prices in Tallliouine, Morocco (Source : ORMVAO).

Figure 3: Effects of increased saffron price variance on variances of wage incomes, production and real income.



Source: LEWIE simulations. All variance shock reported relative to the shock in Saffron price variance

APPENDIX 1: Model Structure

Name	Equation
Price Block	
PVA_EQ(g,h)..	$PVA_{g,h} = (P_{g\|g\in TG} + PE_{g,h\|g\in(NTG)}) - \sum_{gg} idsh_{gg,g,h} \times (P_{gg\|gg\in TG} + PE_{gg,h\|gg\in(NTG)})$
Production Block	
EQ_ZEROPROFIT(g,h)..	$QP_{g,h} \cdot PVA_{g,h} + \sum_{gg,s} ID_{gg,g,h,s} \times (P_{gg\|gg\in TG} + PE_{gg,h\|gg\in(NTG)}) = QP_{g,h} \cdot (P_{g\|g\in TG} + PE_{g,h\|g\in(NTG)})$
FD_EQ(g,f,h,s)	$[R_{g,f,h,s}]_{f\in FIXF} + [WM_{f,s}]_{f\in TF} = \frac{PVA_{g,h} \times QP_{g,h} \times shcobb_{g,f,h,s}}{FD_{g,f,h,s}}$
ID_EQ(gg,g,h,s)..	$ID_{gg,g,h,s} = QP_{g,h} \times idsh_{gg,g,h,s}$
QVA_EQ(g,h)..	$QVA_{g,h} = acobb_{g,h} \times \prod_{f,s} (FD_{g,f,h,s})^{shcobb_{g,f,h,s}}$
EQ_QP(g,h)..	$QP_{g,h} = QVA_{g,h}/vash_{g,h}$
Consumption and income block	
QC_EQ(g,h)..	$QC_{g,h} \cdot (P_{g\|g\in TG} + PE_{g,h\|g\in(NTG)}) = \alpha_{g,h} \times \left(Y_h - \sum_{gg} (P_{gg\|gg\in TG} + PE_{gg,h\|gg\in(NTG)}) \times cmin_{gg,h}\right) + cmin_{g,h}$
Y_EQ(h)..	$Y_h = \sum_{g,fixf,s} (R_{g,fixf,h,s} \times FD_{g,fixf,h}) + \sum_{mapfs(ft,s)} WM_{ft,s} \times endow_{ft,h,s}$
Market clearing block for factors	
FFCLR_EQ(f,g,h,s).. (Fixed factors)	$FD_{f,d,h,s} = FD^0_{f,d,h,s}$
TFCLR_EQHH(f,h,s).. (All tradable factors)	$\sum_{g} FD_{f,g,h,s} - endow_{f,h,s} + HFMS_{f,h,s} = 0$

TFCLR_EQ1(f,s) (factors traded in the economy)	$$\sum_{h} HFMS_{f,h,s} = -FI_f$$
TFCLR_EQ2(f) (factors purchased from the rest of the world)	$$FI_f + \sum_{(h,s)} HFMS_{f,h,s} = 0$$
HFD_EQ(f,h,s)	$$HFD_{f,h,s} = \sum_{g} FD_{f,g,h,s}$$
Market clearing block for commodities	
HHCLR_EQ(g,h)..	$$HMS_{g,h} = QP_{g,h} - QC_{g,h} - \sum_{gg,s} ID_{g,gg,h,s}$$
MKTCLR_EQ(g)..	$$MS_g = \sum_{h} HMS_{g,h}$$
MKTCLR2_EQ(g) for g ∈ NTG	$$HMS_{g,h} = 0$$

SETS		Subsets	
g or gg	commodities	gt	Goods tradable in the district
f	factors	gnt	Goods tradable in the region
h	households	fixf	Fixed factors
s	seasons	ft	Factors tradable in the region
		fnt	Factors integrated to world markets

VARIABLES			
Values		Consumption and income	
P(g)	price of a good at the district level	QC(g,h)	quantity of g consumed by h
PE(g,h)	endogenous price for the household h	Y(h)	nominal household income
PVA(g,h)	price of value added net of intermediate inputs		
R(g,f,h)	rent for fixed factors		
WE(f,d)	endogenous wage in the household		
WM(f)	wage on the market		

Production		Trade	
QP(g,h)	quantity produced of a good by a household	HMS(g,h)	household marketed surplus of good g
FD(g,f,h,s)	factor demand of f in production of g in season s	MS(g)	marketed surplus of good g in the region
ID(gg,g,h,s)	intermediate demand for ff into production of g in season s	HFMS(f,h,s)	factor marketed surplus from the household in season s
QVA(g,h)	quantity of value added created		
HFD(f,h,s)	factor demand in the household in season s		
FI(f)	Imports of a factor into the economy		

PARAMETERS			
Production		Consumption	
acobb(g,h)	production shift parameter for the CD	alpha(g,h)	consumption share parameters in the LES
shcobb(g,f,h,s)	factor share parameter for the CD	cmin(g,h)	minimal consumption in the LES
vash(g,h)	share of value added	exinc(h)	exogenous income of household
idsh(gg,g,h,s)	intermediate input share		
endow(f,h,s)	fixed factor endowment		

APPDENDIX 2: Model input sheet (slightly modified for legibility)

Production Data Inputs:							
variable	name in code	index1	index2	index3	hh1	hh2	hh3
factor share in production	beta	land	lvst	cultiv	0.0885	0.0885	0.0885
		land	lvst	harv	0.0115	0.0115	0.0115
		cap	lvst	cultiv	0.3538	0.3538	0.3538
		cap	lvst	harv	0.0462	0.0462	0.0462
		inp	lvst	cultiv	0.0885	0.0885	0.0885
		inp	lvst	harv	0.0115	0.0115	0.0115
		hml	lvst	cultiv	0.1769	0.1769	0.1769
		hml	lvst	harv	0.0231	0.0231	0.0231
		hfl	lvst	cultiv	0.0000	0.0000	0.0000
		hfl	lvst	harv	0.0000	0.0000	0.0000
		fml	lvst	cultiv	0.0885	0.0885	0.0885
		fml	lvst	harv	0.0115	0.0115	0.0115
		ffl	lvst	cultiv	0.0885	0.0885	0.0885
		ffl	lvst	harv	0.0115	0.0115	0.0115
		land	ag	cultiv	0.1769	0.1769	0.1769
		land	ag	harv	0.0231	0.0231	0.0231
		cap	ag	cultiv	0.0442	0.0442	0.0442
		cap	ag	harv	0.0058	0.0058	0.0058
		inp	ag	cultiv	0.0442	0.0442	0.0442
		inp	ag	harv	0.0058	0.0058	0.0058
		hml	ag	cultiv	0.2654	0.2654	0.2654
		hml	ag	harv	0.0346	0.0346	0.0346
		hfl	ag	cultiv	0.0000	0.0000	0.0000
		hfl	ag	harv	0.0000	0.0000	0.0000
		fml	ag	cultiv	0.1769	0.1769	0.1769
		fml	ag	harv	0.0231	0.0231	0.0231
		ffl	ag	cultiv	0.1769	0.1769	0.1769
		ffl	ag	harv	0.0231	0.0231	0.0231
		land	nag	cultiv	0.0000	0.0000	0.0000
		land	nag	harv	0.0000	0.0000	0.0000
		cap	nag	cultiv	0.1769	0.1769	0.1769
		cap	nag	harv	0.0231	0.0231	0.0231
		inp	nag	cultiv	0.0885	0.0885	0.0885
		inp	nag	harv	0.0115	0.0115	0.0115
		hml	nag	cultiv	0.2654	0.2654	0.2654
		hml	nag	harv	0.0346	0.0346	0.0346

		hfl	nag	cultiv	0.0000	0.0000	0.0000
		hfl	nag	harv	0.0000	0.0000	0.0000
		fml	nag	cultiv	0.1769	0.1769	0.1769
		fml	nag	harv	0.0231	0.0231	0.0231
		ffl	nag	cultiv	0.1769	0.1769	0.1769
		ffl	nag	harv	0.0231	0.0231	0.0231
		land	flw	cultiv	0.3892	0.4280	0.4583
		inp	flw	cultiv	0.2217	0.2438	0.2611
		hml	flw	cultiv	0.1090	0.0000	0.0027
		hml	saf	harv	0.0803	0.0000	0.0000
		hfl	flw	cultiv	0.0228	0.0000	0.0000
		hfl	saf	harv	0.1230	0.0000	0.0024
		fml	flw	cultiv	0.1666	0.2074	0.1637
		fml	saf	harv	0.3989	0.5179	0.5304
		ffl	flw	cultiv	0.0908	0.1208	0.1142
		ffl	saf	harv	0.3978	0.4821	0.4673
		ffl	care	cultiv	1.0000	1.0000	1.0000
		fml	care	cultiv	0.0000	0.0000	0.0000
		ffl	leisure	cultiv	0.2000	0.2000	0.2000
		fml	leisure	cultiv	0.8000	0.8000	0.8000
		ffl	care	harv	1.0000	1.0000	1.0000
		fml	care	harv	0.0000	0.0000	0.0000
		ffl	leisure	harv	0.3333	0.3333	0.3333
		fml	leisure	harv	0.6667	0.6667	0.6667
intermediate demand share	idsh	flw	harv	saf	0.6140	0.5584	0.5214
		ag	cultiv	lvst	0.1000	0.1000	0.1000
		ag	harv	lvst	0.0115	0.0115	0.0115
quantity produced	qp	saffron			1534998	960680	235419
		flowers			942538	536406	122743
		ag			1258940	872208	177222
		lvst			1661038	2554620	1042106
		nag			331725	145513	28124
		care		cultiv	668461	609808	195366
		care		harv	62279	56814	18202
		leisure		cultiv	417788	381130	122104
		leisure		harv	7473	6818	2184

Consumption and Income Data inputs:

	name in code		hh1	hh2	hh3
Consumption values	qc	care in cultiv. Season	668,461	609,808	195,366
		care in harvest season	62,279	56,814	18,202
		leisure in cultiv. Season	417,788	381,130	122,104
		leaisure in harvest season	7,473	6,818	2,184

Consumption shares	qcalph	ag	0.3289	0.2513	0.1608
		non-ag	0.0533	0.0342	0.0394
		livestock	0.3835	0.5645	0.6266
		imports	0.2342	0.1500	0.1732
Remittances	revremit		306,189	505,337	89,134
wage income - females	hlrevfem		13,303	-	70,787
wage income - males	hlrevmal		532,396	273,258	123,665
share of females hired	fwagesh		0.1582	0.0000	0.8418
Share of males hired	mwagesh		0.5729	0.2940	0.1331