Climate Change, Transformative Adaptation Options, Multiscale Polycentric Governance, and Rural Welfare in Oum Er-Rbia River Basin, Morocco

An Empirical Evaluation with Policy Implications

Project Report

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CGIAR Initiative on Climate Resilience

The CGIAR Initiative on Climate Resilience, also known as ClimBeR, aims to transform the climate adaptation capacity of food, land, and water systems and ultimately increase the resilience of smallholder production systems to better adapt to climate extremes**.** Its goal is to tackle vulnerability to climate change at its roots and support countries and local and indigenous communities in six low-and middle-income countries to better adapt and build equitable and sustainable futures.
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Executive Summary

This Study forms part of the research under Work Package #4 (WP4) of CGIAR Research Program: Building Systemic Resilience against Climate Variability and Extremes (ClimBeR), which has the overarching goal of "setting up a bottom-up polycentric governance framework for promoting multiscale transformative adaptation options and targeted climate investments". Consistent with this objective, this study has made an attempt to develop and empirically apply an innovative methodology that builds on the earlier analytical and empirical woks of Saleth, et al., (2007), Saleth and Dinar (2009), and Saleth, Dinar, and Frisbee (2011). This methodology is rooted in an analytical framework that delineates various possible pathways through which the impacts of climate change are transmitted ultimately on rural welfare at the grassroots level. Since these impact pathways are being characterized by various configurations of climatic, economic, policy, technical, institutional, infrastructural, and welfare-related variables, they provide an excellent operational context not only for incorporating various elements of the MPG structure within a unified context but also for evaluating their roles in mediating and enhancing the climate resilience impacts of TAOs both across regional scales and sectoral contexts.

Notably, in contrast to prevalent approaches in current climate adaptation literature, the impact pathway-based analytical framework enables one to evaluate the welfare impacts of climate resilient coping and adaptation strategies in a more dynamic and interactive context. Clearly, the impact pathways, taken together, constitute the basic building blocks of the analytical framework underlying our evaluation methodology. By defining appropriate variables within relevant empirical context, these impact pathways can be formalized as an inter-related set of equations. Such an equation system can represent a mathematical analogue of the analytical framework, which is capable of being empirically estimated with appropriate data.

Empirical Setting: Oum Er-Rbia Basin, Morocco

For piloting the study and practical application and demonstration of its evaluation methodology, the Oum Er-Rbia Basin in Morocco is selected as an empirical context. The study basin and the sample country are selected keeping in mind the requirement of the main objectives of the study. Taking first the sample country, Morocco is an ideal choice for piloting this study, at least, for four important reasons:

(1) Morocco, though one among the fast-growing countries in Africa, is highly susceptible to climatic risks since arid and semi-arid conditions dominate 93% of the country. On top of this, there has been a 10 to 20% reduction in precipitation across the country over the years. Reduced and irregular rain patterns, cold spells, heat waves, and drought conditions are common and regular phenomena severely affecting its agriculture and the economy in general,

(2) With only 16% of its cultivated area being irrigated with the rest relying on highly variable and uncertain rain, agricultural and food production in Morocco remain very precarious and vulnerable with serious welfare and food security implications. For instance, 2016 drought, the worst in past 30 years, reduced cereal yields by 70% and has significantly slowed the overall economic growth,

(3) Equally precarious and vulnerable is also its water sector witnessing an ever-widening water demand-supply gap. Due to climate factors, there has been a 20-percent reduction in overall water resources in the country. As against the average annual water demand of 14.7 Billion

cubic meters (Bm^3), water supply from all sources remains only about 13 Bm^3. With this, water per capita has declined to just 730 m^3, far below water stress threshold of 1,000 m^3,

(4) And, finally but more importantly, Morocco is also one among a few pioneering countries that have already undertaken several major initiatives to counter the impacts of climate change on their agricultural and water sectors. Morocco has experimented several TAOs under its three major programs, i.e., Green Morocco Plan [Plan Maroc Vert (PMV)] covering the period of 2010-20, National Irrigation Water Saving Program [Programme National d'Economie d'Eau d'Irrigation (PNEEI)] promoted since 2009-10, and Green Generation Plan [Plan Génération Verte (PGV)] covering the period of 2020-30. Somme of these TAOs include: (a) Shifting of Crop Pattern to Tree Crops such as olives, oranges, and citrus, (b) Shifting from Flood and Sprinkler to Drip Irrigation Systems, (c) Modernization of Water and Irrigation Infrastructure, (d) Contract Farming/Supply Aggregation/Value Chain Developments, (e) Corporate Farming and Public-Private Partnership in Agriculture (via Land Leased from government and rural communities), usually by national/foreign private investors, and (f) Zero-Tillage Farming Technology, particularly in rainfed regions.

As to the study basin, the Oum Er-Rbia basin, the third largest among the 12 major river basins of Morocco, is selected for conducting field visit and perception-based data for the empirical evaluation of the impact pathway-based methodology. The rationale for the selection the study basin is provided by the following facts:

(1) It is the Oum Er-Rbia basin that is facing the most severe water deficit among all the 12 basins of Morocco. Mostly due to regular drought conditions and partly due to severe siltation problems, water storage in the basin is on a constant decline. For instance, although the five major dams in the basin have a combined storage capacity of 5 Bm^3, the actual storage is not only too low but also has declined from 18.5 to 7.6% during 2021-22.

(2) Despite its water scarcity, Oum Er-Rbia basin plays a central role in agricultural and food production in Morocco. With a share of 33% in the total harvested area in the country, this basin dominates in terms of the area share of most cereals, except wheat, in which it has only the second largest area share.

(3) In terms of irrigated area, the basin also dominates with a 33% share in the total irrigated area of Morocco. The basin also accounts for the major share in total water (both blue and green) used with a water footprint of 7.7 Bm3 as against the total country level water footprint of 23.5 Bm3.

(4) Finally, but more importantly, Oum Er-Rbia basin is extremely vulnerable to the impacts of climate change, including high frequency and intensity of droughts. Historical data suggest that the basin has experienced a 20% reduction in rainfall and a 40 % to 49% decline in annual flow. All these factors tend to affect agricultural and food production in the basis with serious food and welfare implications both within and beyond the basins.

Given the vast size of the study basin, there is need to delineate a study region that is both representative enough to capture the overall basin characteristics and manageable enough from a logistic perspective. The Oum Er-Rbia basin covers—either fully or parts of—three major regions in Morocco, i.e., Beni Mellal-Khenifra, Casablanca-Settat, and Marrakesh-Safi. Since the Beni Mellal-Khenifra region has the major share of agricultural areas within the basin, this region, covering five provinces: i.e., Azilal, Beni Mellal, Fquih Ben Salah, Khenifra, and Khouribga, is selected as the study region. Brief field visit was undertaken to interact with different stakeholder groups and have a first-hand experience with major issues and challenges facing the study basin. However, the sample selection and data collection cover all regional scales and sectoral context, going beyond the study region per se. Similarly, the identification of the candidate TAOs and the key elements of the prevalent MPG structure and impact transmission pathways are based on national, regional, and basin and sectoral level reviews, relying on both policy documents and published literature as well as on interactions with experts, policymakers, and officials. In any case, all these aspects are essential to develop the analytical framework that reflects well the realities of the study region and study basin in general.

Evaluation Methodology

Once the empirical context is identified and its the climatic, water, agricultural, and governance realities are reviewed, it is rather straightforward to develop the evaluation methodology. The evaluation methodology has three components: (a) analytical framework, (b) mathematical model, and (c) empirical approach.

Analytical Framework

The basic building blocks of the analytical framework are impact pathways and their underlying chains of variables. As to the content of the analytical framework that is to be empirically applied in the context of the study region, besides the trigger element of climate change and the ultimate impact variable or policy goal of rural welfare, it covers three sectors, three sets each of TAOs and MPG structure elements, and several impact or impact transmission variables. The three sectors are: water, agriculture, water supply. However, other sectors such as livestock and rural non-farm enterprises are covered implicitly as part of the impact variables. The three TAOs are: (a) contract farming and public-private partnership in agriculture, (b) crop shift towards tree and high-value crops, (c) and drip system conversion and irrigation modernization.

The MPG structure is represented by three groups, i.e., institutions (laws, policies, and organizations), infrastructures (water, agriculture, and environment), and players (the state, corporate sector, service providers, and civil society organizations) operating across regional scales and sectoral contexts. The three governance elements are, in turn, represented by a total of 20 institutional, infrastructural, and player-related variables. The impact or impact transmission variables that are mostly related to production, productivity, cost, and income-related aspects. These aspects are represented by 24 variables. Thus, taken together, the analytical framework captures the structural linkages and interactive effects of a total of 52 variables. It is the different configurations of these variables that characterize various possible pathways linking climate impact and social welfare.

Mathematical Model

The analytical framework and the mathematical model of CC-TAO-MPG-RW are closely linked. This is because by tracing all possible impact pathways and by defining each of them by using the 52 variables, the analytical framework can be translated into a mathematical model with a set of 40 sequentially and simultaneously inter-linked equations. These equations, which are defined by different configurations of variables, characterize, in fact, most of the important layers operating in the process of CC-TAO-MPG-RW interactions in the study basin. The analytical framework and its mathematical representation constitute only the two components of the evaluation methodology. The other, but more important, component relates to the empirical approach that is used to generate data needed for the numerical estimation of the mathematical model involving a system of sequentially and simultaneously linked equations.

Empirical Approach

The empirical approach involves major challenges as most of the 52 variables are inherently ex-ante nature. Observed data on them are either absent or irrelevant as such data remain static, outdated, and devoid of any expectational considerations. Also, since the impacts of these variables not only vary by context but also aggregate, composite, and notional in nature, there is need to generate information on each of them from multiple angles and perspectives. Obviously, observed and single point data are unrealistic to capture these variables. Absence of lack of observed data on most variables does not mean there is a complete absence of information because highly relevant information is constantly being processed, coded, and stored as perceptions in the minds of planners, experts, evaluators, and beneficiaries, and, even, informed common observers. The empirical approach underlying the evaluation methodology is, in fact, trying to elicit such valuable information from a suitable sample of stakeholders using a well-designed questionnaire. While stakeholder-based survey provides flexibility in conceptualizing, defining, and selecting more appropriate and specialized forms of variables, the perception-based data allow a synthesis of objective, subjective, and aspiration-related factors and incorporate both the ex-ante and dynamic elements into the reckoning. Moreover, the use of perception-based data has a strong theoretical legitimacy and their reliance in empirical application and policy analysis also has a long tradition.

Dataset and Model Estimation

While the rationale and legitimacy of subjective and perception-based data is clear, it is important to recognize the way such information is elicited and recorded in the practical context of the study region. The field-tested and finally revised questionnaire covers a total of 300 questions. The first nine questions relate to identifier variables (Respondent's ID, gender, education, discipline, profession, experience, sector, and region). The remaining 291 are specific questions directly aiming to get information on the 52 model variables from different angles and perspectives. While the data on identifier variables are recorded either as real numbers or a category-based integers, the same on the 291 sub-variables are recorded on a 0-10 scale, with zero denoting no effect and 10 denoting the highest possible impact. For the collection of the needed data, the questionnaire was administered to a purposively selected representative sample of 176 respondents dispersed both within and outside the study basin and having diverse characteristics and background. Thus, the original dataset has a dimension of 176 by 300. However, since the 291 sub-variables are related to the different aspects of the 52 model variables, they were summarized using simple. Thus, the final dataset, which was used for estimating the system model, has a dimension of 176 by 61.

With the finalization of the dataset, several diagnostic tests were performed on each of the individual equations of the structural model for evaluating their distributional and other econometric properties. After confirming the reasonable performance of individual equations, the system model with 40 inter-linked equations was estimated using a 3-SLS procedure by assuming four different functional forms (linear vs. logarithmic and constant vs. no constant). Of these alternative estimates, the one with a linear form and no constant term was selected based on criteria such as model fit, explanatory power, and estimation consistency. The results are interesting and highly significant. Going by very high R^2 and χ^2 values in the case of all model equations clearly suggest that the configurations of variables included in them are not only statistically significant but also explain almost all the variations in their respective dependent variables.

The equation-specific analysis of the 3-SLS results provides considerable insights on the relative size, direction and significance of different variables included in the model as well as the relative strength or weakness of inter-linkages among variables and impact flows across pathways. Looking from an overall perspective, of the 209 coefficients in the system model, 163 (78%) are statistically significant at 90% level or better. Only the remaining 46 (22%) are statistically insignificant. It is the information on the size, sign, and statistically significance of the coefficients in different equations that will be used to evaluate the relative role and significance of different policy, institutional, and impact variables that characterize different impact pathways. More importantly, both the overall as well as equation-specific 3-SLS results strongly attest not only to the robustness of individual equations representing different impact pathways but also to empirical validity of the system model, that represents the analytical framework as such.

Limitations and Caveats

Before highlighting some of the important policy implications of the results from the system model, it is necessary to acknowledge some of the major limitations and caveats for the present attempt.

(1) First, the study evaluates only the grassroots level impacts of climate change essentially within the sectoral setting of agriculture, though other related sectors such as water, livestock, non-farm enterprises, and market and trade are also treated both implicitly and explicitly. Given such a focus, social welfare is defined only in the restricted sense of rural welfare.

(2) Second, obviously, the pathways between climate impact and rural welfare are many and varied. But the present study has considered only 40 of these pathways, which are the most important from economic and welfare policy perspectives.

(3) Third, while the MPG structure covers myriad elements, are many vast, the present study has included only a select set within each of the three governance components, i.e., institutions, infrastructures, and players.

(4) Fourth, the same is also the case with TAOs, as the candidate TAOs selected for evaluation are only a few among other possible ones.

(5) Finally, but more importantly, most of the variables defined to represent the sectors, TAOs, MPG elements, and impacts are in a composite or notional form. For instance, water institutions are taken as a single entity; it has many distinct elements (e.g., water rights, water law, water pricing, basin organization, etc.). Such conceptualization is inevitable given an ambitious analytical framework that tries to cover a total of 52 elements representing climate change, three sectors, three TAOs, 20 MPG-related elements, 22 impact variables, and rural welfare within a single framework.

Empirical Results with Policy Highlights

Keeping the limitations of the present attempt as caveats and recognizing well the preliminary and tentative nature of the econometric results, let us list some of the important and policy-relevant implications of empirical results presented in this study. For a better understanding, the implications are listed by equations.

(1) Climate investments are positively influenced not only by climate change impact but also by government institutions—especially those operating in agricultural and environmental sectors—and donor agencies and international investors. Notably, government institutions play a more dominant role.

(2) Climate investments followed by customary institutions have a dominant effect on the overall performance of water institutions. This fact, taken along with the negative effect of climate change, suggests that without substantial investment and significant improvement, existing water institutions in the study basin are under extreme stress due to the challenges of climate change.

(3) The performance of water infrastructure is favorably influenced by climate investment, followed by climate change and state subsidy and tax policies. Climate investment, again, has the highest positive impact as it has both direct effects and as well as capture and brings here the indirect effects of other variables. This suggests some synergy effects of impact

flows across pathways. Notably, climate change, which had a negative effect on water institutions, now has a positive effect, suggesting the potential pressure that climate impacts tend to create for additional investment in or improved maintenance of water infrastructure.

(4) Regarding the growth and performance of rural service providers, corporate sector and climate investment play positive roles. But state taxation policies are immaterial whereas agricultural credit institutions have somewhat an unfavorable role. From a policy perspective, therefore, it is these two weak MPG elements that are to strengthen and reorient for promoting the growth of rural service providers in the study basin.

(5) The extent of water availability for agriculture can be improved considerably by promoting the TAO involving crop pattern shifts, especially towards tree and other high-value crops and infrastructural development in the water sector, especially related to water storage and inter-basin water transfer. But water institutions, especially those related to inter-sectoral allocation, remain a significant constraint for enhancing water availability for agriculture. The insignificant and unexpected effects of the other TAO related to drip system conversion and irrigation modernization and the technical option of climatic information system suggest the need to investigate the missing or unfavorable conditions that limit expected impacts.

(6) Interestingly, water availability for household consumption is not negatively affected either by climate change impact or by enhanced water availability for agriculture. Though looks counter-intuitive, this result can be explained partly in terms of the relatively small share of household water need and partly in terms of the long-standing policy norm for assigning top priority for basic water needs under water-scarcity. Also, under favorable water scenarios, it is natural for water availability to increase for both sectors simultaneously. In any case, a closer investigation is needed to reach a firm conclusion in this respect.

(7) The adequacy and effectiveness of agricultural input supply system are positively influenced by three MPG elements, representing respectively agricultural research and extension system, agricultural credit and investment institutions, and rural service providers. The negative effect of the TAO involving contract farming and public-private partnership in agriculture suggests the fact that the TAO provides input and technical services, they are confined only to a limited areas or groups with participating farmers. Its sector-wide impact, therefore, cannot be expected to be positive.

(8) The main factors having a favorable effect on the overall performance of agricultural sector are a better availability of water, efficient climate information system, and the facilitative land tenure conditions. The positive effects of increasing allocation to household consumption on agricultural performance, though seems contrary to expectations, it can be a possible outcome of a more efficient water use in the face of water scarcity associated with an increasing water allocation to household use. In this respect, one also needs to the fact that against its negative direct effects, water supply for household consumption as a linkage variable also brings here the indirect but dominant positive effects of the variables representing both water availability for agriculture and water infrastructures from previous equations.

(9) The effectiveness and impacts of the TAO involving contract farming and public-private can be improved with a facilitative land tenure system, especially the policy changes allowing long-term land lease from government or rural communities, and better performing water institutions and credit and investment policies. This is an illustration of how the

performance of TAOs is intricately linked with the existence and effectiveness of MPG-related institutional variables as well those related to impact and, even, other TAOs.

(10) Similar to the TAO noted above, the effectiveness and impacts of the TAO involving drip system conversion and irrigation modernization are positively linked with a better performing agricultural sector and water institutional arrangements as well as a facilitative land tenure system, especially the landholding pattern in large irrigation perimeters. But a lack of relevant service providers and the constraining nature of the prevailing water-related infrastructures, especially those related to water conveyance and delivery systems tend to reduce the expansion and effectiveness of the TAO related to drip system conversion and irrigation modernization.

(11) Although the corporate sector, as a player, is one among the key elements of the MPG structure, it is not independent because its extent and effectiveness of involvement in the agricultural sector are affected by several other factors. In this respect, a favorable external trade regime, conducive subsidy and tax policies, and successful contract farming and public-private partnership policies are likely to encourage more extensive involvement of corporate sector. The result also implies that corporate farming is essentially oriented towards export and domestic niche markets of high-value crops.

(12) The impact and performance of agricultural credit and investment institutions are positively influenced by supportive agricultural and environmental institutions, favorable donor and international investments, and proactive corporate sector. Since all these four aspects represent different elements of the MPG structure, the positive relationship observed here illustrates the strategic and beneficial effects of linkages within the MPG structure itself. Notably, the corporate sector, as a linkage variable, also brings here the positive impact flows captured from other pathways.

(13) The extent and effectiveness of yet another TAO involving crop shift towards tree and high-value crops are positively affected not only by the other two TAOs related respectively to contract farming and public-private partnership in agriculture and drip system conversion and irrigation modernization but also by domestic agricultural marketing regime and corporate sector. This result illustrates the linkages and synergies among the TAOs. However, unviable land tenure system coupled with the absence of local level rental or lease market for land, ineffective water institutions, export-oriented market regime, and absence of enough rural service providers remain as major constrains for making crop pattern shift as an ineffective option of transformative adaptation.

(14) The overall performance and impact of agricultural research and extension system are linked with the same of other three MPG elements. That is, a proactive corporate sector, efficient climate information system, and supportive agricultural and environmental institutions tend to improve the effectiveness and impact of agricultural research and extension system. In contrast, the TAO involving contract farming and public-private partnership in agriculture, though provide research extension services to participating farmers, do not contribute much to the overall impact and performance of the sectoral level agricultural research and extension system.

(15) The emergence and performance of the MPG-related institution of agricultural production and marketing cooperatives depend on effectiveness and support of other three MPG-related institutional elements, i.e., agricultural credit and investment institutions, relevant rural service providers, and customary institutions related to customs and traditions affecting management and cooperation. The result suggests that though customs and

traditions remain as constraints, the performance of agricultural production and marketing cooperatives is influenced by the positive support from various kinds of rural service providers as well as agricultural credit and investment agencies.

(16) Agricultural value chain networks can be viewed both as institutions and as infrastructure. The effectiveness and performance of agricultural value chain networks are positively influenced by the role of agricultural credit and investment institutions, marketing cooperatives, export-oriented trade regime, and strong network of rural service providers. On the other hand, domestic-oriented production and corporate groups with their own and exclusive processing networks have unfavorable effects on the growth and performance of agricultural values chain networks.

(17) The extent of cultivated area in the study basin is likely to expand with an increasing trend in crop pattern shift towards tree and high-value crops and drip system conversion and irrigation modernization as well as by favorable changes in land tenure systems such as long-term land lease from state or remote tribal communities and expansion and performance of agricultural value chains. While the favorable effect the TAOs related to crop pattern shift on cultivated area is understandable, the unfavorable effect of TAO involving contract farming and public-private partnership is rather unexpected and requires further investigation on the factors leading to such counter-intuitive effect.

(18) As to the factors affecting land and soil quality, crop-livestock mixed farming and agricultural research and extension system contribute significantly towards improved land and soil quality. But cropping patterns with more intensive land use and cultivation is likely to have a negative effect on land and soil quality. Contrary to expectation, the impact of climate change, which is supposed to be unfavorable for land and soil quality due to factors such as drought and wind erosion, has a positive effect. This may be due to possible scope for soil recuperation associated with long fallow following droughts.

(19) Crop pattern is an important impact variable that provides the context for evaluating the individual and interactive effects of all the three TAOs selected for evaluation in this study. The results support the fact that crop pattern in the sense of crop diversity is favorably influenced by increasing cultivated area, crop shifts towards tree and high-value crops, drip system conversion and irrigation modernization, and land and soil quality. But the production system based on larger farm sizes and oriented towards domestic and international markets tends to promote crop specialization. Crop specialization, though good for productivity, scale economy, and value chain development, tends to expose the production systems to climatic risks and uncertainties.

(20) Land productivity depends on the productivity-enhancing roles of irrigation water availability, agricultural research and extension system, land and soil quality, and effective water institutions. Notably, among these factors both water availability and soil quality have a more dominant effect. However, crop patterns in the sense of crop diversity obviously have an inverse relationship with land productivity. Notably, agricultural input supply system has a rather weak association with land productivity, suggesting the need to strengthen their productivity enhancing role.

(21) The major factors positively influencing the level of water productivity are land and soil quality, crop pattern, land productivity, and water institutions. As in the case of land productivity, land and soil quality also has the dominant impact on water productivity as well. Notably, land productivity, as linkage variable, also transmits the positive effects of factors that it has captured from other pathways. However, the negative effect of cultivated

area means water productivity to be higher when water is used in a limited area rather than spreading its application over a larger area. Similarly, the agricultural input supply system, which implicitly promotes extensive rather than intensive production pattern, is not that conducive for improving water productivity.

(22) Understandably, the most dominant factor that favorably affects the level of labor productivity is land productivity. It clearly confirms the positive association with land and labor productivity levels. has on labor productivity. While crop pattern and cultivated area remain insignificant, agricultural input supply system has a negative effect on labor productivity, possibly reflecting the unfavorable effects of inputs and technologies that tend to favor extensive and labor-intensive cultivation.

(23) The level of food production is favorably influenced by expanding cultivated areas, higher land and water productivity levels, and supportive network of rural service providers. Since all factors are linkage variables, besides their direct effects, they also transmit the indirect effects to other factors as captured in other pathways or linkage equations. Notably, other factors such as agricultural food price policy, agricultural credit and investment institutions, and contract farming have either weak or unfavorable effects on food production. The reasons behind such a lackluster role of these factors require further and more focused investigation.

(24) The production levels of industrial and commercial crops are strongly influenced by the positive effects of export and niche markets and improved water productivity from efficient water use as achieved mainly through dependable irrigation and advanced water and irrigation technologies. In contrast, domestic market regime and corporate sector involvement do not have any favorable effects on the production levels of industrial and commercial crops.

(25) As to the level of feed and fodder supply, a key factor for livestock production in the study basin, is positively affected by crop pattern with diverse cropping system, especially the mixed farming system, and higher levels of industrial and commercial crop production. In terms of the relative magnitude of effects, cropping pattern has much stronger impact. However, cultivated areas and food production level are not that conducive for promoting feed and fodder supply. Notably, with the declining extent and degradation of community pastures and common grazing lands, customary institutions seem to be losing their effectiveness in this regard.

(26) The most dominant factors favorably affecting livestock production and livestock sector in general are diverse livestock composition, favorable domestic market regime, and an expanding corporate investment. Notably, factors such as feed and fodder supply and international trade regime remain insignificant. But agricultural credit and investment institutions have an unfavorable impact on livestock production. This can possibly be because with their predominant orientation towards crop sector, agricultural credit and investment institutions play rather an insufficient or ineffective role in supporting the livestock sector.

(27) The emergence and performance of rural non-farm sector, a key factor mediating rural economic transition, are favorably influenced by a production system oriented towards industrial and commercial crops, facilitative credit and investment institutions, and conducive and complementary value chain networks. But the corporate sector lacks any substantial involvement in rural non-farm activities, possibly due to them being informal in nature and less appealing for large scale corporate investment.

(28) The nature and effectiveness of agricultural trade regime are positively influenced by both food and industrial and commercial-oriented production systems. Viewed from a reverse perspective, it is also equally valid to argue that both the food and industrial and commercial-oriented production systems are also being positively influenced by agricultural trade regime. In terms of the same two-way relationship, the negative effect of livestock production on the trade regime can also be interpreted to mean that increasing domestic livestock production or achieving self-sufficiency in milk and meat production tend to dampen the import dimension of the agricultural trade regime.

(29) Interestingly, the configurations of variables having significant effects on the nature and effectiveness of agricultural market regimes are the same as those affecting the nature and effectiveness of agricultural trade regime. That is, while both food and industrial and commercial-oriented production systems have favorable effects, livestock production has a negative effect for similar reasons as noted above. However, here, there are two additional factors, i.e., agricultural and food price policies and the domestic market impact of agricultural trade regime. Despite having potentially positive effects, they both remain insignificant, clearly implying the ineffective nature of agricultural and food price policies on the one hand and lack of integration between domestic and international spheres of agricultural trade.

(30) Robust domestic agricultural market regime coupled with effective subsidy and taxation policies tend to improve the level and effectiveness of the overall market prices of agricultural products. In contrast, the other two factors, i.e., agricultural and food price policies and agricultural trade regimes, have a rather dampening effect on the level and effectiveness of the overall market prices of agricultural products. Interestingly, however, it seems that the negative effects emanating from the less integrated export trade regime and weak agricultural and food price policies are more than counter-balanced by the combined positive effects of effective domestic agricultural market regime and favorable subsidy and taxation policies.

(31) As to the factors affecting overall cultivation in the study basin, crop pattern has a negative effect, but cultivated area, agricultural input supply system, and subsidy and tax policy all have positive effects. The results imply that while diverse crop patterns tend to reduce average cultivation costs through crop composition-based scale economies, cultivated area raises cultivations possibly due to the absence of any significant area-based scale economies on the cost side. Contrary to expectation, agricultural input supply system and subsidy and tax policies raise cultivations costs, possibly due to distortions caused by intervening factors. More information is needed to identify these factors causing such distortions.

(32) The income levels from crop enterprises depend on the strong favorable effects of area cultivated, agricultural market regime, and crop and employment insurance policies. A cultivated area, though has a positive effect on crop income, implicitly means crop income to increase essentially through area expansion rather than through productivity increase. This is reinforced by the positive but insignificant effect of land productivity. Besides it also explains as to why crop pattern has an unfavorable effect on crop income in terms of the inverse association between crop diversity and land productivity.

(33) The three main factors affecting rural wage levels are labor productivity, employment level in rural non-farm sector, and production systems oriented to industrial and commercial crops. The first factor has positive effects, the last one has a negative effect. The positive effect of labor productivity underlines the economic significance of productivity aspects, but

that of rural non-farm sector implies the positive effects that the potential competition in rural labor markets have on wage levels. The negative effects of industrial and commercial crop production systems, on the other hand, are an outcome of its labor-intensive practices involving cheaper labor.

(34) The level of rural jobs is favorably affected by industrial and commercial crop production system, rural wage levels, and crop and employment insurance schemes. The positive effect of industrial and commercial crop production system om rural employment is consistent with its negative effect on rural wages. The positive effect of rural wages suggests employment level is directly related to wage level. The inverse relation between labor productivity and rural employment is not only consistent with the above results but also implies a low-level equilibrium, where low employment level co-exists with high wage and low productivity levels. The negative effect of rural non-farm employment suggests the expansion of rural non-farm sector to change only the sectoral composition (i.e., by shifting labor force across sectors) but not the overall level of rural employment.

(35) The level of household income of farmers is positively affected by the level of income derived from all three sources, i.e., crop and livestock enterprises as well as government safety net policies. But the same is negatively affected by income from rural non-farm participation, suggesting a tradeoff between non-farm income and overall household income. This can mean the income from non-farm participation is either relatively low or such income is realized only at the expense of the same from crop and livestock activities. It can also mean that those participating in non-farm activities do not have much income scope from crop and livestock activities. However, a clear explanation in this respect requires further and closer investigation.

(36) The level of household income of laborers or rural workers having no land or participation in crop production, on the other hand, depends largely on wage levels and benefits from government employment insurance program. Neither the level of employment nor the income from livestock sector have any significant role in determining the household income of rural workers. In contrast, rural non-farm participation, again, has a negative effect as in the case of farm income, suggesting the relevance of the same arguments and caveats made earlier.

(37) The level of food availability, the key factor determining the supply side of food security, depends both on favorable supply side condition as determined by food production level as well as on favorable demand side condition as related to price levels in domestic agricultural markets. In contrast, the supply conditions related to livestock production and market conditions affecting agricultural trade seem to have negative effects on food availability. The bright side here is the fact that the positive effects are more than counter the negative effects.

(38) Regarding the level of food prices, the factor determining the demand side of food security, the two inter-related factors, i.e., food availability and food production, both have positive effect. This result seems to be counter intuitive as the food price levels are expected to decline with higher food production and food availability. But, if one considers the reverse side of the two-way flow of impacts, the result is consistent in the sense that higher food prices tend to enhance both food production and food availability. This is an important insight that underlines the need to consider the two-way nature of impact flows with both forward and reverse feedback in many contexts.

(39) Water security is as important as income and food security in view of the central role of water as a key component of the basic need dimension of rural welfare. The level of water security is positively influenced by better water supply for household consumption and more effective water institutions. Clearly, this is consistent with the favorable effects of both adequate allocation for meeting basic water needs as well as institutional norms that guarantee basic need-based water allocation. While the negative effects of climate change on water security are also consistent with expectation, the same related to customary institutions suggests the declining significance of customary institutions in ensuring household level water security.

(40) Finally, rural welfare at the household level, the ultimate policy goal that captures the impact flows across all pathways in the system, depends on the five penultimate factors, representing the roles of two income-related factors, two food consumption-related aspects, and water as basic needs. The results suggest rural welfare at the household level is directly and favorably affected by the farm income, food availability, and water security. But, as expected, the same has an inverse or unfavorable relationship with the level of labor income and food prices. Notably, the welfare implications of food prices are universal in the sense that they affect all households, the same associated with labor income also are specific only to non-farming households, which rely exclusively on wage income employment and income from other non-crop crop sectors such as livestock and rural non-farm activities. Obviously, it is these or similar households that are particularly vulnerable from the unfavorable welfare effects of climate change in the study region.

Key Contributions of the Study

Despite the analytical limitations of the evaluation methodology and the tentative nature of the empirical results presents here, the study is still able to make significant contributions to both climate adaptation literature and policy. Using impact pathways as key building blocks of the evaluation methodology, the study has added dynamic aspects by bringing together all relevant elements, i.e., climate change, adaptation options, governance structure, impact transmission mechanism, and welfare, into a single analytical framework. The empirical approach has also opened up new avenues both in ways the variables are conceptualized and analytically approached and also in the way perception-based information can be used as a valid and legitimate source of information in many difficult and deficient contexts in climate-welfare interaction in particular and institutional and impact assessment in general. The empirical results presented in this study also clearly demonstrate not only the realistic nature of the evaluation methodology and empirical approach but also the practical and policy-relevant theoretical insights that one can gain on the process of CC-TAO-MPG-RR interactions in the study basin. In this respect, the following points can be highlighted:

(1) The MPG structure is conceptualized by distinguishing three sets of elements, i.e., institutions (laws, policies, and organizations), infrastructure, and key players in the state, private sector, and civil society spheres. Despite such an analytical decomposition, there are strong strategic and operational connections among these three components of governance elements both across regional scales and sectoral contexts. For instance, the players form part of the strategic and decision-making dimension of governance, whereas the institutions and infrastructures form part of the operational dimension of governance. In other words, the former represents the process perspective of governance, but the latter represents the structural perspective of governance.

(2) Rural welfare is conceptualized in terms of basic needs perspective by focusing on three key dimensions, i.e., income security, food security, and water security. While income security

is represented by variables to distinguish the income levels of farmers from that of rural workers, food security is represented by two variables to capture both supply and demand aspects. Water security is represented by a variable capturing water availability for household consumption.

(3) Although the four key dimensions rural production system, i.e., food production, industrial and commercial crop production, are intricately linked, they are analytically separated essentially to highlight their differential socio-economic significance, climatic exposure, and configuration of underlying factors. Feed and fodder supply, though comes as by-products of food and commercial crops, is treated separately to highlight the role of mixed-farming and exclusive fodder-oriented production in the study basin. Similarly, livestock production is separated partly due to its industrial scale operation at regional scale partly due to its role as a climate adaptation strategy at household level.

(4) Likewise, based on similar reasoning, the productivity is also distinguished in terms of its three dimensions, i.e., land, land, water, and labour productivities. But such an analytical separation or distinction, as in the case of production, is also used not only to understand their distinct individual roles and impacts but also to evaluate their operational linkages and interactive impact.

(5) Since the evaluation framework is vase canvas covering 52 variables and their intricate interactions, it is but natural that by conceptualization, most of them are composite in nature and notional in character. As a result, the roles and effects cannot be uniform, but vary considerably by context. For instance, when considering aspects such as productivity, it has a negative effect due to the constraining role of holding size. But, in context of contract farming and public-private partnership, it has a positive effect due to the facilitative effects of the introduction of the policy of promoting long-term land lease from government or rural communities.

(6) As to the legitimacy and acceptability of the estimated results, it is important to understand their true nature. Since the coefficients of all model variables are estimated using perception-based data, the relative size, direction, and significance of their impacts on one or more other variables are to be interpreted as an econometric representation of the prevailing consensus on the same among the sample stakeholders in the study basin. As long as the stakeholder sample is representative and the perceptional information is a faithful reflection of basin realities, the results can be considered as realistic and reliable. This fact provides legitimacy for the policy implications derived from the nature and behavior of variables in different equations.

(7) The impact-pathway-based analysis clearly demonstrates the mechanics and implications of the roles and impacts of the linkage variables (i.e., those appear as dependent variables in the system model). These variables capture and transmit the impacts across pathways in terms of both their direct and indirect effects, which are nothing by the effects other variables that are captured by a given linkage variable in other related equations. Notably, since the coefficients of these linkage variables capture and quantify the relative size, direction, and significance of these dual effects together, their behaviors vary across equations or impact pathways. For instance, if the direct effect of a given linkage variable remains positive and exceeds its indirect but negative effect, then, it is likely to have a positive coefficient and vice versa. But, if both or either of these effects remain too weak to be significant, then, the variable is likely to have an insignificant coefficient.

(8) With its results, the study also confirms the impact flows both within and across impact pathways are not unidirectional, but a two-way process. For instance, it is as reasonable to postulate that agricultural trade regime affecting domestic agricultural production—covering both food and industrial and commercial production—as the domestic production system affecting agricultural trade. Similar is also the case of the two-way relationship between land and water productivity levels. What is this means from a policy perspective is that for improving overall economic and welfare benefits in contexts involving two-way impact flows, policies can be implemented focusing on either or both sides, depending on investment availabilities and strategic considerations.

(9) Another strategically important key result of this study is that variables differ in terms of the extent of linkages with other variables and the relative size of the total impacts of variables is directly proportional to the extent of their linkages with other variables or the number of impact pathways where they appear. For instance, the number of links varies from one (livestock composition and wage and labor laws) to 10 (cultivated area and corporate sector). Among other variables, four MPG-related institutional elements (water institutions, agricultural credit and investment, and market and trade regimes) and two production-related elements (food and livestock production) have nine links each. On the other hand, another four variables (crop pattern, industrial and commercial crop production, land tenure, and rural service providers) have eight links each. Among the TAOs, while contract farming and public-private partnership has eight links, drip system conversion and irrigation modernization and crop shift to tree and high-value crops have five and four links respectively. It is obvious that it is these variables with extensive links and larger total impacts that are to be prioritized while framing adaptation policies to counter the negative economic and welfare effects of climate change.

Overall, the study has made important contributions with considerable implications for theory, methodology and policy within the realm of climate adaptation literature. But it is certainly not free of limitations and caveats. While this is understandable for a study on a pilot scale with severe time and resource limitations, there is considerable scope for improvement. More analysis of even the results obtained with current limitations is possible and such analysis can also provide still more interesting insights on impact synergies among factors operating within the intrinsic process of climate-adaptation-governance-welfare interactions. The current methodological framework is rather ambitious in terms of its coverage, but the advantages of scale also have their inevitable tradeoffs in terms of lack of specificity. It needs to be refined for a more focused and in-depth analysis and finer and disaggregated treatment of variables and impact layers. These and related factors provide directions for future research on this important frontier area of empirical analysis of climate-welfare interactions.

Given the vast size of the study basin, there is need to delineate a study region that is both representative enough to capture the overall basin characteristics and manageable enough from a logistic perspective. The Oum Er-Rbia basin covers—either fully or parts of—three major regions in Morocco, i.e., Beni Mellal-Khenifra, Casablanca-Settat, and Marrakesh-Safi. Since the Beni Mellal-Khenifra region has the major share of agricultural areas within the basin, this region, covering five provinces: i.e., Azilal, Beni Mellal, Fquih Ben Salah, Khenifra, and Khouribga, is selected as the study region. A brief field visit was undertaken to interact with different stakeholder groups and have a first-hand experience with major issues and challenges facing the study basin. However, the sample selection and data collection cover all regional scales and sectoral context, going beyond the study region per se. Similarly, the identification of the candidate TAOs and the key elements of the prevalent MPG structure and impact transmission pathways are based on national, regional, and basin and sectoral level reviews, relying on both policy documents and published literature as well as on interactions with experts, policymakers, and officials. In any case, all these aspects are essential to develop the analytical framework that reflects well the realities of the study region and study basin in general.

Climate Change, Transformative Adaptation Options, Multiscale Polycentric Governance, and Rural Welfare in Oum Er-Rbia Basin, Morocco: Empirical Evaluation with Policy Implications

1. Context and Setting

Agriculture is the main source of food, income, and livelihood for millions of people across the world. But this sector is also the most vulnerable to climate change with significant welfare implications and spillover effects also on other sectors having critical input-output linkages with agriculture. Since agriculture is the sector where land, water, and climate converge, it provides the most apt context both for understanding the impacts of climate change as well as for evaluating how these impacts can be managed through transformative adaptation options (TAOs). TAOs cover various coping strategies and climate-resilient interventions, including targeted investments in the agricultural, water, and environmental sectors.

Grassroots level impacts of climate change are often evaluated in terms of key dimensions of social welfare such as food, income, and livelihood. The evaluation of the impacts on these welfare dimensions is usually based on static or time-invariant indicators or variables. But when the evaluation is performed in terms of dynamic impact pathways, as characterized by chains of both sequentially and simultaneously interacting variables, it is possible to bring together both *institutional* as well as *non-institutional variables*—operating both within and across economic sectors and regional scales—within a unified analytical framework. Institutional variables cover both governance and infrastructural aspects[1] whereas non-institutional variables capture physical, economic, environmental, and technological aspects, including TAOs. The impact pathway approach, therefore, has the analytical advantage and ability to provide a more comprehensive and realistic methodological framework to capture and evaluate the entire process of interactions among climate change, TAOs, multiscale polycentric governance (MPG), and social welfare.

Unfortunately, current literature is focused more on evaluating the effectiveness of one or more TAOs in coping with the impacts of climate change, but not that much on exploring whether relevant institutions exist and how effective are they to underpin the implementation and effectiveness of TAOs. Besides, with an exclusive focus on the roles of the easy-to-handle non-institutional variables, current research either ignores institutional variables or treats them only tangentially without recognizing their intrinsic operational linkages with the non-institutional variables. Such an insufficient treatment of institutional variables is due to the presumed difficulties in conceptualizing and operationalizing them in an empirical context and the tendency to assume that relevant institutions are in place and are also working properly.

To overcome the limitations of current literature on climate change impacts and TAOs, this Study aims to develop and empirically apply a methodology in the context of Oum Er-Rbia Basin, Morocco. Such a methodology, within a unified analytical framework, brings together all relevant institutional and non-institutional variables that characterize the main layers of the process of the interactions among climate change, TAOs, MPG, and social welfare   interactions. Since impact pathways are defined by

[1] As will be explained later, institutional variables are conceived broadly to cover both institutional and infrastructural factors as well as key players in the state, private, and civil society spheres. This is on the reasoning that institutions often play infrastructural roles and *vice versa* and players are part of the decision-making process. All these elements form part of the governance structure.

functionally related and structurally embedded sets of institutional and non-institutional variables across sectors and scales, they serve as analytical contexts to link and evaluate the interacting roles of TAOs and institutional factors in mediating the welfare impacts of climate change on the rural economy through various chains of non-institutional variables within a sectoral and regional settings. The impact pathways, taken together, form the building blocks of analytical framework, which is, then, translated into a mathematical model capable of being empirically applied and quantitatively evaluated with observed and/or perception-based data pertaining to the study region. Empirical results from the application of the model are presented along with their theoretical, methodological, and policy implications, limitations, and directions for future research.

2. Objectives and Scope

The Study forms part of the research under Work Package #4 (WP4) of CGIAR Initiative of Climate Resilience. It will support the achievement of the overarching objective of WP4, i.e., setting up a bottom-up polycentric governance framework for multiscale transformative adaptation and targeted climate investments. It will also have analytical and empirical contributions to other components of WP4 such as ClimaAdapt-Gov dashboard and AWARE platform. It will also have implicit contributions to parts of WP2 and WP3, particularly in the form of evaluating the impacts of variables capturing transformative adaptation options and their performance linkages with institutional variables or governance elements.

The overall objective of the proposed research is to develop and empirically apply a methodology that can capture and evaluate the critical linkages between the relative success of transformative adaptation options and their relative effectiveness as determined by the underlying institutions at various scales and contexts. The specific objectives of the proposed research are as follows:

(1) Set the stage by developing a conceptual and operational understanding of MPG structure based on the intrinsic functional connections among institutions, infrastructures, and governance using definitions, terminologies, and stylized facts from institutional economics.

(2) Provide a quick description of the study country (Morocco) and sample basin Oum Er-Rbia), focusing on the economic, social, and environmental significance of the agricultural and water sectors, especially from the perspective of climate change.

(3) Develop and explain an analytical framework that will capture the specific roles of institutions in different impact pathways as defined by the chains of interacting sets of variables—both institutional and non-institutional—through which climate change impacts and mediating effects of TAOs are conveyed to water and agriculture sectors and transmitted ultimately onto social welfare;

(4) Define a set of institutional and non-institutional variables and mathematically translate the analytical framework into an empirically applicable model that captures all major impact pathways and their underlying chains of variables;

(5) Discuss the issues and options involved in the empirical application, especially as related to sample selection, questionnaire design, data collection, and model estimation;

(6) Apply the model empirically to evaluate the relative roles of various institutional elements of MPG structure in enhancing the effectiveness of select set of TAOs in coping with the impacts of climate change on social welfare in the study basin; and

(7) Finally, conclude by highlighting the implications of the results for theory, methodology, and policy and their limitations and caveats and indicating possible directions for future research.

As to its scope, the Study deals mainly with the grassroots level impacts of climate change largely within the sectoral setting of water and agriculture, though other related sectors such as livestock, non-farm enterprises, and market and trade are also treated both implicitly and explicitly. While both the macro and micro effects are considered, the coverage is limited only to some of the major impact pathways having a direct bearing on the climatically most sensitive water, agricultural, and rural sectors at the grassroots level. Since the evaluation is largely confined to agricultural and rural sectors, social welfare is conceived mainly in terms of rural welfare. While the impact pathways capturing various layers of the process of climate change-TAO-MPG-rural welfare (CI-TAO-MPG-RW) interactions are many and varied, the framework covers only a few pathways, which are the most important from economic and welfare policy perspectives.

Similarly, the MPG structure covers only three broad sets of governance elements, i.e., institutions, infrastructures, and players in the state, private, and civil society spheres. Although the candidate institutions, infrastructures, and players considered here for evaluation are a few, they do cover the most important ones in the agricultural, rural, water, and trade sectors. The same can also be said about TAOs, as only a select set is considered for evaluation. Finally, the evaluation will focus on both the individual and interacting effects of governance elements in enhancing the effectiveness and contributions of TAOs to climate resilience and rural welfare.

3. Conceptual Setting

Before developing the methodology based on impact pathway approach for evaluating CC-TAO-MPG-RW interactions, it is necessary to set the conceptual foundation of the study having major implications for the theoretical and operational aspect of its evaluation methodology. The two key conceptual dimensions deserving detailed treatment here relate respectively to the operational aspects of the MPG structure and scenario-based theoretical basis of the evaluation methodology.

3.1. Operationalizing the MPG Structure

To gain better insights on how the MPG structure mediates and facilitates the climate resilient effectiveness and impacts of TAOs, it is necessary to identify and understand the role of its underlying constituents. For this, the MPG structure is to be unbundled and operationalized in line with the objectives and scope of this Study and those of the WP4 program in general. When the MPG structure is unbundled, it is possible to highlight the intrinsic functional connections among the governance elements, i.e., institutions and infrastructures as well as state, private, and civil society players, which are operating across sectoral contexts and regional scales. For this purpose, we need to rely on the following definitions, terminologies, and stylized facts from institutional economics:

(1) Since institutions are entities defined interactively by legal, policy, and organizational components, these components and their constituent elements together form the *institutional structure*. The institutional structure is, in turn, embedded and functioning within a given physical, socio-economic, political, and technological milieu. This milieu or setting forms part of the *institutional environment.*

(2) Institutions and infrastructures, though distinct, are functionally inter-related because many institutions often perform infrastructural roles (e.g., role of agricultural extension system as input distribution network) and many infrastructures perform institutional roles (e.g., role of water conveyance networks in water rights allocation).

(3) Besides institutions and infrastructures, there are also many players having a strong say—either individually or collectively—in their creation and functioning. They include key players such as the state, private and corporate entities, and community and civil society leaders.

(4) From the perspective of this Study, the MPG structure covers three key governance elements, i.e., institutions, infrastructures, and key players, operating across sectoral and regional scales and contexts.

(5) The three governance elements have both strategic and operational connections. While the players are part of the strategic and decision-making dimension of governance, institutions, and infrastructures form part of the operational dimension of governance. Conceptualizing MPG structure in this way, therefore, covers not only the software and hardware dimensions but also the process and outcome dimensions of governance involving, *inter alia*, participation, decision-making, and accountability.

(6) While the process perspective of governance has received wider research attention, the institutional and infrastructural perspective of governance has not received the level of research attention that it really deserves. The latter, for instance, is very important from an empirical and diagnostic perspective, particularly in understanding and evaluating the relative roles of underlying institutional and infrastructural elements that together determine the overall governance performance and effectiveness, particularly in the context of mediating the climate resilient impacts of various interventions, including TAOs across scales and contexts.

(7) Just like institutions, governance systems are also hierarchical and contextual in nature. Obviously, they vary by region, sector, and context, displaying multiscale and polycentric features. Despite such variations, they do display intricate functional linkages with interactive impacts flowing across scales and contexts. Thus, governance, by its very nature, is inherently MPG in character.

(8) Finally, but importantly, like the way institutions are unbundled, governance can also be unbundled at three levels regardless of its scale and context:

    (a) *Governance structure* can be distinguished from the *governance environment*. The latter covers the overall physical, social, economic, political, and technological milieu within which the former is embedded and operating.

    (b) As noted already, governance structure can be unbundled into its three core elements, i.e., institutions, infrastructures, and players; and

    (c) Each of the governance elements can also be decomposed to identify its respective constituents. For instance, institutions include three key constituents, i.e., laws, policies, and organizations.[2] Similarly, infrastructures include constituents such as water transfer, storage, and conveyance system, input supply systems, market yards and processing and warehousing networks. Players include entities such as the state, corporate sector, foreign investors, donor agencies, service providers, cooperatives, and community organizations.

With the facts noted above, it is now possible to conceive and operationalize the MPG structure essentially as a set of layers of linkages both within and between institutions, infrastructures, and players across scales and context. With these layers of linkages within the MPG structure and given a set of impact variables, it is possible to trace and evaluate the climate resilience impacts of TAOs rural social welfare.

[2] The institutional/governance components are contextual in the sense that in agricultural context, the components will be: agricultural laws, agricultural policies, and agricultural organizations. Similarly, for water context, they will be: water laws, water policies, and water administration and so on.

3.2. Conceptual Foundation

With the characterization of the MPG structure and its central roles in the process of CC-TAO-MPS-RW interactions, let us focus on the other dimension of the conceptual foundation that provides the theoretical basis for the analytical framework and evaluation methodology. As can be seen in Figure 1, the conceptual foundation is based essentially on contrasting three scenarios: (a) evaluating the impact of climate change on the overall goal, which we have taken here as rural welfare; (b) evaluating the impact of climate change on rural welfare, taking into account the role of TAOs; and (c) evaluating the impact of climate change on rural welfare, taking into account not only the role of TAOs but also the mediating effects of MPG structure. The analytical framework and evaluation methodology to be developed and empirically applied is obviously based on the more realistic scenario 3.

The analytical framework and methodology, which are developed on the conceptual foundation discussed above, are to be evaluated in the empirical context of the Oum Er-Rbia Basin of the Kingdom of Morocco. A brief description of the sample county and study basin is useful to provide not only the rationale and justification for their choice but also a strong background for the study.

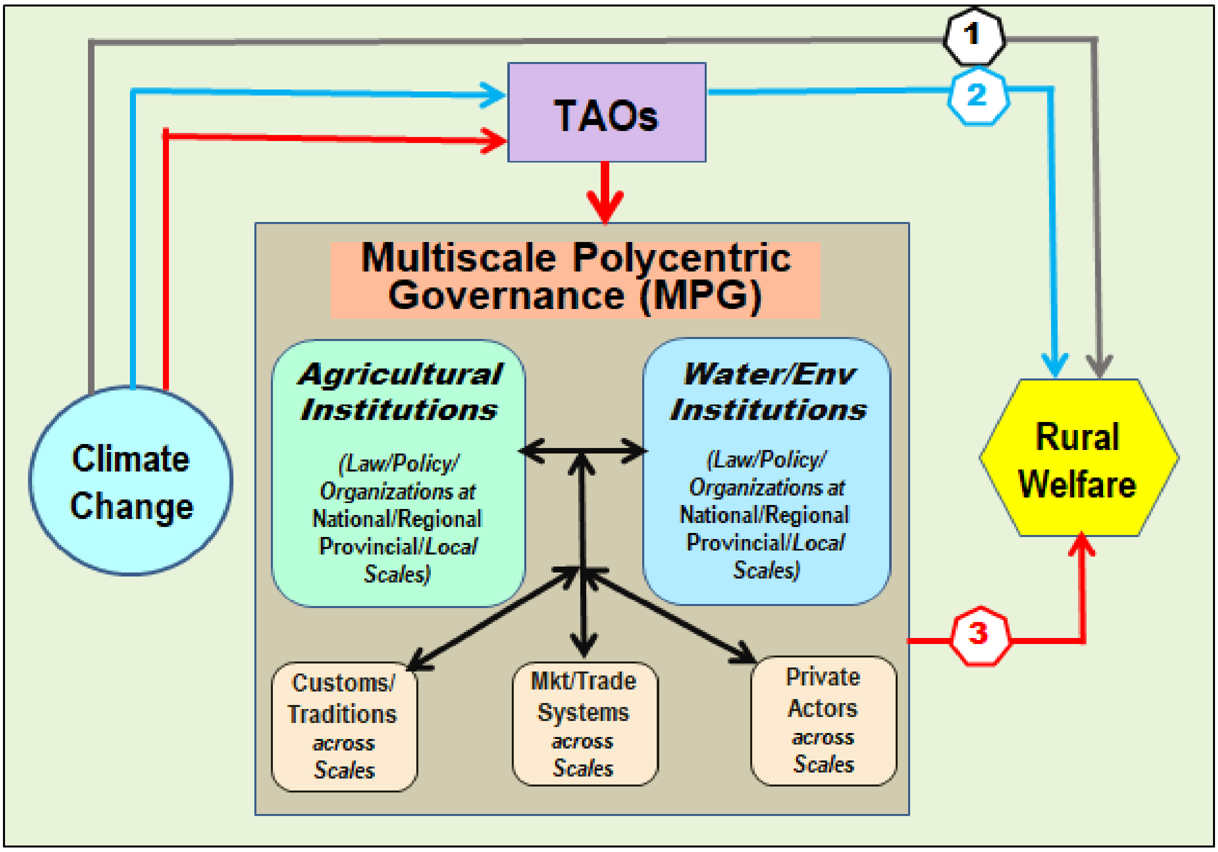

Figure 1: Climate Change-TAOs-MPG-Welfare Interaction: Three Stylized Scenarios

4. Empirical Setting: Country Context

Let us begin first with the description of country context, focusing on general aspects of polity, economy, and geography, and agricultural and water sector challenges, including food security and climate impacts. The focus will also be on major government initiatives for improving the climate resilience of the agricultural and water sectors and also identifying candidate TAOs for evaluation within our methodological framework.

4.1. Morocco: Polity, Economy, and Geography

Morocco, officially the Kingdom of Morocco, is the westernmost country in the Maghreb region of North Africa (see Figure 2). It has a total area of about 71 million ha (mha) with a population of about 37.9 million, growing at an annual rate of 1.2%. It is projected to reach 66.4 million by 2030 and 72.8 million by 2050. Urban population constitutes 62% at present but expected to reach 69% and 77% by 2030 and 2050 respectively (World Bank, 2021).

On the economic front, Morocco is a relatively liberal market-based economy, following a policy of privatization and liberalization since 1993. With a Gross Domestic Product (GDP) of $112.8 billion, Morocco remains the fifth largest economy in Africa and wields significant influence both within Africa and the Arab world (World Bank, 2021). Alshare service and industry sectors, including mining, dominate GDP with a 50 and 25% share respectively, agricultural sector, with just a just 14% share, is

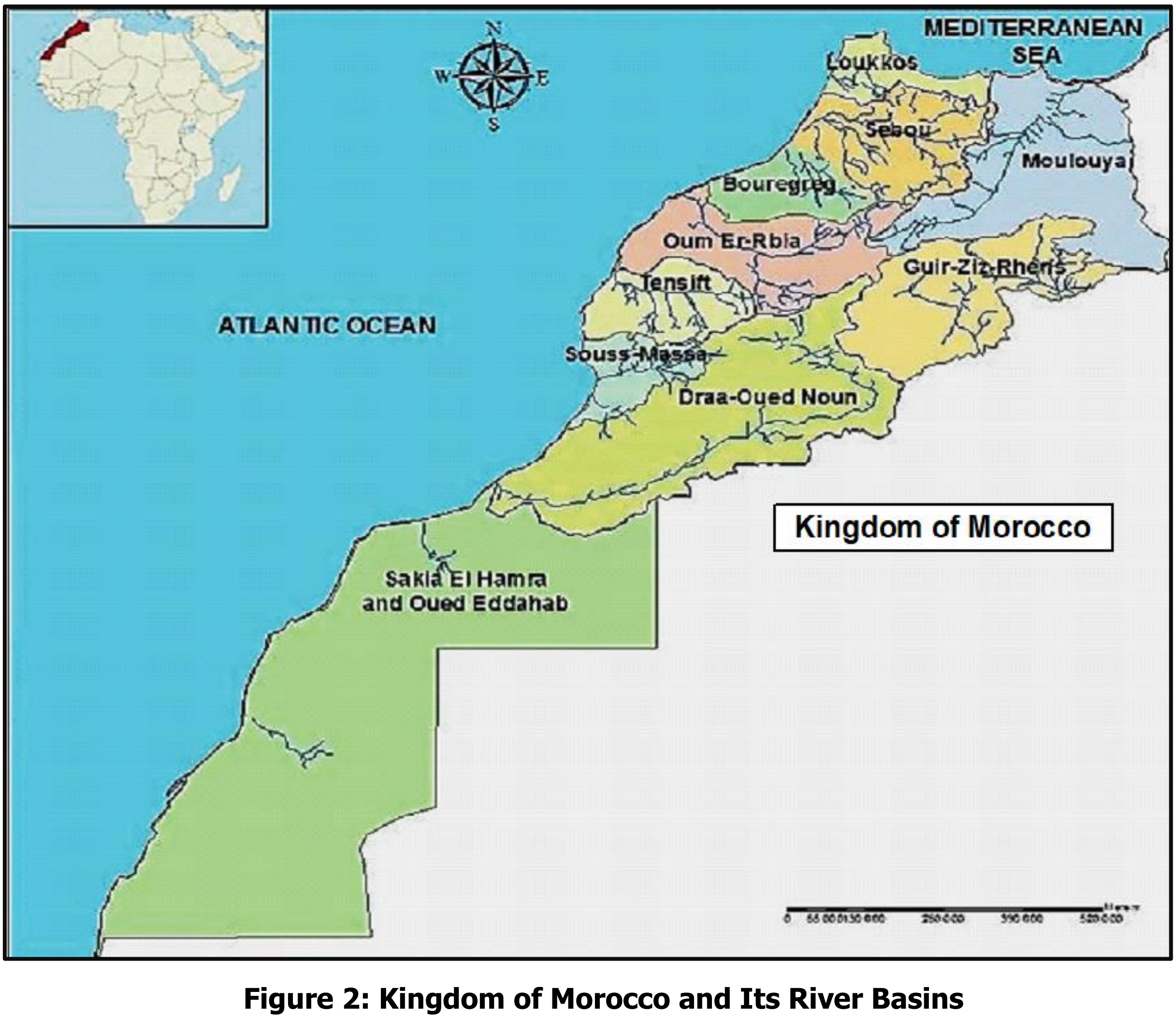

Figure 2: Kingdom of Morocco and Its River Basins

strategically very important. Moroccan agriculture is the largest employer, accounting 43% of all employment and 78% of rural employment.

Politically, Morocco is a unitary semi-constitutional monarchy with an elected parliament with two chambers. The executive branch is led by the King and the Prime Minister, while the legislative power is vested with the parliament and Judicial power rests with the Constitutional Court. The King holds vast executive and legislative powers, though the 2011 constitutional reforms have enhanced the executive roles of the Prime Minister. Administratively, Morocco is divided into 12 regions, covering 62 provinces and 13 prefectures.

From a geographic perspective, Morocco is highly susceptible to climatic risks. The country has three distinct geographic regions: the Atlantic coastal lowlands, the mountainous interior, covering the Atlas and Rif Mountain ranges, and the arid and desert regions of the east and south. With diverse topography ranging from mountains and plateaus to plains, oasis. and Saharan dunes, Morocco displays varying climatic conditions with extreme rainfall variability across space and over time. Climatically, 93% of Morocco is characterized by arid and semi-arid conditions (USAID, 2010). Irregular rain patterns, cold spells, heat waves, and drought conditions severely affect agriculture in particular and the economy in general.

4.2. Morocco: Agriculture

Agricultural production is based on an arable area of 8.7 mha, supporting diverse cropping and mixed farming systems. While 16% of this area with irrigation can support food and other high-value crops, production in over 80% of the area depends on highly variable and uncertain rain. In terms of crop pattern, of the total cultivable area, about 43% is devoted to cereals, 7% to plantation crops (olives, almonds, citrus, grapes, dates, etc.), 3% to pulses, 2% each to forage, vegetables, and industrial crops like sugar beets, sugar cane, cotton and oilseeds, and the rest 41% remain as fallow.

Given the climatic and rainfall conditions of Morocco, irrigation plays a key role both in the level and stability of production, employment, and incomes in rural areas. There is a strong correlation between annual agricultural output and annual rainfall. Due to this correlation and the strong economic weight of the agricultural sector, each rainfall deficit impacts the whole economy. Despite representing slightly over 16% of the cultivated land, irrigated agriculture contributes to about 50% of agricultural GDP, 75% of agricultural exports, and 15% of the overall merchandise exports. The country has 1.46 million ha of permanently irrigated land, 682,600 ha of which are part of nine Large Scale Irrigation (LSI) perimeters operated by nine public agricultural development agencies (ORMVA) (World Bank, 2015). Since most arable land and rangeland are in areas receiving less than 400 mm of rainfall, rainfed cereals and small ruminants, mainly sheep, form an integral components of an extensive dryland production system.

Moroccan agriculture is characterized by a dichotomy of traditional and market-oriented agriculture, which also coincides, to some extent, with a dichotomy of irrigated and rainfed agriculture. Market agriculture is concentrated mostly in irrigated areas focused mainly on high-value crops for export and industrial production. In contrast, traditional sectors involving smaller farms in rainfed areas is focused predominantly on cereals, legumes, and livestock production. The rural population, which represents about 34% of total population, is composed of small subsistent farmers whose production depends almost entirely on rainfall. Agriculture in rainfed regions is based largely on a mixed and integrated crop/livestock farming system, representing the main income source for the majority of rural households.

4.3. Morocco: Food Security and Poverty

The agricultural sector suffers from deep structural problems. It remains very sensitive to climatic fluctuations and economic pressures of agricultural trade liberalization with the European Union. Under normal rainfall conditions, Morocco produces enough food for domestic consumption, except in the case of grains, sugar, coffee, and tea. More than 40% of Morocco's consumption of grains and flour is imported from the US and France. However, Morocco is almost self-sufficient in meat production and trying to become self-sufficient in dairy production as well. Morocco is one of the few Arab countries that has the potential to achieve self-sufficiency in food production. But achieving this potential requires a complete climate-proofing of Moroccan agriculture. From the perspective of food security, during 2019-21, 3.1 million people are severely food insecure, and another 8.6 million people are considered to be moderately food insecure.

From an overall perspective, Morocco has made tremendous progress on the quality of life and socio-economic fronts. While the country has made strides in poverty reduction, its economic vulnerability remains a major challenge. Evaluation of progress in these fronts, though constrained by lack of recent data, available evidence suggests that progress is significant. Absolute poverty did decline from 15 to 9% during 2001–2007. Yet 27% of the population, especially in rural areas, is still considered to be poor, vulnerable, or near poor (World Bank 2009a; World Bank 2009b; USAID, 2010). Since 70% of these poor live in rural areas, they remain the main source of massive rural exodus towards cities or the EU. It is this groups that is particularly vulnerable to the adverse economic and welfare consequences of impact of climate change in Morocco.

4.4. Morocco: Water Sector

With a long-term average precipitation of 346 mm/year, the total renewable water resources of Morocco are estimated to be 29 billion cubic meter (Bm3)/year. Of this ultimate potential, the total resources that can be exploited under current technical and economic conditions is estimated to be only at 22 Bm3/year—18 Bm3 of surface water and 4 Bm^3 of groundwater. At this level, water per capita for Morocco would be just 730 cum, which is far below the United Nations' water stress threshold, i.e., 1,000 cum. The overall water deficit is estimated at around 2 Bm3 (MEMEE, 2011; Plan Bleu, 2011; World Bank 2015).

Notably, spatial concentration of the already developed water resources is also a serious problem because more than 50% of which are distributed only in the Central and Northern regions of the country. Even across basins, three of the 12 basins, i.e., Loukkos, Sebou and Oum Er-Rbia, account for 71.5% total surface water resources in the country. In contrast, underground resources are relatively better distributed over the territory. Of the 96 aquifers listed, 21 are deep aquifers and 75 are shallow ones. The largest aquifer systems cover a total area of nearly 80,000 km^2, or about 10% of the territory (MEMEE, 2009).

Although Morocco has the capacity to develop irrigation to the extent of 2.5 mha, the area currently equipped with full irrigation is only 1.46 mha (FAO, 2015). In terms of irrigation methods, flood irrigation dominates with 71% of this area, followed by drip (20%) and Springler (9%) systems. In terms of irrigation types, major irrigation (those managed by ORMVAs) accounts for 47%, small and medium irrigation for 23%, and private irrigation for 30%.

From a supply-demand perspective, Morocco has developed over the years a vast water infrastructure system to store, transfer, divert, and extract water resource from different sources. This includes 135 large dams with a combined storage capacity of 17 Bm3, another 14 large dams with a storage capacity of 2.6 Bm^3, hundreds of small dams with a combined storage of 0.1 Bm^3, 13 water transfer structures with a total length of 785 km with a capacity to transport more than 2.7 Bm^3, an vast network of wells, boreholes, and springs that can mobilize nearly 4 Bm^3 of groundwater, and traditional water diversion structures, particularly in mountain regions, with an average diversion capacity of 1.7 Bm3 (MEMEE, 2011; CES, 2014).

Considering the damaging effects of siltation on dam storage capacity, year-to-year variations in rainfall, and other uncertainties, the currently build water infrastructure system can be expected to provide an average annual supply of around 13 Bm^3 (Plan Bleu, 2011). But average annual water demand amounts to 14.7 Bm^3. Of this total water demand, 13.2 Bm^3 (90%) are for meeting irrigation needs while the rest for meeting the drinking (1.1 Bm^3) and industrial and environmental (0.4 Bm3) needs (Plan Bleu, 2011). In view of the demand-supply gap, there is a water deficit of around 4 Bm3, of which around 1 Bm^3 is met by groundwater water overexploitation (CSEC, 2014).

Since irrigation water needs are not fully satisfied, agricultural production is reduced, particularly in ORMVA regions. Of the 12 basins, water deficit is particularly severe in the Oum Er-Rbia, where it is estimated to be nearly 1.2 Bm^3 (Plan Bleu, 2011). The consequence of such a water deficit is a serious overexploitation of aquifers, leading to a lowering of water table even to the extent of almost 2 m/year (CSEC, 2014). The problem and consequences of water deficit is going to get further complicated with the further growth in water demand and the potential effects on water supply from already visible impacts of climate change.

4.5. Morocco: Impacts of Climatic Change on Water and Agriculture

Obviously, Morocco is highly vulnerable to climate change and variability. The country is regularly facing extended periods of dry spells, drought episodes, and wet periods with a regime of uncertain and irregular precipitation, causing flash floods at times. Global climate change is likely to complicate the existing problems.

Climate variability and change are putting increased pressure on the climate-sensitive water and agricultural sector, which, in turn, affects the overall economic performance of Morocco. For instance, 2016 drought, the worst in past 30 years, reduced cereal yields by 70% and has significantly slowed the overall economic growth (USAID (2016). The predominant climate concern for Morocco relates to its impact on the limited and declining water resources. While water demand is expected to increase due to population growth, economic expansion, and rising irrigation needs, water resources are projected to decline due to frequent and recurrent drought conditions, reduced storages from dam siltation, and physical limits for future water development.

Water per capita has declined by almost 60% since 1960 due to non-climate stressors such as population growth, urbanization, and economic development. At the same time, there has been a 20-percent reduction in the overall water resource availability in the last 30 years due essentially to natural and climate stressors such as erratic rainfall and rising temperatures, evaporation, and siltation. Due to declining rainfall and increasing siltation, there has also been a continuing reduction in the water storage levels of many dams over the years. For example, in the context of two major dams, i.e., Hassan Addahkhil and Idriss I, both are critical water sources in the country, supply is projected to decline by 7 to 40% by 2080.

Climate change, which tends to negatively affect the overall water resources availability, is also likely to raise the demand for irrigation by raising temperature and evaporative requirements of crops. The irrigation sector though has a 90% share in available water, covers only 16% of farm area. Since 84% of crop production (particularly, barley and wheat) remains rainfed, Moroccan agriculture is highly vulnerable to the vagaries of climate change. For instance, the 2016 drought has reduced harvested yields by 70% as compared to that in 2015. The hotter and drier conditions during this drought have also led to a 12% increase in crop water requirements, raising the demand for irrigation and adding more stress on the already limited and declining water resources.

Climate variability is expected to add pressures on water resources in Morocco. Projections indicate 10 to 20% decreases in precipitation across the country, with the most severe in the Saharan region by 2100. Additionally, climate change will reduce snowpack in the Atlas Mountains. This puts pressure on water resources, already stressed by other sources such as population expansion, urban growth, industry, and tourism. Furthermore, many coastal aquifers will increasingly become stressed because of coastal salinization. There are several studies that have evaluated the impacts of climate change on the water and agricultural sectors of Morocco from different perspectives and contexts (Schilling, et al., 2012; Tramblay, et al, 2014; El Baki, et al., 2021; Echakraoui, et. al., 2018).

4.6. Morocco: Major Initiatives to Enhance Climate Resilience

In recent years, the Government of Morocco has taken several innovative initiatives to enhance the climate resilience of its agricultural and water sectors. These initiatives attempt to address some of the major technical, institutional, and structural issues and constraints affecting the performance levels of agricultural and water sectors. These initiatives focus on improving agricultural and water productivity levels by expansion of irrigated areas, development of water infrastructures, and modernization of the agricultural and water sectors. Most of these initiatives form part of three programs: Green Morocco Plan [Plan Maroc Vert (PMV)] implemented during 2010-2020, National Irrigation Water Saving Program [Programme National d'Economie d'Eau d'Irrigation (PNEEI)] promoted since 2009-10, and Green Generation Plan [Plan Génération Verte (PGV)] being implemented for the period of 2020-30. The PMV is a broad strategy with a larger mandate for combating climate by producing half of the country's energy by renewables, removing fossil fuel subsidy, and generating green employment by 2030. It also aims to double agricultural value-added and create 1.5 million jobs by 2020 and, thereby, transform agriculture into a stable source of growth, competitiveness, and broad-based economic development. To address the dualistic nature of Moroccan agriculture, this strategy has two pillars—one targeting commercial farmers and the other targeting small farmers in marginal areas.

PNEEI has promoted a shift from flood irrigation to drip irrigation systems with a view to saving water and improving, thereby, water use efficiency and productivity. This program aims to shift 555,090 ha to drip irrigation—337,150 ha of individual conversion and 217,940 ha of collective conversion of family farms in major schemes. This process is supported by up to 100% subsidy for adopting drip and micro-sprinkler irrigation, and up to 70% subsidy for sprinkler irrigation. Since its launch in 2008, PNEEI has promoted the adoption of drip irrigation in over 200,000 ha (60% of the 2020 target) of privately developed irrigation areas. In LSI perimeters, drip conversion is ongoing only in 57,000 ha due to the delay in investments on irrigation networks. In this way, PNEEI contributes to the modernization of irrigation delivery system.

The Green Generation Plan, being implemented since 2020, promotes several key social and organizational options covering both human and sustainability elements. Under the human element, the Plan aims to create and strengthen rural middle class, diversify rural jobs, and promote new production organizations involving young rural entrepreneurs. Sustainability element covers climate resilience and agricultural sustainability. This Plan also provides for crops and employment insurance and stipend for poor farmers.

These initiatives, especially PMV, have generated major benefits. For instance, since PMV's launch in 2008, production has increased by 45%, agricultural exports have risen by 18%. Since agricultural GDP has increased annually by 5.25% against 3.8% for the other sectors, there has been an additional value added to the extent of 47 billion MAD. Also, exports of agricultural products increased by 117% from

15 to 33 billion MAD. On the social level, PMV has also enabled the creation of 342,000 additional jobs. Furthermore, the number of working days per year and per worker has increased from 110 days/year to 140 days/year due to the expansion of cultivated areas, crop diversification, and enhanced production.

Under PMV, agricultural value added has increased through two processes: agricultural aggregation and Public-Private Partnership (PPP) around the leased lands from the state and tribal communities. With the dedicated incentive system established under Law No: 04-12m 63 aggregation projects, covering a total area of 177,000 ha, were implemented for the benefit of 55,000 farmers, 80% of whom are small farmers owning less than 5 hectares. Under PPP involving leased of state-owned land, 1,575 projects were set up covering an area of nearly 112,000 ha and projected investment of 22.3 billion MAD and generating 63,000 jobs. Notably, 720 of the projects were allocated to small farmers and entrepreneurs in the agricultural sector. More importantly, the plantations carried out under pillar II, despite their young ages, would have contributed carbon sequestration in the order of 1.9 million tons equivalent of CO_2.

From a climate resilience perspective, the initiatives and programs have promoted several Transformative Adaptation Options (TAOs) within the agricultural and water sectors. These most important one among these options, especially, as applicable to the study basin, include:

(1) Shifting of crop pattern to tree and high-value crops (e.g., olives, oranges, etc.)
(2) Shifting areas under flood and sprinkler irrigation towards drip irrigation,
(3) Modernization of water and irrigation infrastructures
(4) Contract farming/supply aggregation/value chain developments,
(5) Corporate farming and public-private partnership (PPP) in agriculture (via long-term land leases from government and rural communities), and
(6) Zero-Tillage Farming Technology, particularly in rainfed regions.

It will be very interesting to empirically evaluate how some of these TAOs can improve climate resilience and contribute to the overall rural welfare in the study basin, especially when they are supported by an effective MPG structure—involving institutional, infrastructural, and player-related elements—operating at various regional scales and sectoral contexts.

5. Empirical Setting: Basin Context

The sample basin selected for this study is Oum Er-Rbia Basin (see Figure 3). Let us provide a brief description of the study basin, focusing particularly on its key features and agricultural significance and climatic vulnerability.

5.1. Oum Er-Rbia: Key Features

Oum Er-Rbia is the second largest River in Morocco after the Sebou River. It has an average water throughput of 105 m3/s. This basin has six major dams (including Al Massira, the second largest dam in Morocco with 2.65 Bm3 storage capacity) and five minor dams. The combined storage capacity of these dams is estimated to be 5 Bm3. But due to drought condition and siltation, the actual storage 2022 is just 7.6% of their capacity (even as against 18.5% in 2021).

The Oum Er-Rbia Basin covers—either fully or parts of—three major regions of Morocco, i.e., Beni Mellal-Khenifra, Casablanca-Settat, and Marrakesh-Safi. Since the Beni Mellal-Khenifra region accounts for the major share of agricultural areas within the basin, this region is obviously selected as the study region. The study region comprises of five provinces, i.e., Azilal, Beni Mellal, Fquih Ben Salah, Khenifra, and Khouribga. These five provinces are selected for undertaking field visits and also conducting sample surveys subsequently.

5.2. Oum Er-Rbia: Agricultural Role and Climatic Sensitivity

Oum Er-Rbia is very important for agricultural production. This basin accounts for 33% of the total harvested area in the country. Major Crops grown include Wheat and Barley (largely under rainfed

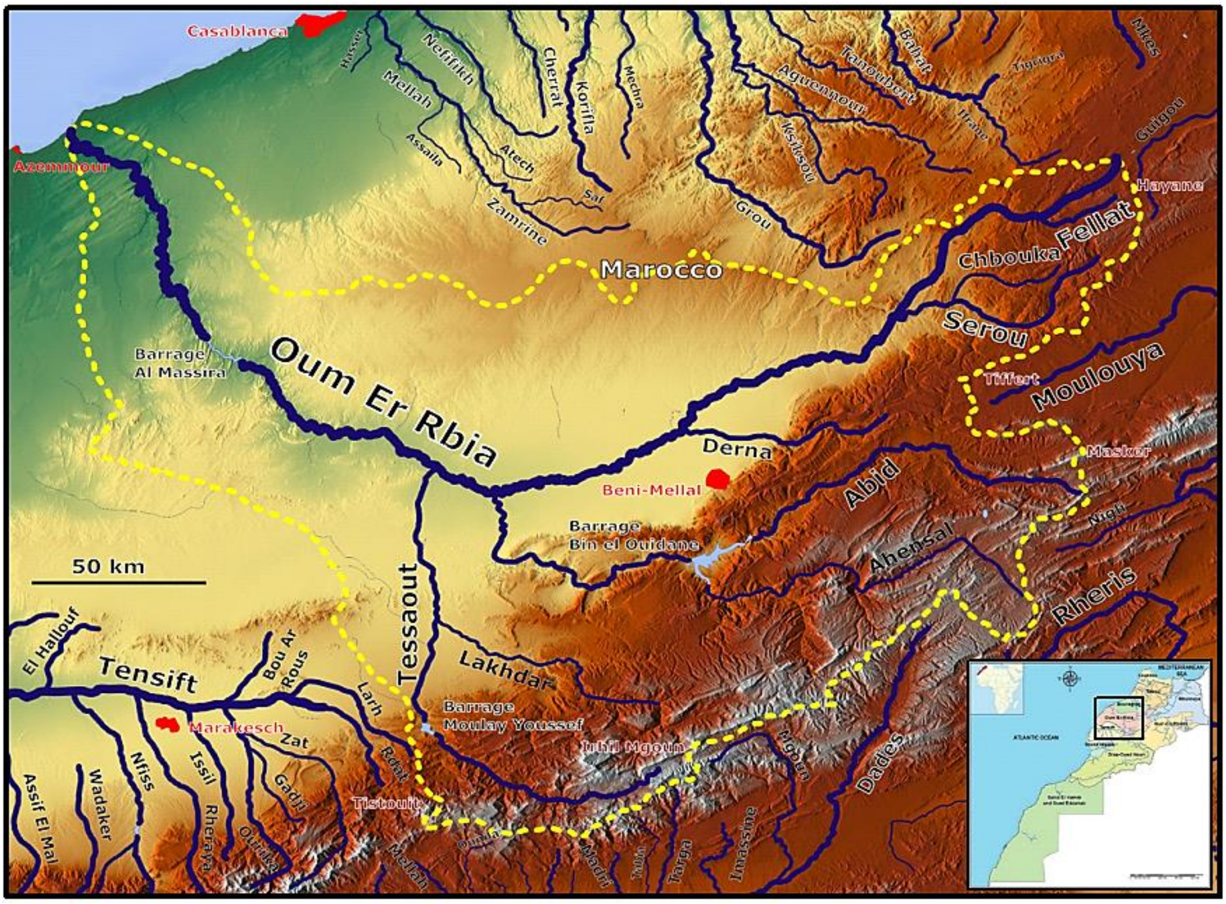

Figure 3: Oum Er-Rbia River Basin, Morocco

conditions) and Maize, Olives, Almonds, Sugar Beets, Oranges, Dates, etc. (mostly under irrigated conditions). This basin has the top share in the harvested area of most crops, except wheat in which it has only the second highest share after the Sebou basin. Oum Er-Rbia basin also accounts for 33% (0.48 mha) of the total irrigated area (1.46 mha) in country (FAO, 2013). In terms of water footprint (both green and blue water use), the basin dominates with a 7.7 Bm^3, representing over third of the total water footprint of Morocco (23.5 Bm^3).

This basin is highly susceptible to climate change impacts, including high frequency and intensity of droughts. Based on historical data, it has been estimated that over the years, Oum Er-Rbia basin has experienced a 20% reduction in rainfall and 40 to 49% decline in annual flow.

6. Evaluation Methodology

Having described the conceptual foundation and empirical context, let us discuss the evaluation methodology for the study. The evaluation methodology builds on the original works of Saleth, et al., (2007), Saleth and Dinar (2009), and Saleth, Dinar and Frisbie (2011) by specializing the same to the particular economic, institutional, and climatic realities facing agricultural and water sectors in the Oum Er-Rbia Basin, Morocco. It has three inter-related components: (a) an analytical framework based on impact pathways and variable chains, (b) a structural model of the process of CC-TAO-MPG-RW interactions, which is a mathematical representation of the analytical framework, and (c) an empirical approach for collecting information on all variables that characterize all these interactions or impact pathways.

6.1. Analytical Framework: Impact Pathways and Variable Chains

The analytical framework captures the major impact pathways within the process of CC-TAO-MPG-RW interactions in the context of the agricultural and water sectors of Oum Er-Rbia Basin of Morocco. It is important to note that the analytical framework captures the impact pathways as characterized by the chains of institutional and non-institutional variables. The evaluation methodology, on the other hand, involves the empirical approach for quantitatively or numerically evaluating the nature and magnitude of impact transmission occurring through various impact pathways and variables chains. The analytical framework can also be visualized in terms of path diagram as shown in Figure 4, depicting the analytics and pathways involved in the process of CC-TAO-MPG-RW interactions.

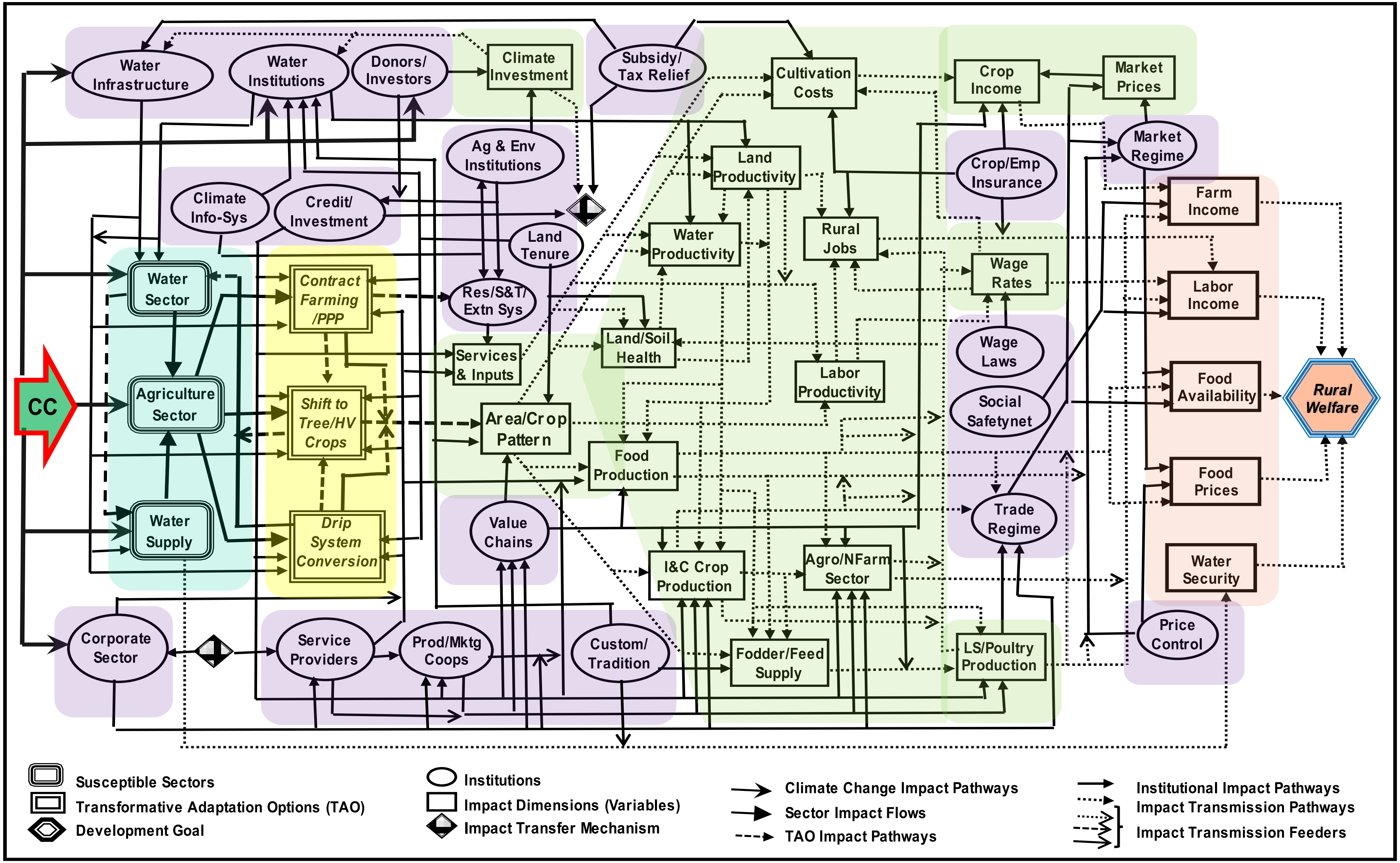

FIGURE 4: CC-TAO-MPG-RW INTERACTION: ANALYTICS AND PATHWAYS.

As can be seen, the impacts of climate change are transmitted through a variety of impact pathways, which are characterized by various chains of institutional and non-institutional variables. In such an impact transmission process, the institutional variables can either magnify or moderate the initial impacts of independent and intermediate variables. It is these roles that will determine the effectiveness and performance of MPG structure on the impact mediating process. Before proceeding further, it is useful to note a few key points related to the reading and interpretation of Figure 4. For reading and interpreting Figure 4, one needs to proceed from left to right and, at each stage, move down from top to bottom. The arrows (both solid and dotted) show the direction of flow.

(1) As to its content and configurations, Figure 4 covers three sectors (water, agriculture, and water supply) explicitly and a few others (livestock, non-farm, and trade) implicitly, three sets of interrelated TAOs (contract farming and PPP in agriculture, Shifting of crops to Tree and High-value ones, and conversion to drip irrigation and irrigations modernization), 20 institutional variables, and 24 impact variables.[3]

(2) For distinctions, the initial variable (climate change) and the ultimate impact variable (Rural welfare) are placed in Figure 4 within hexagons. The immediate variables on which climate impact is felt first are the three sectors, which are placed within three-lined rounded rectangles and the three TAOs are placed within double-lined rectangles. The 20 intermediary impact variables are placed within single-lined rectangles whereas the four penultimate impact variables are placed within bold-lined rectangles. The 20 variables representing the institutions, infrastructures, and players are placed in ovals. The distinctive color scheme is also used to distinguish these five sets of variables underlying various impact pathways.

(3) The three sets of TAOs explicitly included in Figure 4 capture adaptive options such as crop shifts, drip irrigation, and new modes of organizing farm production. Some other coping and adaptive options are also implicitly captured as part of some institutional or impact variables. For instance, the institutional variable, i.e., science, technology, research, and extension system, covers options such as improved crop varieties, farm technologies, precision farming, deficit irrigation, zero-tillage, etc. Similarly, the impact variable, i.e., crop pattern, also covers options such as multiple cropping, cropping intensity, and crop diversification.

(4) Although climate change is included in a very generic format, its specific formats may include various combinations of temperature and rainfall along with their impacts in terms of floods, waterlogging, droughts, etc. All these impacts fall most immediately on the water and agricultural sectors. The only difference is that while climate change affects the water sector directly, the same affects agricultural sector both directly via rainfall and temperature and indirectly via water storage and irrigation availability.

(5) When considering climate change's impacts, the water sector plays a pivotal role. This is because water remains the main medium through which most of the impacts of climate change are transmitted to agriculture and the economy in general. Water—both natural and applied—remains critical not only for ensuring agricultural production and productivity but for meeting the basic amenities of both rural and urban population. Climate impacts on the water sector can, therefore, be captured in terms of two main aspects, i.e., water availability for irrigation and water supply for meeting basic needs.

[3] Note that most of the impact variables are dependent (endogenous) on the effects of other variables. But, as we will see subsequently, although institutional, infrastructural, and player-related variables are motley independent (exogenous) in nature, some of them can be dependent when they are likely to be influenced by other institutional and impact variables.

(6) The impacts of climate change on agriculture can be captured in a variety of forms (e.g., change in cultivated area, crop pattern, cropping intensity, production, or productivity). Climate adaptation in agriculture, therefore, involves suitable adjustments not only in cropping systems and land and water use patterns but also in input and extension systems, including technologies and investments. Besides, such adjustments also require more effective and proactive institutions and infrastructure operating in agricultural and water sectors. The ultimate impacts of climate change on agriculture, including the intervening roles of factors noted above, can be captured in terms of a comprehensive conceptual notion, i.e., overall performance of agriculture.

(7) Figure 4 is somewhat abstract and aggregative. It does not exhaust the full range of intricate and multifarious linkages within the process of CC-TAO-MPG-RW interactions. But it is fair to say that Figure 4 does capture the most important and policy-wise more relevant linkages and pathways. Limited coverage, in this respect, is only for analytical simplification and also for sharpening the focus on key pathways and their underlying institutional and non-institutional variables.

(8) And, finally, irrespective of the depth and details of the analytical framework, it depicts clearly the far-reaching and system-wide impacts of climate change and the overall implications for rural welfare. However, the exact nature and magnitude of the welfare effects of climate change depends clearly on which climate scenario is expected to prevail in a given spatial and temporal context. In this sense, the analytical framework in Figure 4 can also be used as a platform for performing sensitivity analysis with different climate scenarios.

With these points, it is straight forward to interpret and understand the analytical framework specified in Figure 4.

6.2. Mathematical Model of CC-TAO-MPG-RW interactions

By defining suitable sets of variables, various layers of impact pathways evident in Figure 4 can be formally translated to form a mathematical model, involving a system of inter-linked equations with sequential and simultaneous linkages. Such an equation system can capture the entire process of CC-TAO-MPG-RW interactions evident within the analytical framework as depicted in Figure 4. It is this system model that forms the mathematical component of the evaluation methodology. Similarly, when all relevant variables are suitably conceptualized and translated into comprehensible formats, they can be used to elicit information from a diverse group of stakeholders within the study basin. The development of an effective survey instrument and selection of sample stakeholders to represent different sectors, regions, and socio-economic groups obviously constitute the empirical dimension of the evaluation methodology.

For developing a mathematical representation of the analytical framework, let us define the following five sets of variables with each set containing the number of variables as indicated within bracket:

Trigger Variable **(1)**

CLCIMPACT = Climate Change Impact

Overall Development Goal or Ultimate Impact variable **(1)**

RURWELFAR = Rural Wellbeing

Sector/Sub-Sector Variables **(3)**

WATRAVAIL = Water Resource Availability *(Water Sector)*

AGPERFORM = Agricultural Sector Performance *(Agricultural Sector)*

WATRSUPLY = Water Supply *(Water for People, Animals, and Industries)*

<u>Transformative Adaptive Options (TAOs) Variables</u> **(3)**

CONFAMPPP = Contract Farming and Public-Private Partnership

CROPSHIFT = Shift to Tree and High-Value Crops

DCONVIMOD = Drip System Conversion and Irrigation Modernization

<u>Variables Capturing Institutions, Infrastructures, and Players</u>

<u>(Elements of Multiscale Polycentric Governance)</u> **(20)**

AFPRPOLCY = Agricultural and Food Price Regulation Policies

AGCRINSTN = Agricultural Credit and Investment Institutions

AGENINSTN = Agricultural and Environmental Institutions

AGWAGELAW = Agricultural Wage Laws and Regulations

AMKTREGIM = Agricultural Market Regime

APMKTCOOP = Agricultural Production and Marketing Cooperatives

ARESEXSYS= Agricultural Science/Technology, Research, Extension System

ATRDREGIM = Agricultural Trade Regime

AVALCHAIN = Agricultural Value Chains

CLIMINSYS= Climate Information and Decision Support System

CORPSECTR = Corporate Sector Agencies/Players

CREMINSUR = Crop and Employment Insurance

CUSTINSTN = Customary and Traditional Institutions

DONINVSTR = International Donors and Investors

LANDTENUR = Land Tenure *(Farm Size, Land Leasing, etc.)*

RSPROVIDR = Rural Service Providers

SNETPOLCY = Rural Social Safetynet Policies

STAXPOLCY = Subsidy and Tax Relief Policies

WATRINFRA = Water Infrastructures

WATRINSTN = Water Institutions

<u>Impact or Impact Transmission Variables</u> **(24)**

AGINSUPLY = Agricultural Service and Input Supply

AGNFSECTR = Agro-industries and Non-farm Sector

AMKTPRICE = Market Prices of Farm Products

CLIMINVST= Climate Investment Level

CROPATERN = Cropping Pattern

CROPINCOM = Income only from Crop Enterprises

CULTIAREA = Cultivated or Cropped Area

CULTICOST= Cultivation Costs

FARMINCOM = Farmers' Income from agriculture, livestock, and other sources

FEEDSUPLY = Fodder and Feed Supply

FOODAVAIL = Food Availability

FOODPRICE = Food Prices

FOODPRODN = Food Production

INDCPRODN = Industrial and Commercial Crop Production

LABRINCOM = Labour Income from wage, non-farm, and other sources

LABRPRODY = Labor Productivity

LANDPRODY = Land Productivity

LANDSQLTY = Land Quality and Soil Health

LIVSIZCOM= Livestock and Poultry Population Size and Composition

LIVSPRODN = Livestock and Poultry Production

RURALJOBS = Rural Jobs

RURALWAGE = Rural Wage Rates

WATRPRODY = Water Productivity

WATRSECUR = Water Security for People, Animals, and Nature

Given the defined sets of variables, the analytical framework specified in Figure 4 can be mathematically converted into a model of CC-TAO-MPG-RW interactions, involving the following system of 40 equations:

CLIMINVST= ***f_1*** (CLCIMPACT <u>*AGENINSTN*</u> <u>*DONINVSTR*</u>) .... [1]

<u>*WATRINSTN*</u> = ***f_2*** (CLCIMPACT CLIMINVST <u>*LANDTENUR*</u> <u>*CUSTINSTN*</u>).. [2]

<u>*WATRINFRA*</u> = ***f_3*** (CLCIMPACT CLIMINVST <u>*STAXPOLCY*</u> <u>*DONINVSTR*</u>) .... [3]

<u>*RSPROVIDR*</u> = ***f_4*** (CLIMINVST <u>*AGCRINSTN*</u> <u>*STAXPOLCY*</u> <u>*CORPSECTR*</u>) .... [4]

WATRAVAIL = ***f_5*** (CLCIMPACT **CROPSHIFT DCONVIMOD** <u>*WATRINSTN*</u> <u>*WATRINFRA*</u>
<u>*CLIMINSYS*</u>) .... [5]

WATRSUPLY = ***f_6*** (CLCIMPACT WATRAVAIL <u>*WATRINSTN*</u> <u>*WATRINFRA*</u>) .... [6]

AGINSUPLY = ***f_7*** (<u>*ARESEXSYS*</u> <u>*AGCRINSTN*</u> <u>*RSPROVIDR*</u> **CONFAMPPP**) .... [7]

AGPERFORM = ***f_8*** (CLCIMPACT WATRAVAIL WATRSUPLY <u>*CLIMINSYS*</u> AGINSUPLY
<u>*LANDTENUR*</u>) .... [8]

CONFAMPPP = ***f_9*** (AGPERFORM <u>*LANDTENUR*</u> <u>*WATRINSTN*</u> <u>*AGCRINSTN*</u> <u>*RSPROVIDR*</u>) .... [9]

DCONVIMOD = ***f_{10}*** (AGPERFORM <u>*LANDTENUR*</u> <u>*WATRINSTN*</u> <u>*WATRINFRA*</u> <u>*RSPROVIDR*</u>) .... [10]

<u>*CORPSECTR*</u> = ***f_{11}*** (CLCIMPACT <u>*ATRDREGIM*</u> CLIMINVST <u>*STAXPOLCY*</u> **CONFAMPPP**) .... [11]

AGCRINSTN = ***f***$_{12}$ (*AGENINSTN* *DONINVSTR* *CORPSECTR*) .... [12]

CROPSHIFT = ***f***$_{13}$ (**CONFAMPPP DCONVIMOD** *LANDTENUR* *WATRINSTN* *AMKTREGIM* *ATRDREGIM* *RSPROVIDR* *CORPSECTR*) .... [13]

ARESEXSYS= ***f***$_{14}$ (*AGENINSTN* **CONFAMPPP** *CLIMINSYS* *CORPSECTR*) .... [14]

APMKTCOOP = ***f***$_{15}$ (*AGCRINSTN* *RSPROVIDR* *CUSTINSTN*) .... [15]

AVALCHAIN = ***f***$_{16}$ (*AGCRINSTN* *APMKTCOOP* *AMKTREGIM* *ATRDREGIM* *RSPROVIDR* *CORPSECTR*) .... [16]

CULTIAREA = ***f***$_{17}$ (**CONFAMPPP CROPSHIFT DCONVIMOD** *LANDTENUR* *AVALCHAIN* *CUSTINSTN*) .... [17]

LANDSQLTY = ***f***$_{18}$ (CLCIMPACT *LANDTENUR* CROPATERN *ARESEXSYS* LIVSPRODN) .... [18]

CROPATERN = ***f***$_{19}$ (CULTIAREA **CROPSHIFT CONFAMPPP DCONVIMOD** *AMKTREGIM* *LANDTENUR* LANDSQLTY) .... [19]

LANDPRODY = ***f***$_{20}$ (CULTIAREA CROPATERN WATRAVAIL AGINSUPLY *ARESEXSYS* LANDSQLTY *WATRINSTN*) .... [20]

WATRPRODY = ***f***$_{21}$ (CULTIAREA CROPATERN LANDPRODY AGINSUPLY *ARESEXSYS* LANDSQLTY *WATRINSTN*) .... [21]

LABRPRODY = ***f***$_{22}$ (CULTIAREA CROPATERN LANDPRODY AGINSUPLY) .... [22]

FOODPRODN = ***f***$_{23}$ (*AFPRPOLCY* CULTIAREA LANDPRODY WATRPRODY *AGCRINSTN* **CONFAMPPP** *RSPROVIDR*) .... [23]

INDCPRODN = ***f***$_{24}$ (CULTIAREA LANDPRODY WATRPRODY *AMKTREGIM* *ATRDREGIM* *STAXPOLCY* *CORPSECTR* *AVALCHAIN*).. [24]

FEEDSUPLY = ***f***$_{25}$ (CULTIAREA CROPATERN FOODPRODN INDCPRODN *CUSTINSTN*)...................... [25]

LIVSPRODN = ***f***$_{26}$ (LIVSIZCOM FEEDSUPLY *AGCRINSTN* *AMKTREGIM* *ATRDREGIM* *CORPSECTR*) .... [26]

AGNFSECTR = ***f***$_{27}$ (FOODPRODN INDCPRODN *AGCRINSTN* *AVALCHAIN* *CORPSECTR*) .... [27]

ATRDREGIM = ***f***$_{28}$ (FOODPRODN LIVSPRODN INDCPRODN *CORPSECTR*) .... [28]

AMKTREGIM = ***f***$_{29}$ (FOODPRODN LIVSPRODN INDCPRODN *AFPRPOLCY* *ATRDREGIM*) .... [29]

AMKTPRICE = ***f***$_{30}$ (AFPRPOLCY *STAXPOLCY* *AMKTREGIM* *ATRDREGIM*) .... [30]

CULTICOST= ***f***$_{31}$ (CULTIAREA CROPATERN AGINSUPLY *STAXPOLCY* *CREMINSUR*) .... [31]

CROPINCOM = ***f***$_{32}$ (CULTIAREA CROPATERN LANDPRODY CULTICOST AMKTPRICE *AVALCHAIN* *CREMINSUR*) .... [32]

RURALWAGE = ***f***$_{33}$ (LABRPRODY FOODPRODN INDCPRODN LIVSPRODN AGNFSECTR *AGWAGELAW*) .... [33]

RURALJOBS = f_{34} (LANDPRODY LABRPRODY RURALWAGE FOODPRODN INDCPRODN LIVSPRODN AGNFSECTR *CREMINSUR*) .... [34]

FARMINCOM = f_{35} (CROPINCOM LIVSPRODN AGNFSECTR *SNETPOLCY*) .... [35]

LABRINCOM = f_{36} (RURALJOBS RURALWAGE LIVSPRODN AGNFSECTR *CREMINSUR* *SNETPOLCY*) .... [36]

FOODAVAIL = f_{37} (FOODPRODN LIVSPRODN INDCPRODN *AMKTREGIM* *ATRDREGIM*) .... [37]

FOODPRICE = f_{38} (FOODPRODN FOODAVAIL *AMKTREGIM* *AFPRPOLCY*) .... [38]

WATRSECUR = f_{39} (CLCIMPACT WATRSUPLY *WATRINFRA* *WATRINSTN* *CUSTINSTN*) .... [39]

RURWELFAR = f_{40} (FARMINCOM LABRINCOM FOODAVAIL FOODPRICE WATRSECUR) .... [40]

At the outset, certain key features of the system of equations [1] to [40] and their methodological, econometric, and empirical implications deserve to be highlighted. These features and implications are as follows:

(1) The three variables in bold (i.e., CONFAMPPP, CROPSHIFT, and DCONIVMOD) represent the three TAOs selected for modelling and evaluation.

(2) Similarly, the 20 variables with underlined italics represent the three sets of governance elements, i.e., institutions (e.g., AGENINSTN, AFPRPOLCY, ATRDREGIM, CUSTINSTN, LANDTENUR, and ATRINSTN), infrastructures (i.e., AVALCHAIN and WATRINFRA), and key players or actors (e.g., CORPSECTR, DONINVSTR, and RSPROVIDR).

(3) The 24 impact variables link the trigger variable CLCIMPACT with the goal or impact variable RURWELFAR by transmitting the individual and interactive effects of the TAOs and MPG elements through various impact pathways. They represent not only the physical effects (e.g., CROPATERN, CROPPRODN, LANDPRODY, and WATRPRODY) but also economic impacts (e.g., AMKTPRICE, CULTICOST, RURALWAGE, FARMINCOM, and LABRINCOM). They also capture overall sectoral impacts on agriculture (i.e., AGPERFORM) and water (i.e., WATRAVAIL to represent irrigation need) and WATRSUPLY to represent water for basic needs).

(4) Of the 52 variables included in the model of CC-TAO-MPG-RW interactions, 40 variables are dependent or endogenous whereas 12 are independent or exogenous. As can be seen, the endogenous variables are those that appear as dependent variables in each of the 40 equations. The 12 exogenous variables, which depend neither on any endogenous nor exogenous variables, are: AGENINSTN, AFPRPOLCY, AGWAGELAW, CLIMINSYS, CLCIMPACT, CREMINSUR, CUSTINSTN, DONINVSTR, LANDTENUR, LIVSIZCOM, SNETPOLCY, and STAXPOLCY.

(5) It also needs to be noted that the effects of the variables are not uniform across various impact pathways. The same variable can have different kinds and levels of effects on different variables, depending upon the impact pathways. The magnitude and direction of their effects also depend on the length, strength, and variable configurations of different impact pathways.

(6) Turning now to the key features of the equations, they characterize the configuration and behavior of different impact pathways. As such, equations [1] to [40], taken together, capture most of the key impact pathways between the trigger variable (i.e., CLCIMPACT) and the final goal of impact variable (i.e., RURWELFAR). These equations together define a

structural or system model, where the dependent variable in one equation enter as the independent variables in other equations.

(7) Given such structural and functional linkages, the equations system has to estimate together as a single model with several sequentially and simultaneously linked set of equations. In such estimation, the order in which equations are listed will not affect the results. In view of the structural linkages among equations, the system-wide impacts of a marginal change in any variable in one equation can be easily traced by evaluating the behavior of various variables operating in all subsequent equations. It is this structural feature of the model that can be utilized to track down the individual and interactive effects of TAOs and MPG elements in improving climate resilience and enhancing, thereby, rural welfare.

(8) To track and evaluate the relative roles and impacts of different sets of variables in the model, the system of equations can be reduced to a single but long equation chain within which equations [1] to [40] are appropriately embedded. By differentiating this single equation with respect to each of the 52 variables, the nature and magnitude of the performance enhancing roles of all impact variables as well as those representing TAOs and MPG elements. Since this exercise can identify gaps and weak spots across impacts pathways, it helps in designing suitable sector and scale-specific corrective policies.

(9) It goes without saying that the analytical framework presented in Figure 4 and the model defined by equations [1] to [40] are neither complete nor unique. Neither does Figure 4 exhausts all possible impact pathways nor does the system model capture all the chains of variables underlying even the impact pathways analytically delineated in Figure 4. It is fair to say that the particular analytical framework and system model specified here forms as only one among many feasible ones. But the approach behind the framework and model can certainly be generalized—with suitable adjustments—to reflect conditions of other basin and county contexts.

(10) And, finally, but most importantly, we need to note one of the most important econometric conditions that the system model should satisfy. This relates to fulfilment of the Order and Rank conditions so that each equation in the model can be econometrically identified to have consistent and efficient estimates (Koutsoyiannis, 1973; Kennedy, 1987; Rehal, 2023).[4] Of the two conditions, the first is only a necessary condition whereas the second is the sufficient condition. Checking for the order condition is straightforward, but the same for Rank condition requires to have a non-zero determinant of a large matrix. However, as can

[4] The Order and Rank conditions are inter-related (Koutsoyiannis, 1973). To understand them better, let us note that all the system equations defined by 52 variables involve a 40 by 52 matrix. Denoting E as the total number of equations, K as the total number of variables, M as the number of variables included in each equation under consideration, the Order condition can be stated as: $(K-M) \geq (E-1)$. The Order condition requires that for each equation, the number of excluded (exogenous) variables cannot be less than the number of dependent (endogenous) variables in the system, excluding the one in that equation. In simple terms, this condition ensures that there are enough exogenous variables excluded so that they can serve as instrumental variables for estimating the endogenous variable appearing as dependent variable in each equation. The Rank condition, though quite technical, requires, in simple terms, that all equations are distinct in the sense that none of them can be formed with the linear combinations any other two equations in the system. This can be ensured by checking whether the determinant of the matrix of dimension: $(E-1)\times(K-M)$ is non-zero. Note this matrix is formed by excluding the row corresponding to the equation in question and the columns corresponding to all independent variables included in that equation (see Kennedy, 1987: 138 & 142; Rehal, 2023).

be seen in Annex-A, we have verified that all equations in the model satisfy both the Order and Rank conditions, ensuring their econometric identification and unbiased estimation.

While the analytical and structural aspects of system model are clear, the main challenge lies in generating appropriate information needed for its empirical estimation in the context of the study basin.

6.3. Empirical Approach

Having developed the model of CC-TAO-MPG-RW interactions and discussed its functional linkages, structural features, methodological aspects, and econometric implications, let us turn to the other component of the evaluation methodology, i.e., the empirical approach needed for generating data for empirical application of the system model in the specific context of out study basin. Considering the inherently *ex-ante* nature of many variables and their impact transmission process, it is hard to get observed or quantitative information on many variables in the system. Even if we can have observed information on some aspects (e.g., production, productivity, price, costs, and income), they are most likely to relate to a past situation, making them less appropriate to capture either the current or future conditions. Moreover, such observed information is also less likely to synthesize expectations or capture diversity.

Still more difficult is to get objective data on variables representing elements of TAOs and MPG structure, especially given their diverse roles and performance impacts both within and across impact pathways. Another major problem for data collection relates to the aggregate and notional way in which most variables are conceptualized and defined. For instance, CLCIMPACT is a composite variable, capturing changes in various aspects such as temperature and rainfall. Similarly, the variable WATRINFRA covers a range of infrastructural elements such as water transfer, storage, and conveyance structures as well as flood control and water harvesting systems. The same is the case with most other variables (e.g., AGENINSTN, AMKTREGIM, ARESEXSYS, FARMINCOM LABINCOME, LIVSIZCOM, RSPROVIDR, and RURWELFAR).

For all similar cases noted above, one approach is to collect information on the status and performance of each of the relevant elements and sum them appropriately to get a value for overall impact or performance. Another approach is to directly elicit subjective and gut-feeling response straight from experts and other knowledge people on the status and performance of composite or notional variables. Although this approach is subjective, it has the advantage of internalizing both the notional coverage variables as well as the standard on which their performance are evaluated. When such information is collected from a large and diverse set of stakeholders, one can expect a tendency for both the notion and standard to converge. This fact justifies comparability and amenability for statistical treatment of obtained information.

The deficiency or lack of observed data on most variables does not, however, mean a complete absence of information. In fact, highly relevant information is constantly being processed, coded, and stored as perceptions in the minds of individuals involved in the development process either as planners, experts, evaluators, beneficiaries, or just as informed observers. Such real, but latent, information embodied in individuals can be tapped though carefully designed and conducted stakeholder surveys. Interestingly, this form of information has many desirable properties often missed in objective or observed data. For example, unlike the observed data characterizing a past and static situation, perception-based data, if elicited carefully, can synthesize objective, subjective, and aspiration-related factors as well as the *ex-ante* and dynamic elements. The use of such perception-based data for policy analysis has a strong theoretical legitimacy and strong empirical tradition in current literature.[5]

Given the rationale and legitimacy of using subjective and perception-based data in the context of institutional analysis, they can be generated by using suitably designed survey tools and appropriately selected sample of stakeholders for any given empirical and spatial context. Notably, such data are usually recorded as scores on a scale of 0-10 with zero denoting no effect and 10 denoting the highest possible impact. In the case of quantifiable variables (e.g., production, price, income, employment, and food availability), if needed, such scores can also be converted into quantitative equivalents by using the range of their minimum and maximum values obtained from published or household data.[6] This Study has used a similar empirical approach for collecting all relevant information needed for the empirical evaluation of the system model.

The initial versions of the analytical framework and the corresponding questionnaire[7] were developed after a week-long field visit undertaken during late October 2022 that provided opportunity to meet key stakeholders at basin and national level, collect valuable data and materials, and get familiarized with the agricultural and water sector issues as well as ongoing initiatives to combat climate changes impacts. The questionnaire was field-tested with multiple respondents and then revised and finalized based on feedback. The details of the survey instrument used for collecting perception-based data is given in Annex-B.

As can be seen in Annex-B, the questionnaire has six parts, each covering respectively instructions, analytical framework, explanations of key concepts and definition of variables, respondent details, and the questionnaire itself. The part with respondent detail is the basis for developing nine identifier variables, representing respectively respondent ID number, gender, education, disciplinary background, profession, experience, and location on sectoral and regional scales. The core part of survey instrument with the questionnaire covers 291 specific questions, pertaining to various aspects of the 52 variables in the system model. Note that the aspects or dimensions on which information is gathered for these 52 variables range from three to 10, depending upon the levels of details required on these variables.

7. Sample Profile and Data Description

The process of sample selection and data collection proceeded during May-June 2023. The questionnaire was administered after selecting a stakeholder sample of 176 respondents spread across sectoral contexts and regional scales. The sample is based on a purposive sampling approach to cover stakeholders with a variety of educational, professional, and disciplinary backgrounds. The final dataset became available in mid-July and the same was finalized by end-July 2023. Let us now describe the overall profile of the sample and key features of the dataset.

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[5] The theoretical legitimacy comes from the subjective nature of institutions (Douglas, 1986; Ostrom, 1990), stakeholders as 'agents of institutional change' (North, 1990), and the human practice of 'adaptive instrumental evaluation' (Kahneman and Tversky, 1984; Bromley, 1985). The empirical precedence includes studies on institutional analysis (e.g., Gray and Kaufman, 1998; Kaufmann, et al., 2006) and impact assessment (e.g., Neubert, 2000; Coudouel, Dani, and Paternostro, 2006; Saleth and Dinar, 2008 and 2009).

[6] Notably, when using qualitative variables within cross-sectional regression, the results in terms of the sign and magnitude of their estimated coefficients will not be qualitatively different, regardless of whether the scores or their quantitative equivalents are being used.

[7] It is to be noted that since the analytical framework (Figure 4) is actually the basis for developing the questionnaire, there is a correspondence between the two.

7.1. Sample Profile

Table 1 shows the frequency and distribution of the sample in terms of its gender, age, educational, and professional composition and its sectoral and spatial distribution.

Table 1: Eum Er-Rbia Bain, Morocco: Sample Profile

(a) Sample Distribution by Gender

Category	*Frequency*	*(%)*
Female	28	16
Male	148	84
All	176	100

(b) Sample Distribution by Age Group

Years	*Frequency*	*(%)*
20-30	15	9
31-40	40	23
41-50	41	23
51-60	46	26
Over 60	34	19
All	176	100

(c) Sample Distribution by Education

Level	*Frequency*	*(%)*
Up to Primary School	28	16
High School	48	27
Graduate	46	26
Post-graduate	43	24
Technical Education	11	7
All	176	100

(d) Sample Distribution by Experience

Level	*Frequency*	*(%)*
0-10	62	35
11-20	56	32
21-30	24	14
Over 30	34	19
All	176	100

(e) Sample Distribution by Spatial Scale

Scale	*Frequency*	*(%)*
International	21	12
National	30	17
Regional	40	23
Provincial	25	14
Community/Local	60	34

(f) Sample Distribution by Sector

Sectors	*Frequency*	*(%)*
Agriculture	105	60
Water & Environment	18	10
Agro-Industry/Livestock/ Non-Farm/Service Sectors	25	14
Academics/NGOs/Others	28	16

All	176	100

All	176	100

(g) Sample Distribution by Profession		
Profession	***Frequency***	***(%)***
Government Officials	27	15
Researches/Experts	21	13
Trade/Business/ Insurance/Finance	29	16
Farmers	67	38
Service Providers	32	18
All	176	100

(h) Sample Distribution by Discipline		
Discipline	***Frequency***	***(%)***
Agronomy/Soil Science	49	28
Engineering/Hydrology/ Water Sciences	26	15
Economics/Social Sciences	28	16
Finance/Management	13	7
Others	60	34
All	176	100

As can be seen from Table 1, the sample covers stakeholders of different age groups and educational, professional, and disciplinary backgrounds. Notably, women account for 16% of the sample. It includes not only government officials, experts, researchers, private sector, community representatives, and local leaders but also farmers, cooperative members, and rural service providers. The sampled stakeholders are spread across agriculture, water, and environment sectors and operate at national, regional, provincial, and local levels. Even though 60% of the sample represents the agricultural sector, the sample still cover other sectors because it is actually a composite sector, where agriculture, water, and environment converge. Besides, though climate change affects water and environment sectors more directly, it is the agriculture sector that bears the ultimate impact.

7.2. Data Description

Turning now to the nature and quality of data, as noted already, data on all the 52 model variables are based on the perception of stakeholders and the same was recorded on a scale of 0-10, with zero denoting no impact and 10 denoting the highest possible impact. Also noted is the fact that the perceptional information on each of the 52 model variables are collected by looking at them from different angles. Since such angles or dimensions for the model variables ranged from three to 10, the database has 291 sub-variables for each respondent. Given these 291 variables plus the nine identifier variables (capturing respondents' characteristics) and the sample size, the full database will have a dimension of 176 by 300. But to derive the final database needed for estimating the system model, there is a need to summarize the information on all sub-variables into a single value for each of the 52 model variables.

While there are more sophisticated econometric approaches available for deriving summary value (e.g., Principal Component Analysis, Linear Discriminant Analysis, etc.). here, for simplicity, we use just the averaging approach. Under this approach, the information collected on different dimensions or sub-variables were just averaged to derive a single summary value for each of the model variables. Thus, the final dataset, excluding the nine identifier variables, will have a dimension of 176 by 61. A key point on the final dataset requires nothing. In the final dataset, the variables with zero and fractional values less than one were rounded to one so as to have the option for a logarithmic transformation of dataset. It is this dataset that is used for the empirical estimation of the model of CC-TAO-MPG-RW interactions. The results from such estimation will be the basis evaluating how the welfare and climate resilience impacts of TAOs are mediated and facilitated by MPG elements. Given the centrality of the dataset for the entire empirical analysis, its key features deserve our attention.

Table 2 provides the descriptive statistics for all variables in the final dataset. While the values of descriptive statistics are easy to interpret and understand, a few aspects need to be highlighted. Although Table 1 provides information on the age, education, and experience-wise distribution, Table 2 sheds some additional lights in terms of mean and range values. For instance, the average age of stakeholders is 48 years, but with an age range of 21-80 years. The mean educational level is below 4,

Table 2: CC-TAO-MPG-Welfare Interaction Model:

Descriptive Statistics for All Variables

Sl. No:	*Variables*	*Obser-vations*	*Mean*	*Std. Dev.*	*Min*	*Max*
1	Respondent Number	176	-	-	1	176
2	Gender *(Female=1;*	176	-	-	1	2
3	Age	176	48.27	12.63	21	80
4	Education *(Levels)*	176	3.73	1.28	1	7
5	Experience *(Years)*	176	17.72	11.91	1	55
6	Scale *(Spatial Levels)*	176	-	-	1	6
7	Sector	176	-	-	1	8
8	Profession	176	-	-	1	8
9	Discipline	176	-	-	1	7
10	CLCIMPACT	176	8.25	1.49	3.50	10.00
11	WATRAVAIL	176	6.70	1.33	1.00	10.00
12	AGPERFORM	176	7.50	1.37	3.33	10.00
13	WATRSUPLY	176	7.06	1.30	2.25	10.00
14	CONFAMPPP	176	5.74	1.88	1.00	9.29
15	CROPSHIFT	176	6.31	1.58	1.25	9.63
16	DCONVIMOD	176	6.07	2.69	1.00	10.00
17	LANDTENUR	176	6.44	1.89	1.00	10.00
18	CUSTINSTN	176	4.85	2.36	1.00	9.67
19	WATRINSTN	176	5.20	2.02	1.00	10.00
20	WATRINFRA	176	6.80	1.59	1.00	10.00
21	AGENINSTN	176	5.39	1.91	1.00	9.60
22	DONINVSTR	176	4.57	2.23	1.00	10.00
23	CLIMINSYS	176	6.16	1.85	1.00	9.75
24	AGCRINSTN	176	4.95	2.05	1.00	8.60
25	ARESEXSYS	176	6.15	1.80	1.00	9.67
26	CORPSECTR	176	5.71	1.76	1.00	9.33
27	RSPROVIDR	176	6.04	1.72	1.00	9.50
28	APMKTCOOP	176	6.33	1.37	1.00	9.20
29	AVALCHAIN	176	6.11	1.52	1.00	9.50
30	STAXPOLCY	176	6.49	1.79	1.00	10.00
31	AGWAGELAW	176	5.63	1.76	1.00	10.00
32	SNETPOLCY	176	5.90	2.10	1.00	10.00
33	CREMINSUR	176	5.91	1.85	1.00	9.40
34	AMKTREGIM	176	6.51	1.53	1.00	10.00
35	ATRDREGIM	176	6.58	1.67	1.00	10.00
36	AFPRPOLCY	176	6.18	2.06	1.00	10.00

Table 2: CC-TAO-MPG-Welfare Interaction Model:

Descriptive Statistics for All Variables

Sl. No:	***Variables***	***Obser-vations***	***Mean***	***Std. Dev.***	***Min***	***Max***
37	CULTIAREA	176	6.91	1.56	1.40	10.00
38	CROPATERN	176	6.78	1.51	1.00	10.00
39	CLIMINVST	176	5.34	1.99	1.00	9.80
40	AGINSUPLY	176	5.35	1.86	1.00	8.67
41	LANDSQLTY	176	6.81	1.77	1.00	10.00
42	LANDPRODY	176	6.92	1.54	1.00	10.00
43	WATRPRODY	176	6.73	1.68	1.00	10.00
44	LABRPRODY	176	6.66	1.71	1.00	10.00
45	FOODPRODN	176	6.50	1.37	1.00	10.00
46	INDCPRODN	176	5.92	1.60	1.00	10.00
47	FEEDSUPLY	176	6.69	1.45	1.00	10.00
48	LIVSIZCOM	176	6.30	1.66	1.00	10.00
49	LIVSPRODN	176	6.43	1.34	1.00	10.00
50	AGNFSECTR	176	4.85	1.85	1.00	9.29
51	RURALJOBS	176	5.96	1.50	1.00	9.63
52	RURALWAGE	176	5.86	1.71	1.00	10.00
53	CULTICOST	176	6.07	1.46	1.00	8.83
54	AMKTPRICE	176	6.00	1.26	1.00	8.50
55	CROPINCOM	176	6.30	1.55	1.00	8.83
56	LABRINCOM	176	6.20	1.53	1.00	9.00
57	FARMINCOM	176	6.30	1.52	1.00	10.00
58	FOODPRICE	176	6.62	1.43	1.00	9.40
59	FOODAVAIL	176	6.54	1.38	1.00	9.17
60	WATRSECUR	176	6.54	1.60	1.00	9.40
61	RURWELFAR	176	6.05	1.49	1.00	9.50

indicating that the educational level of most stakeholders to be graduation and below. But, as per Table 1, 43% of the sample has education below high school with the rest having graduate level education and above. The stakeholders' average experience is about 18 in their respective profession, but the experience level is ranging from one to 55 years. As to the model variables, CLCIMPACT has the highest mean value of 8.25 whereas DONINVSTR has the lowest mean value of 4.57. The ultimate impact variable RURWEFAR has a mean value of 6.05. The mean values of other variables range from 4.85 to 7.50. Regarding the range, most variables have a minimum value of one and a maximum value of 10.

8. Model of CC-TAO-MPG-RW Interaction: Results and Analysis

The system model of CC-TAO-MPG-RW interactions was empirically estimated using the dataset containing the average values of 52 variables after performing some standard diagnostic tests on the individual equations to ascertain their econometric properties. The structural model was also estimated assuming different functional forms with a view to identifying the functional form that best fits with the dataset and provides intuitively more consistent results. Specifically, the model was estimated with four alternative forms. First, the model was estimated both with and without the constant term for all model equations. Then, the model was also estimated by assuming both linear and logarithmic forms for all model equations. The linear form used the dataset with the simple average values whereas the logarithmic form involved the dataset with average values transformed into their natural logarithmic forms. All the four forms of the model were estimated with a 3-Stage Least Square (3-SLS) estimation procedure using STATA version 15.0. Of the four alternative estimates, the one with a linear form and no constant term was selected based on criteria such as model fit, explanatory power, and estimation consistency. This section presents the results of diagnostic tests and the 3-SLS estimates for the model.

8.1. Diagnostic Tests

Before presenting and discussing the 3-SLS results for the structural model, it is instructive to present the rationale for diagnostic tests and understand the implications for model results. The descriptive statistics (see Table 2) provides information on the nature of only the individual variables, particularly in terms of their mean, dispersion, and range. But, for evaluating their behavior, distribution, and inter-relationship, we need to individually consider and evaluate each of the 40 equations, which are defined by different configurations of the 52 variables. It is this need for evaluating individual equations (or, sub-models) within the structural model that provides the rationale for performing the diagnostic tests. In this respect, we performed 6 different diagnostic tests on all equations to check them for aspects such as predictive ability, autocorrelation, multicollinearity, heteroskedasticity, and distribution normality.[8] While equation-specific diagnostic test results are presented in Annex-C, the summary of the same is presented in Table 3.

Table 3: CC-TAO-MPG-Welfare Interaction Model: Summary of Diagnostic Test Results

Sl. No:	Diagnostic Tests *(Statistics Used)*	Testing Whether an Equation Has:	Test Result	Equations Met Tests	
				(Number)	*(%)*
(1)	**F-Test** (*F-Statistic*)	Good Predictive Ability	Yes	40	100
(2)	**Durbin-Watson Test** *(d-Statistic)*	1st Order Autocorrelation	Yes	6	15
(3)	**Breusch-Godfrey Test** [*Lagrange Multiplier Statistic (χ^2)*]	Higher Order Autocorrelation	Yes	19	47
(4)	**Mean-Variance Inflation Factor** (*VIF*)	Multicollinearity	Yes	39	97
(5)	**White's Test** (χ^2)	Heteroskedasticity	Yes	33	82
(6)	**Skewness-Kurtosis Test** *(Adj. χ^2)*	Normality of Distribution	Yes	4	10

As can be seen in Table 3, all the equations within the structural model have good predictive ability. Regarding autocorrelation (i.e., relationship with previous and higher order rows), 34 equations are free from first order autocorrelation and 21 are free from higher-order autocorrelation. But almost all equations in the structural model display high degree of multicollinearity and heteroskedasticity,

[8] For definition and detailed explanation for these tests, see Kennedy (1987) and Koutsoyiannis (1973).

implying respectively strong interdependence among the independent variables and disproportionate relationship between the dependent and independent variables across equations. In terms of the nature of their distribution, all equations, except four, suffer from non-normal distribution, indicating highly skewed distribution with sharp modes. Given the scale and perception-based nature of the dataset on the one hand and the need for the equations to capture multiple and inter-linked pathways on the other, it may not be reasonable to expect the equations to exactly meet all econometric requirements. It is fair to say, however, that the model equations performed well, at least, in the case of some key diagnostic tests, especially those related to predictive ability and autocorrelation. In any case, the diagnostic test results do suggest some important caveats and limitations within which the 3-SLS results of the model are approached and interpreted.

8.2. Model Estimation: 3-SLS Results and Analysis

We reached the core part of the study that will present and analyze the econometric results. Before proceeding further, it is necessary to note the following points:

(1) As noted already, the empirical results for the model of CC-TAO-MPG-RW interactions is based on a specification with no constant term and linear form for all model equations.

(2) Under the 3-SLS estimation procedure, since all the equations of the system model are estimated together as a simultaneous system, the estimated results can obviously capture the structural and functional linkages across equations and among all TAO, MPG, and impact-related variables.

(3) How strong are the relationships and how significant are the coefficients of variables in each of the equations are evaluated normally using respectively the values of χ^2 (Chi-square) and z (Standard Normal Variate).[9] The level of statistical significance indicated in terms of their corresponding P values.[10]

(4) The generally used critical value of P is 0.05 (i.e., 95-percent significance level). But, given the large model size and special nature of dataset, we relax the P value to be 0.10 (i.e., 90-percent significance level). Thus, when P values are 0.10 or better, we will take them as implying statistically significance.

(5) And, finally, the 3-SLS procedure provides two sets of results. While the first set provides simple results on the model fit and explanatory power, the second set, in contrast, provides estimates for the size, direction, and statistical significance of the coefficients of variables included in each of the equations within the system model. The latter results are more important from the perspective of the objectives and scope of this study.

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[9] The χ^2 is actually a ratio of two estimates—one based on observed relationship between dependent and independent variables and the other based on null hypothesis with no relationship. z is defined as: [(x – μ)/σ], where x = observed value, μ = mean, and σ = standard deviation. When μ = 0 and σ =1, Z becomes standard normal variate with a probability density function within unit interval. It can allow comparison across variables differing in magnitude and distribution.

[10] Since the level of statistical significance is defined as: (1-P), the level of significance is inversely related to P value. The level of significance is customarily expressed in percentage terms.

All the points noted above are to be kept in mind, while interpreting the results and their statistical significance and reliability.

Table 4 presents results on equation-specific overall statistics that can indicate the explanatory power and statistical fit of all model equations. Since R^2 values approach one for all equations, the configurations of variables included in each equation, taken together, explain almost all the variations in their respective dependent variables.

Table 4: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific Overall Statistics.

Eqn. No:	*Equation Name (Dependent Variable)*	*Obser-vations*	*Parameters (Independent variables)*	*RMSE*	*R^2*	*χ2*	*P*
1	CLIMINVST	176	3	1.55	0.93	2292.48	0.00
2	WATRINSTN	176	4	1.61	0.92	2403.96	0.00
3	WATRINFRA	176	4	1.63	0.95	3986.61	0.00
4	RSPROVIDR	176	4	1.18	0.96	4939.38	0.00
5	WATRAVAIL	176	6	1.56	0.95	4139.81	0.00
6	WATRSUPLY	176	4	1.25	0.97	5734.60	0.00
7	AGINSUPLY	176	4	1.58	0.92	1882.50	0.00
8	AGPERFORM	176	6	1.31	0.97	7684.33	0.00
9	CONFAMPPP	176	5	1.28	0.96	3964.64	0.00
10	DCONVIMOD	176	5	2.57	0.85	1337.74	0.00
11	CORPSECTR	176	5	1.37	0.95	3323.89	0.00
12	AGCRINSTN	176	3	1.54	0.92	1987.34	0.00
13	CROPSHIFT	176	8	3.15	0.77	1597.50	0.00
14	ARESEXSYS	176	4	1.28	0.96	4643.69	0.00
15	APMKTCOOP	176	3	1.60	0.94	2886.89	0.00
16	AVALCHAIN	176	6	2.52	0.84	2800.31	0.00
17	CULTIAREA	176	6	1.69	0.94	3966.55	0.00
18	LANDSQLTY	176	5	1.46	0.96	4810.10	0.00
19	CROPATERN	176	7	0.98	0.98	9625.46	0.00
20	LANDPRODY	176	7	1.26	0.97	5865.72	0.00
21	WATRPRODY	176	7	1.27	0.97	6874.33	0.00
22	LABRPRODY	176	4	1.42	0.96	4359.09	0.00
23	FOODPRODN	176	7	0.96	0.98	7585.38	0.00
24	INDCPRODN	176	8	1.87	0.91	1925.03	0.00
25	FEEDSUPLY	176	5	2.46	0.87	1924.74	0.00
26	LIVSPRODN	176	6	1.03	0.98	8913.06	0.00
27	AGNFSECTR	176	5	1.57	0.91	1645.11	0.00
28	ATRDREGIM	176	4	1.41	0.96	3424.66	0.00
29	AMKTREGIM	176	5	1.43	0.95	2929.32	0.00
30	AMKTPRICE	176	4	1.43	0.95	3932.42	0.00
31	CULTICOST	176	5	1.57	0.94	3661.34	0.00
32	CROPINCOM	176	7	1.23	0.96	5757.18	0.00
33	RURALWAGE	176	6	2.27	0.86	2058.07	0.00
34	RURALJOBS	176	8	1.78	0.92	3832.35	0.00

35	FARMINCOM	176	4	1.24	0.96	4886.74	0.00
36	LABRINCOM	176	6	1.20	0.96	6216.95	0.00
37	FOODAVAIL	176	5	1.81	0.93	3513.75	0.00
38	FOODPRICE	176	4	0.97	0.98	9160.95	0.00
39	WATRSECUR	176	5	1.76	0.93	2949.37	0.00
40	RURWELFAR	176	5	1.83	0.91	4385.00	0.00

Since the P (i.e., Probability) values is approaching zero, the χ^2 (i.e., Chi-square) values are statistically very significant in the case of all equations.[11] All the results presented in Table 4, therefore, are suggestive of the fact that both the model specified and the relationships postulated for each of the equations within the structural model are not only realistic with good explanatory power but also strong with high degree of statistical significance.

Table 5 presents the equation-specific 3-SLS estimates for all the model equations. It provides information on the relative size, direction, and standard error (or square of standard deviation) for the estimated coefficients for all model equations. The values of z and P>|z| enable us to evaluate the relative statistical significance of the coefficients. While former represents the standard normal variate for variables, the latter the probability with which z exceed its critical value reported in standard normal or unit normal table. Notably, Table 5 also gives important information, i.e., 95% confidence interval for all model variables. It is actually the range within which one can be 95% certain that the estimated coefficients of model variables are likely to take value if the model is repeatedly with different sampling of the same population. The confidence interval is, therefore, very useful for simulating the model with different values of the coefficients taken from that interval.

As noted already, although the structural model has 52 variables in all, it has only 40 equations. This means that 12 variables, which do not appear as dependent variables in any equation, are exogenous for the entire system. The 40 dependent variables, which enter as independent variables in other equations, are exogenous only in the context of those equations, not for the entire model. But these dependent variables are critical because they create linkages both within and across equations and it is these linkages that play major roles in the impact transmission process. As such, by evaluating each of the equations in the structural model, it is possible derive knowledge on the relative size, direction, and intensity of effects being transmitted in different layers of impact pathways between the trigger variable (CLCIMPACT) and ultimate goal (RURWELFAR).

Looking from an overall perspective, of the 209 coefficients in Table 5, 163 (78%) are statistically significant at 90% level or better (or, P ≤ 0.10). Only the remaining 46 (22%) are statistically insignificant. These coefficients along with their variable name and P values are marked with grey color. It is the information on the size and sign of the statistically significant coefficients that will be used to evaluate the relative role and significance of different policy, institutional, and impact variables that characterize different impact pathways. From this perspective, the overall results that most of the variables have statistically significant coefficients suggest the fact the impact pathways as characterized different equations within the system model are empirically realistic and practically important. This also indicates the relative efficacy of the analytical framework and structural model themselves.

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	**Dependent / Independent Variables**	**Coeff.**	**Std. Error**	**z**	**P > |z|**	**[95% Confidence**	**Interval]**
[1]	CLIMINVST						
	CLCIMPACT	0.239	0.030	8.040	0.000	0.181	0.297
	AGENINSTN	0.504	0.050	10.020	0.000	0.406	0.603

[11] The statistically significant χ^2 values, therefore, suggest to accept the alternative hypothesis of strong relationships between variables on both sides of all equations.

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	DONINVSTR	0.146	0.048	3.080	0.002	0.053	0.240
[2]	WATRINSTN						
	CLCIMPACT	-0.104	0.043	-2.420	0.016	-0.189	-0.020
	CLIMINVST	0.775	0.051	15.120	0.000	0.675	0.876
	LANDTENUR	0.084	0.040	2.090	0.036	0.005	0.162
	CUSTINSTN	0.295	0.033	8.900	0.000	0.230	0.359
[3]	WATRINFRA						
	CLCIMPACT	0.337	0.040	8.350	0.000	0.258	0.416
	CLIMINVST	0.770	0.092	8.340	0.000	0.589	0.951
	STAXPOLCY	0.069	0.060	1.140	0.253	-0.049	0.187
	DONINVSTR	-0.130	0.050	-2.590	0.010	-0.229	-0.032
[4]	RSPROVIDR						
	CLIMINVST	0.452	0.075	6.010	0.000	0.304	0.599
	AGCRINSTN	-0.130	0.058	-2.250	0.024	-0.244	-0.017
	STAXPOLCY	-0.064	0.052	-1.240	0.215	-0.166	0.037
	CORPSECTR	0.813	0.069	11.730	0.000	0.677	0.948
[5]	WATRAVAIL						
	CLCIMPACT	0.046	0.060	0.770	0.440	-0.072	0.165
	CROPSHIFT	0.664	0.123	5.410	0.000	0.423	0.905
	DCONVIMOD	0.030	0.064	0.470	0.638	-0.096	0.156
	WATRINSTN	-0.551	0.092	-5.980	0.000	-0.732	-0.371
	WATRINFRA	0.713	0.131	5.420	0.000	0.455	0.970
	CLIMINSYS	-0.003	0.051	-0.070	0.946	-0.103	0.097
[6]	WATRSUPLY						
	CLCIMPACT	0.199	0.063	3.140	0.002	0.075	0.323
	WATRAVAIL	0.563	0.107	5.280	0.000	0.354	0.773
	WATRINSTN	0.015	0.076	0.200	0.843	-0.134	0.164
	WATRINFRA	0.229	0.133	1.720	0.086	-0.032	0.490
[7]	AGINSUPLY						
	ARESEXSYS	0.299	0.120	2.490	0.013	0.064	0.535
	AGCRINSTN	0.416	0.088	4.710	0.000	0.243	0.588
	RSPROVIDR	0.548	0.151	3.630	0.000	0.252	0.843
	CONFAMPPP	-0.333	0.096	-3.460	0.001	-0.522	-0.144
[8]	AGPERFORM						
	CLCIMPACT	0.044	0.089	0.490	0.621	-0.130	0.218
	WATRAVAIL	0.571	0.155	3.680	0.000	0.267	0.874
	WATRSUPLY	0.828	0.220	3.760	0.000	0.397	1.260
	CLIMINSYS	0.126	0.049	2.570	0.010	0.030	0.222
	AGINSUPLY	-0.437	0.098	-4.480	0.000	-0.629	-0.246
	LANDTENUR	-0.155	0.045	-3.420	0.001	-0.243	-0.066
[9]	CONFAMPPP						
	AGPERFORM	0.114	0.051	2.230	0.026	0.014	0.215
	LANDTENUR	0.487	0.048	10.220	0.000	0.394	0.581

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	WATRINSTN	0.561	0.085	6.600	0.000	0.394	0.727
	AGCRINSTN	0.125	0.061	2.050	0.040	0.006	0.245
	RSPROVIDR	-0.299	0.097	-3.080	0.002	-0.490	-0.109
[10]	DCONVIMOD						
	AGPERFORM	0.789	0.144	5.490	0.000	0.507	1.070
	LANDTENUR	0.360	0.082	4.390	0.000	0.199	0.520
	WATRINSTN	1.468	0.151	9.720	0.000	1.172	1.764
	WATRINFRA	-0.431	0.223	-1.930	0.053	-0.868	0.006
	RSPROVIDR	-1.131	0.167	-6.770	0.000	-1.458	-0.803
[11]	CORPSECTR						
	CLCIMPACT	-0.046	0.042	-1.110	0.265	-0.128	0.035
	ATRDREGIM	0.521	0.087	6.010	0.000	0.351	0.691
	CLIMINVST	0.012	0.077	0.160	0.875	-0.138	0.162
	STAXPOLCY	0.156	0.056	2.810	0.005	0.047	0.265
	CONFAMPPP	0.283	0.057	4.940	0.000	0.171	0.395
[12]	AGCRINSTN						
	AGENINSTN	0.358	0.061	5.850	0.000	0.238	0.478
	DONINVSTR	0.367	0.061	6.070	0.000	0.249	0.486
	CORPSECTR	0.225	0.059	3.780	0.000	0.108	0.341
[13]	CROPSHIFT						
	CONFAMPPP	0.924	0.222	4.170	0.000	0.490	1.358
	DCONVIMOD	0.215	0.102	2.110	0.035	0.015	0.415
	LANDTENUR	-0.395	0.136	-2.900	0.004	-0.661	-0.128
	WATRINSTN	-0.291	0.112	-2.590	0.009	-0.511	-0.071
	AMKTREGIM	2.229	0.386	5.770	0.000	1.472	2.987
	ATRDREGIM	-2.129	0.402	-5.300	0.000	-2.916	-1.341
	RSPROVIDR	-1.022	0.430	-2.380	0.018	-1.865	-0.179
	CORPSECTR	1.649	0.427	3.860	0.000	0.812	2.485
[14]	ARESEXSYS						
	AGENINSTN	0.191	0.048	3.930	0.000	0.096	0.286
	CONFAMPPP	-0.212	0.082	-2.570	0.010	-0.373	-0.050
	CLIMINSYS	0.250	0.053	4.750	0.000	0.147	0.353
	CORPSECTR	0.828	0.101	8.210	0.000	0.630	1.025
[15]	APMKTCOOP						
	AGCRINSTN	0.219	0.073	3.000	0.003	0.076	0.363
	RSPROVIDR	0.878	0.064	13.790	0.000	0.753	1.003
	CUSTINSTN	-0.036	0.044	-0.820	0.410	-0.122	0.050
[16]	AVALCHAIN						
	AGCRINSTN	0.163	0.062	2.620	0.009	0.041	0.284
	APMKTCOOP	1.110	0.118	9.410	0.000	0.879	1.342
	AMKTREGIM	-2.013	0.297	-6.770	0.000	-2.596	-1.431
	ATRDREGIM	1.652	0.268	6.160	0.000	1.127	2.178
	RSPROVIDR	0.725	0.242	3.000	0.003	0.251	1.199
	CORPSECTR	-0.681	0.252	-2.710	0.007	-1.175	-0.188
[17]	CULTIAREA						
	CONFAMPPP	-1.272	0.201	-6.320	0.000	-1.666	-0.877
	CROPSHIFT	1.026	0.215	4.760	0.000	0.604	1.448

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	DCONVIMOD	0.289	0.112	2.580	0.010	0.069	0.509
	LANDTENUR	0.509	0.116	4.390	0.000	0.281	0.736
	AVALCHAIN	0.466	0.112	4.170	0.000	0.247	0.685
	CUSTINSTN	-0.032	0.080	-0.390	0.693	-0.189	0.126
[18]	LANDSQLTY						
	CLCIMPACT	0.112	0.053	2.100	0.036	0.007	0.216
	LANDTENUR	0.075	0.047	1.600	0.111	-0.017	0.168
	CROPATERN	-0.369	0.150	-2.460	0.014	-0.663	-0.075
	ARESEXSYS	0.400	0.089	4.500	0.000	0.226	0.574
	LIVSPRODN	0.854	0.142	5.990	0.000	0.575	1.133
[19]	CROPATERN						
	CULTIAREA	0.821	0.137	5.990	0.000	0.552	1.089
	CROPSHIFT	0.375	0.203	1.840	0.065	-0.024	0.774
	CONFAMPPP	-0.174	0.133	-1.320	0.188	-0.434	0.085
	DCONVIMOD	0.151	0.042	3.580	0.000	0.068	0.234
	AMKTREGIM	-0.206	0.084	-2.450	0.014	-0.370	-0.041
	LANDTENUR	-0.153	0.046	-3.320	0.001	-0.244	-0.063
	LANDSQLTY	0.168	0.097	1.730	0.084	-0.022	0.359
[20]	LANDPRODY						
	CULTIAREA	0.254	0.246	1.030	0.303	-0.229	0.736
	CROPATERN	-0.787	0.257	-3.060	0.002	-1.291	-0.283
	WATRAVAIL	0.586	0.151	3.880	0.000	0.290	0.881
	AGINSUPLY	-0.017	0.091	-0.180	0.853	-0.195	0.161
	ARESEXSYS	0.270	0.109	2.470	0.013	0.056	0.484
	LANDSQLTY	0.617	0.105	5.860	0.000	0.410	0.823
	WATRINSTN	0.155	0.063	2.470	0.014	0.032	0.278
[21]	WATRPRODY						
	CULTIAREA	-0.544	0.252	-2.160	0.031	-1.039	-0.050
	CROPATERN	0.500	0.246	2.030	0.042	0.017	0.983
	LANDPRODY	0.389	0.215	1.810	0.070	-0.032	0.810
	AGINSUPLY	-0.272	0.087	-3.130	0.002	-0.443	-0.102
	ARESEXSYS	-0.010	0.134	-0.070	0.940	-0.273	0.253
	LANDSQLTY	0.741	0.166	4.460	0.000	0.415	1.067
	WATRINSTN	0.168	0.057	2.940	0.003	0.056	0.280
[22]	LABRPRODY						
	CULTIAREA	0.114	0.302	0.380	0.705	-0.478	0.707
	CROPATERN	0.020	0.288	0.070	0.945	-0.545	0.585
	LANDPRODY	1.059	0.140	7.550	0.000	0.784	1.333
	AGINSUPLY	-0.299	0.101	-2.960	0.003	-0.496	-0.101
[23]	FOODPRODN						
	AFPRPOLCY	0.045	0.027	1.630	0.103	-0.009	0.098
	CULTIAREA	0.341	0.096	3.540	0.000	0.152	0.530

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	LANDPRODY	0.309	0.143	2.160	0.031	0.029	0.589
	WATRPRODY	0.240	0.115	2.090	0.036	0.015	0.464
	AGCRINSTN	-0.038	0.044	-0.860	0.389	-0.125	0.049
	CONFAMPPP	-0.098	0.064	-1.530	0.126	-0.223	0.027
	RSPROVIDR	0.142	0.085	1.680	0.094	-0.024	0.309
[24]	INDCPRODN						
	CULTIAREA	0.162	0.130	1.250	0.213	-0.093	0.416
	LANDPRODY	0.473	0.312	1.520	0.129	-0.138	1.084
	WATRPRODY	0.496	0.247	2.010	0.044	0.013	0.980
	AMKTREGIM	-1.096	0.341	-3.220	0.001	-1.765	-0.428
	ATRDREGIM	1.069	0.302	3.540	0.000	0.476	1.661
	STAXPOLCY	-0.090	0.089	-1.010	0.314	-0.264	0.085
	CORPSECTR	-0.393	0.153	-2.560	0.010	-0.693	-0.092
	AVALCHAIN	0.182	0.128	1.420	0.155	-0.068	0.431
[25]	FEEDSUPLY						
	CULTIAREA	-1.126	0.375	-3.000	0.003	-1.861	-0.391
	CROPATERN	2.516	0.450	5.600	0.000	1.635	3.397
	FOODPRODN	-0.989	0.448	-2.210	0.027	-1.868	-0.111
	INDCPRODN	0.836	0.337	2.480	0.013	0.176	1.497
	CUSTINSTN	-0.241	0.072	-3.360	0.001	-0.381	-0.100
[26]	LIVSPRODN						
	LIVSIZCOM	0.350	0.071	4.920	0.000	0.210	0.489
	FEEDSUPLY	0.081	0.102	0.800	0.426	-0.119	0.282
	AGCRINSTN	-0.087	0.044	-1.980	0.048	-0.173	-0.001
	AMKTREGIM	0.338	0.145	2.330	0.020	0.054	0.623
	ATRDREGIM	-0.153	0.172	-0.890	0.375	-0.491	0.185
	CORPSECTR	0.506	0.086	5.880	0.000	0.337	0.674
[27]	AGNFSECTR						
	FOODPRODN	-0.283	0.331	-0.860	0.392	-0.932	0.366
	INDCPRODN	0.647	0.253	2.560	0.010	0.152	1.142
	AGCRINSTN	0.300	0.084	3.560	0.000	0.135	0.466
	AVALCHAIN	0.494	0.169	2.920	0.004	0.162	0.826
	CORPSECTR	-0.280	0.126	-2.220	0.026	-0.527	-0.033
[28]	ATRDREGIM						
	FOODPRODN	0.737	0.264	2.800	0.005	0.221	1.254
	LIVSPRODN	-0.551	0.205	-2.690	0.007	-0.953	-0.149
	INDCPRODN	0.817	0.214	3.830	0.000	0.399	1.236
	CORPSECTR	0.089	0.094	0.940	0.348	-0.096	0.274
[29]	AMKTREGIM						
	FOODPRODN	0.700	0.296	2.360	0.018	0.119	1.281
	LIVSPRODN	-0.433	0.236	-1.840	0.066	-0.895	0.029
	INDCPRODN	0.656	0.254	2.580	0.010	0.157	1.154
	AFPRPOLCY	0.048	0.034	1.420	0.157	-0.018	0.114
	ATRDREGIM	0.083	0.210	0.400	0.692	-0.329	0.495
[30]	AMKTPRICE						
	AFPRPOLCY	-0.080	0.034	-2.350	0.019	-0.147	-0.013
	STAXPOLCY	0.248	0.058	4.270	0.000	0.134	0.362

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	AMKTREGIM	1.289	0.169	7.640	0.000	0.959	1.620
	ATRDREGIM	-0.539	0.192	-2.810	0.005	-0.915	-0.163
[31]	CULTICOST						
	CULTIAREA	1.075	0.258	4.170	0.000	0.570	1.579
	CROPATERN	-0.725	0.272	-2.660	0.008	-1.259	-0.191
	AGINSUPLY	0.374	0.082	4.560	0.000	0.213	0.535
	STAXPOLCY	0.196	0.060	3.280	0.001	0.079	0.314
	CREMINSUR	0.046	0.053	0.870	0.387	-0.058	0.149
[32]	CROPINCOM						
	CULTIAREA	0.630	0.285	2.210	0.027	0.071	1.189
	CROPATERN	-0.662	0.278	-2.380	0.017	-1.206	-0.117
	LANDPRODY	0.088	0.176	0.500	0.616	-0.257	0.433
	CULTICOST	-0.027	0.180	-0.150	0.881	-0.380	0.326
	AMKTPRICE	0.725	0.207	3.510	0.000	0.320	1.131
	AVALCHAIN	0.120	0.122	0.990	0.324	-0.118	0.359
	CREMINSUR	0.153	0.057	2.670	0.008	0.041	0.266
[33]	RURALWAGE						
	LABRPRODY	1.449	0.320	4.530	0.000	0.823	2.075
	FOODPRODN	0.312	0.367	0.850	0.395	-0.407	1.032
	INDCPRODN	-2.098	0.417	-5.040	0.000	-2.915	-1.282
	LIVSPRODN	0.230	0.261	0.880	0.377	-0.281	0.742
	AGNFSECTR	0.951	0.174	5.460	0.000	0.610	1.293
	AGWAGELAW	0.088	0.065	1.370	0.171	-0.038	0.215
[34]	RURALJOBS						
	LANDPRODY	-0.031	0.278	-0.110	0.910	-0.577	0.514
	LABRPRODY	-0.761	0.296	-2.570	0.010	-1.341	-0.181
	RURALWAGE	0.867	0.131	6.640	0.000	0.611	1.123
	FOODPRODN	0.339	0.451	0.750	0.452	-0.544	1.223
	INDCPRODN	1.331	0.388	3.430	0.001	0.571	2.091
	LIVSPRODN	-0.422	0.262	-1.610	0.107	-0.936	0.091
	AGNFSECTR	-0.374	0.166	-2.260	0.024	-0.699	-0.050
	CREMINSUR	0.100	0.059	1.680	0.093	-0.016	0.216
[35]	FARMINCOM						
	CROPINCOM	0.539	0.103	5.240	0.000	0.337	0.740
	LIVSPRODN	0.576	0.114	5.070	0.000	0.353	0.799
	AGNFSECTR	-0.308	0.097	-3.180	0.001	-0.498	-0.118
	SNETPOLCY	0.116	0.036	3.230	0.001	0.046	0.187
[36]	LABRINCOM						
	RURALJOBS	-0.238	0.302	-0.790	0.430	-0.830	0.354
	RURALWAGE	0.802	0.239	3.360	0.001	0.334	1.270
	LIVSPRODN	0.365	0.106	3.460	0.001	0.158	0.573
	AGNFSECTR	-0.302	0.108	-2.810	0.005	-0.514	-0.091
	CREMINSUR	0.307	0.084	3.660	0.000	0.142	0.472
	SNETPOLCY	0.038	0.042	0.910	0.363	-0.044	0.121
[37]	FOODAVAIL						
	FOODPRODN	0.807	0.392	2.060	0.040	0.039	1.575
	LIVSPRODN	-0.474	0.252	-1.880	0.060	-0.968	0.019

Table 5: Structural Model of CC-TAO-MPG-RW Interactions:

Equation-Specific 3-SLS Estimates

Eqn. No	Dependent / Independent Variables	Coeff.	Std. Error	z	P > |z|	[95% Confidence Interval]	
	INDCPRODN	0.373	0.257	1.450	0.147	-0.131	0.877
	AMKTREGIM	1.257	0.200	6.270	0.000	0.864	1.649
	ATRDREGIM	-0.910	0.275	-3.310	0.001	-1.448	-0.371
[38]	FOODPRICE						
	FOODPRODN	0.550	0.117	4.690	0.000	0.320	0.780
	FOODAVAIL	0.751	0.094	7.990	0.000	0.567	0.935
	AMKTREGIM	-0.263	0.136	-1.930	0.053	-0.529	0.004
	AFPRPOLCY	-0.049	0.031	-1.590	0.113	-0.110	0.012
[39]	WATRSECUR						
	CLCIMPACT	-0.512	0.100	-5.140	0.000	-0.707	-0.316
	WATRSUPLY	1.243	0.172	7.210	0.000	0.906	1.581
	WATRINFRA	0.046	0.182	0.250	0.800	-0.310	0.403
	WATRINSTN	0.460	0.106	4.330	0.000	0.252	0.668
	CUSTINSTN	-0.150	0.047	-3.200	0.001	-0.242	-0.058
[40]	RURWELFAR						
	FARMINCOM	0.858	0.309	2.780	0.005	0.253	1.464
	LABRINCOM	-0.853	0.268	-3.180	0.001	-1.378	-0.327
	FOODAVAIL	1.065	0.294	3.620	0.000	0.488	1.642
	FOODPRICE	-1.091	0.342	-3.190	0.001	-1.761	-0.421
	WATRSECUR	0.923	0.204	4.520	0.000	0.523	1.324

Taking equation [1], it captures the impact pathway that transmits the effects of one impact variable (CLCIMPACT) and two MPG variables (AGENINSTN and DONINVSTR) on CLIMINVST, which is an impact variable. As can be seen in Table 5, the coefficients of all three variables have statistically significant coefficient with expected positive sign. However, their relative magnitude differs considerably with the institutional or MPG available AGENINSTN having a more dominant effect followed, then, by the other two impact variables: CLCIMPACT and DONINVSTR.

Equation [2] captures another impact pathway that transmits the effects of two impact variables (CLCIMPACT and CLIMINVST) and institutional or MPG variables (LANDTENUR and CUSTINSTN) on the institutional variable of WATRINSTN. Although all four variables have statistically significant effects on WATRINSTN, one of them, i.e., CLCIMPACT, has a negative effect, suggesting climate change has a negative impact on the functioning and performance of water institutions. This can possibly suggest that from an overall perspective, without significant improvement, existing water institutional arrangements in the study basin are under extreme pressure to face the challenges of climate change. In terms of relative magnitude, CLIMINVST has the most dominant effect on WATRINSTN. Such a dominant role can be understandable in the light of the fact that CLIMINVST, the dependent variables in equation [1] feeds into equation [2], signifying sequential linkage between the two pathways as characterized by these equations. As a results, besides its direct effect, CLIMINVST also transmits the effects of all the independent variables in equation [1]. Another point to be noted here is that since CLCIMPACT has simultaneous effects on both equations, it has as both a direct effect on WATRINSTN as well as indirect on the same via CLIMINVST. As can be seen, while direct effect of CLCIMPACT is negative, the indirect effect of CLCIMPACT via CLIMINVST is positive.

Equation [3] represent the impact pathway transmitting the effects of four variables on WATRINFRA. Of the four, two are impact variables (CLCIMPACT and CLIMINVST) and two are policy and institution-related variables (STAXPOLCY and DONINVSTR). Both impact variables have a positive and statistically significant effect. In terms of their relative magnitude, CLIMINVST has the highest impact followed by CLCIMPACT. As noted already, this is mainly due to the fact that CLIMINVST affects WATRINFRA both directly (via equation [3]) and also indirectly (via equation [2]) and both effects are also positive. In terms of the coefficients of two MPG variables, STAXPOLCY has a positive but statistically insignificant effect whereas DONINVSTR has a negative but significant effect. Though the direct effect of DONINVSTR is negative, its indirect effect via CLIMINVST is, however, positive. As we compare the absolute size of its coefficients in equation [1] and [3], the positive effect of DONINVSTR marginally exceeds the negative effect.

Moving to equation [4], it capture the impact pathway in which RSPROVIDR—the MPG variables representing local players providing agricultural and rural services—captures the effects of one impact variable (CLIMINVST) and three MPG variables (AGCRINSTN, STAXPOLCY, and CORPSECTR), representing respectively agricultural credit institutions, state taxation policies, and corporate players involved in agricultural production, processing, trade, and exports. Of the four, CLIMINVST and CORPSECTR have significant positive effects on the growth and performance of RSPROVIDR. In terms of the relative size of their coefficients, CORPSECTR has the largest impact as compared to CLIMINVST despite the latter, as linkage variable, has both direct and indirect impacts. Although the coefficients both AGCRINSTN and STAXPOLCY are negative, unlike the latter, the former is statistically significant. These results imply that, as per the perception of sample stakeholders, while state taxation policies are immaterial, agricultural credit institutions have somewhat an unfavorable role in the development and performance of rural service providers in the study region.

Equation [5] characterizes the pathway in which WATRAVAIL captures the impacts of six variables—one impact variable (CLCIMPACT), two TAO-related variables (CROPSHIFT and DCONVIMOD) and three MPG-related variables (WATRINSTN, WATRINFRA, and CLIMINSYS). Since WATRAVAIL relates to water availability for agricultural sectors, it represents the agricultural component of the water sector. Equation [5] assumes much importance for two reasons. First, it shows how WATRAVAIL captures the direct effects of the two of the three candidate TAOs selected for evaluation, i.e., crop shift to tree and high-value crops and drip irrigation conversion and irrigation modernization. Second, it also captures the impact flows of equations [1], [2], and [3] not only directly via the two institutional variables: WATRINSTN and WATRINFRA but also indirectly via the two impact variables: CLCIMPACT and CLIMINVST, which appear across all the three equations. In terms of statistical significance, however, only three of the six variables perform better. They are: CROPSHIFT, WATRINFRA, and WATRINSTN. While the first two have positive impact and last one has a negative effect. In terms of the absolute size of their coefficients, WATRINFRA has the highest impact followed, then, by CROPSHIFT. This suggests water availability for agriculture can be improved considerably by promoting crop pattern shifts, especially towards tree and other high-value crops and infrastructural development in the water sector, especially related to water storage and inter-basin water transfer. The negative effect of WATRINSTN, in fact, reinforces our earlier observation that current water institutional arrangements are somewhat less effective to enhance water availability to agriculture. Notably, neither the TAO of drip system conversion and irrigation modernization nor the institutional and technical option of climatic information system has any effect on agricultural water availability.

Equation [6] represents the impact pathway in which WATRSUPLY—the other component of water sector related to urban/rural water supply—captures the effects of four variables: CLCIMPACT, WATRAVAIL, WATRINSTN, and WATRINFRA. Obviously, the impact pathway underlying equation [6] captures both the direct and indirect effects of all these and other variables as channeled via the impact pathways represented by all preceding equations. In this respect, it is needless to say that most of the observations made in the context equation [5] are equally valid here as well. All variables, except WATRINSTN, are statistically significant. Going by the absolute size of their coefficients, WATRAVAIL has the highest impact, followed, then, by WATRINFRA and CLCIMPACT. Regarding the signs of the significant variables, while the positive sign for WATRINFRA is clear, the same for WATRAVAIL and CLCIMPACT is somewhat counter-intuitive. This is because the result actually implies that the water availability for household consumption is not negatively affected either by climate change impact or by enhanced water availability for agriculture. Though seems theoretically counter-intuitive, this result can be explained partly in terms of the relatively small share of household water need and partly in terms of the long-standing policy norm for assigning top priority for basic water needs under water scarcity. Besides, under favorable water scenarios, it is natural for water availability to increase for both sectors simultaneously. In any case, it is not reasonable to say anything assertively on this issue without further investigation.

As we move beyond Equation [6], the attention now shifts to the multifarious impact pathways both within and through the agricultural sector. These pathways also tend to display an increasing number of inter-linkages leading to impacts flowing both sequentially and simultaneously across equations. Since such impact flows involve both direct and indirect effects of different sets of variables across equations, the task of evaluating their relative role and significance in the entire impact transmission process becomes more and more complicated. Nevertheless, it is possible to provide an indicative analysis by understanding the linkages that a given equation has with other—both preceding and succeeding—equations and the configuration and statistical behavior of the coefficients of variables that characterize these linked equations or impact pathways.

For instance, equation [7] represents the impact pathway showing how the impact variable AGINSUPLY—agricultural input supply—captures the individual and joint effects of three MPG variables (ARESEXSYS, AGCRINSTN, and RSPROVIDR) and one TAO variable (CONFAMPPP), which represents the third candidate of TAO selected for evaluation, i.e., contract farming and public-private partnership in agriculture. Notably, in view of its functional linkages, equation [7] also captures both the direct and indirect impact flows from other pathways as represented by equations: [4], [9], [12], and [14]. As a result, therefore, the relative behavior and significance of the variables in equation [7] need to the interpreted and understood only in the light of multifarious impact flows. As can be seen from Table 5, all variables, except CONFAMPPP, are significant with expected positive sign, suggesting the adequacy and effectiveness of agricultural input supply are positively influenced by their institutional variables representing respectively agricultural research and extension system, agricultural credit and investment institutions, and rural service providers. CONFAMPPP, the TAO variable, though statistically significant, has a negative effect on AGINSUPLY. This means that though CONFAMPPP usually provides input and technical services, such provision is confined only to a limited area or group of participating farmers. Its sector-wide impact, therefore, cannot be expected to be positive.

Equation [8] represents another critical impact pathway showing how AGPERFORM captures the effects of six variables—four impact variables (CLCIMPACT, WATRAVAIL, WATRSUPLY, and AGINSUPLY) and two MPG variables (CLIMINSYS and LANDTENUR). It is also obvious that equations [8] also captures both the direct and indirect impact flows from three preceding equations: [5] to [7]. All variables, except CLCIMPACT, have statistically significant coefficients. Of them, three have positive effects (WATRAVAIL, WATRSUPLY, and CLIMINSYS) and two have negative effect (AGINSUPLY and LANDTENUR) on the performance of agricultural sector. In terms of the absolute size of their coefficients, WATRAVAIL has the highest impact, followed by WATRAVAIL and CLIMINSYS. The positive coefficients of WATRAVAIL and CLIMINSYS and the negative coefficient of LANDTENUR is understandable. This is in view of the favorable effects of better water availability for agriculture and efficient climate information system and the constraining effects of uneconomic holdings and absence of land markets on improved agricultural sector performance. But the dominant positive effects of WATRSUPLY are contrary to expectation in view of the presumed conflicts in inter-sectoral water allocation. To resolve such contrary behavior, besides the tentative arguments made in the context of equation [5], one also needs to consider the fact that WATRSUPLY also brings here the indirect but dominant effects of both WATRAVAIL and WATRINFRA from equation [5].

Equation [9] highlights an important feature of TAOs. That is, even though they serve as policy instruments, they are not entirely independent because their impacts and performance depend critically on the existence and effectiveness of other institutional, impact, and, even, other TAO variables (see equations [10] and [13]). As can be seen, equation [9] postulates that the performance of CONFAMPPP depends on one impact variable (AGPERFORM) and four MPG or institutional variables (LANDTENUR, WATRINSTN, AGCRINSTN, and RSPROVIDR). Its variable configuration clearly suggests this equation to have strong structural linkages not only with the four equations: [2], [4], [8], and [12] but also with those linked with these equations. This means that equation [9] captures not only the direct effects from these four variables but also the indirect impact flows as captured by them in these equations. Interestingly, all the variables are statistically significant and have the expected sign. In terms of the absolute values of their coefficients, WATRINSTN has the highest impact, followed by LANDTENUR, AGCRINSTN, and AGPERFORM. The positive coefficients associated with the first four variables clearly suggest that facilitative land tenure system[12] and better performing water institutional arrangements and credit and investment policies, and agricultural sector create a conducive climate for the emergence, growth, and performance of contract farming and public-private partnership in agricultural sector. Since the agencies involved in contract and corporate farming meet their own input and service needs from internal sources, there is less scope for the growth of independent and small-scale rural service providers. This fact explains the negative coefficient associated with RSPROVIDR.

The impact pathway represented by Equation [10] also shows how the performance of another TAO related to drip system conversion and irrigation modernization depends on the existence and effectiveness of other impact and institutional variables. Equation [10] also postulates the performance of DCONVIMOD to depend on one impact variable (AGPERFORM) and four MPG or institutional variables (LANDTENUR, WATRINSTN, AGCRINSTN, and RSPROVIDR).[13] Since it has structural linkages not only with equations: [2], [3], [4], and [8] but also with those linked with these four equations, it also captures the multiple impact flows across pathways. All variables, except WATRINFRA and RSPROVIDR, have statistically significant coefficients and expected signs. Among the variables having a positive effect, WATRINSTN has the highest impact, followed by AGPERFORM and LANDTENUR. The positive coefficients associated with the first three variables implies that better

[12] It is to be noted that, like most other variables in the structural model, the nature of the roles and impacts of LANDTENUR as an institutional variable are not uniform across equations, but vary depending considerably on context. For instance, in equation [8], capturing the impact on agricultural performance, LANDTENUR has a negative effect in terms of holding size and lack of rural land markets. But in equation (9), capturing the impact on contract farming and public-private partnership, LANDTENUR has a positive effect in terms of policy changes facilitating long-term land lease from government or rural communities.

[13] Notice the close resemblance between equations [9] and [10], as both of them have the same set of independent variables, except for WATRINFRA.

performing agricultural sector and water institutional arrangements and facilitative land tenure system promote for the expansion and effectiveness of the process of drip system conversion and irrigation modernization. While the explanation for the negative effect of RSPROVIDR provided in the context of equation [9] is equally relevant here, the negative effect of WATRINFRA suggests that prevailing water-related infrastructures, especially those related to water conveyance and delivery systems remain a major constraint for drip system conversion and irrigation modernization.

The impact pathway represented by Equation [11] also show how the performance and impact OF CORPSECTR are influenced by five variables, i.e., two impact variable (CLCIMPACT and CLIMINVST) and two MPG or institutional variables (ATRDREGIM and STAXPOLCY), and one TAO-related variable (DCONVIMOD). Since it has structural linkages not only with equations: [1], [9], and [28] but also with those linked with these equations, it also captures the multiple impact flows across pathways. Of the five variables in [11], only three variables are statistically significant, i.e., ATRDREGIM, CONFAMPPP, and STAXPOLCY. Of these them, ATRDREGIM has the most dominant effect, followed by CONFAMPPP, and STAXPOLCY. This result clearly shows that a favorable trade regime, conducive subsidy and tax policies, and successful contract farming and public-private partnership policies are likely to encourage more extensive involvement of corporate sector. Viewed from another perspective, the results also suggests that corporate farming is essentially oriented towards export and domestic niche markets of high-value crops.

Equation [12] represents the impact pathway that shows how the impact and performance of AGCRINSTN depend on three MPG or institutional variables, i.e., AGENINSTN, DONINVSTR, and CORPSECTR. Of these three institutional variables, the first are completely exogenous (i.e., they do not depend on any other variables in the system), the last one is endogenous or linkage variable bringing impact flows of equation [11] into the present equation. Obviously, all the variables that have affected CORPSECTR in [11] will also positively affect the performance of AGCRINSTN. In terms of statistical significance, all three explanatory variables in equation [12] are significant with expected positive sign. This result suggests that the impact and performance of agricultural credit and investment institutions are positively influenced by supportive agricultural and environmental institution, favorable donor and international investments, and proactive corporate sector.

The impact pathway represented by Equation [13] show how the TAO-related variable CROPSHIFT captures the effects of two TAO-related variable (CONFAMPPP and DCONVIMOD) and seven MPG-related institutional variables (LANDTENUR, WATRINSTN, AMKTREGIM, ATRDREGIM, RSPROVIDR, and CORPSECTR). In terms of structural linkages, equation [13] assumes much significance for two important reasons. First, it is this equation that brings together all three TAO-related variables into a single context. Second, it also captures the impact flows from seven other equations, which are both preceding and succeeding to it, i.e., [2], [4], [9], [10], [11], [28], and [29]. Although all the eight variables included in equation [13] are statistically significant, they have different sign, some consistent with expectations, but others are not. For instance, CONFAMPPP, DCONVIMOD, AMKTREGIM, and CORPSECTR have positive sign, suggesting that contract farming and public-private partnership in agriculture, drip system conversion and irrigation modernization, domestic agricultural marketing regime, and corporate sector participation facilitate crop pattern shift towards tree and high-value crops. But the four MPG-related institutional variables, i.e., LANDTENUR, WATRINSTN, ATRDREGIM, and RSPROVIDR, have negative sign, suggesting that unviable land tenure coupled with the absence of local level rental or lease market for land, ineffective water institutions, export-oriented market regime, and absence of enough rural service providers can discourage crop pattern shift and make this as an ineffective option for transformative adaptation.

Equation [14] represents the impact pathway that show how the impact and performance of ARESEXSYS are affected by the same of one TAO-related variables (CONFAMPPP) and three MPG-related institutional variables (AGENINSTN, CLIMINSYS, and CORPSECTR). Interestingly, this equation captures one among the many layers of linkages among institutional and TAO-related variables. In terms of structural linkages, equation [14] captures the impact flows from equations [9] and [11] respectively via the two variables: CONFAMPPP and CORPSECTR. In terms of statistical significance, all the four variables are significant, though only three have the expected positive sign. Among these statistically significant variables with positive sign CORPSECTR has the highest impact, followed, however, distantly by CLIMINSYS and AGENINSTN. This result suggests that proactive corporate sector, efficient climate information system, and supportive agricultural and environmental institutions can improve the impact and performance of agricultural research and extension system. On the other hand, the negative effect of contract farming and public-private partnership in agriculture that contract and corporate farming, though help with participating or involved farmers, do not contribute much to the overall impact and performance of agricultural research and extension system.

The impact layer represented by equation [15] shows how the emergence and performance of APMKTCOOP depends on three MPG-related institutional variables (AGCRINSTN, RSPROVIDR, and CUSTINSTN). In terms of inter-linkages, equations [15] obviously captures the impact flows from equations [4] and [12] respectively via the two variables RSPROVIDR and AGCRINSTN. Of the three variables, the first two are statistically significant with positive sign whereas the last one is insignificant with negative sign. Of the significant variables with positive sign, RSPROVIDR has the highest impact, followed distantly by AGCRINSTN. The result suggests that although customs and traditions may be a constraint, the functioning and performance of agricultural marketing cooperatives can be enhanced considerably by effective support from various kinds of rural service providers as well as agricultural credit and investment agencies.

As can be seen from Table [5], equation [16] represents yet another layer of linkages essentially within MPG and especially among MPG-related institutional variables. It shows how the performance of AVALCHAIN depends on six MPG-related institutional variables: AGCRINSTN, APMKTCOOP, AMKTREGIM, ATRDREGIM, RSPROVIDR, and CORPSECTR. Of these six variables, the first four represent institutions proper while the last two represent players. It can also be noted that AVALCHAIN can be viewed both as institution and as infrastructure. In terms of structural linkages, equation [16] also captures the impact flows from six other both preceding and succeeding equations: [4], [11], [12], [15], [28], and [29]. It goes without saying that equation [16] also captures the impact flows from still other equations, which are, in turn, linked with these equations. In terms of statistical significance, AGCRINSTN, APMKTCOOP, ATRDREGIM, and RSPROVIDR are significant with positive sign suggesting their favorable effect on the growth and performance of agricultural value chain. But AMKTREGIM and CORPSECTR have negative effect suggesting their unfavorable effects on agricultural value chains. In terms of the relative size of the coefficients of variables with positive effect, ATRDREGIM has the highest impact, followed by APMKTCOOP, RSPROVIDR, and AGCRINSTN. From an overall perspective, these results imply the positive role of agricultural credit and investment institutions, marketing cooperatives, export-oriented trade regime, and strong network of rural service providers. On the other hand, domestic-oriented production and corporate groups with their own and exclusive processing networks have unfavorable effects on the growth and performance of agricultural values chains.

The impact pathway represented by equation [17] shows how the extent and change in CULTIAREA are affected by six variables, i.e., three TAO-related variables (CONFAMPPP, CROPSHIFT, and DCONVIMOD) and three MPG-related institutional variables (LANDTENUR, AVALCHAIN, and

CUSTINSTN). Equation [17] assumes significance as it captures the simultaneous impacts of all three TAO-related variables on CULTIAREA. By virtue of including the four variables, i.e., CONFAMPPP, DCONVIMOD, CROPSHIFT, and AVALCHAIN, equation [17] also captures the impact flows from equations [9], [10], [13], and [16] respectively. Such impact flows are likely to have strong effects both on the significance as well as the magnitude and direction of the coefficients of these and other variables in the present equation. As can be seen from Table 5, all variables, except CUSTINSTN, are statistically significant. Among the statistically significant variables, all have the expected positive sign, except CONFAMPPP. The coefficients with positive sign clearly suggest that the extent of change in cultivated area in the study basin is likely to increase with crop shift to tree and high-value crops, drip system conversion and irrigation modernization, land tenure changes such as long-term land lease from state or remote tribal communities, and expansion of agricultural value chains. The negative effect of CONFAMPPP is somewhat counter-intuitive result because contract farming and corporate agriculture under public-private partnership arrangements are likely to promote cultivated area.

Equation [18] represents the impact pathway wherein the impact variable LANDSQLTY captures both the individual and joint effects of three impact variables (CLCIMPACT, CROPATERN, and LIVSPRODN) and two MPG-related institutional variables (LANDTENUR and ARESEXSYS). Notice that CLCIMPACT and LANDTENUR are exogenous variables whereas others are endogenous or linkage variables, which brings the impact flows from equations [14], [19], and [26] into the present equations. To understand the overall rationale behind the specification of the model in equation [18], some clarification may be added here. For instance, the inclusion of CLCIMPACT is to capture possible effects of soil erosion caused by the vagaries of climatic factors. Similarly, LIVSPRODN is include to capture possible soil quality effects crop-livestock mixed farming in terms of the potential usage of farm biomass residues and farmyard manure. In terms of statistical significance, all variables, except LANDTENUR, are significant. Among the four significant variables, all, except CLCIMPACT, have the expected signs. While LIVSPRODN and ARESEXSYS have a positive sign, CROPATERN has a negative sign. Among the variables with positive sign, LIVSPRODN has the highest impact, followed by ARESEXSYS. The statistically significant positive effects of these two variables suggest that crop-livestock mixed farming and agricultural research and extension system contribute significantly towards improved land and soil quality. But the negative coefficient of CROPATERN suggests that crop pattern with more intensive land use is likely to have a negative effect on land and soil quality. Although CLCIMPACT is expected to have a negative effect on land and soil quality, the results show that it has a positive effect. While such a counter-intuitive result requires more investigation, a possible explanation for the positive effect of on land and soil quality can be potential scope for soil recuperation usually associated with long fallow following droughts or dry conditions.

Equation [19] is another important impact pathway in the system, which, along with other institutional and impact variables, brings together the effects of all three TAO-related variables in one context. It shows how the nature of CROPATERN—whether it is diverse or specialized—depends on the effects on three TAO-related variables (CROPSHIFT, CONFAMPPP, and DCONVIMOD), two impact variables (CULTIAREA and LANDSQLTY), two MPG-related institutional variables (AMKTREGIM and LANDTENUR). While LANDTENUR is an exogenous variable, all the remaining variables are endogenous or linkage variables, bringing here impact flows from other key equations such as: [9], [10], [13], [17], [18], and [29]. As per the results in Table 5, all variables, except CONFAMPPP, have statistically significant coefficients, though they differ in terms of the direction of their effects. The positive coefficients associated with CULTIAREA, CROPSHIFT, DCONVIMOD, and LANDSQLTY suggest that crop pattern in the sense of crop diversity is favorably influenced by increasing cultivated area, crop shifts towards tree and high-value crops, drip system conversion and irrigation modernization, and land and soil quality. The negative effects of AMKTREGIM and LANDTENUR suggest that production system based on larger farm size and oriented towards market regime tend to promote crop specialization. While crop specialization can be good on grounds of productivity, scale economy, and value chain development, it has less ability to cope with the effects of climatic uncertainties.

The next three equations, i.e., [20], [21], and [22], represent pathways that capture the impacts of different variables on three key dimensions of productivity in agriculture sector, i.e., land, water, and labor productivity levels. Taking first equation [20], it represents the impact pathway that show how LANDPRODY is affected by the individual and joint effects of seven variables, i.e., four impact variables (CULTIAREA, CROPATERN, WATRAVAIL, and LANDSQLTY) and three MPG-related institutional variables (AGINSUPLY, ARESEXSYS, and WATRINSTN). Since all these seven variables are endogenous or linkage variables, they are instrumental in bringing the impact flows from the preceding equations in the system, i.e., [2], [5], [7], [13], [14], [17], and [18]. The results show that all variables, except CULTIAREA and AGINSUPLY are statistically significant. All significant variables, except CROPATERN, also have a positive sign. The negative effect of CROPATERN clearly supports the inverse relationship between productivity and crop diversity. Among the variables with statistically significant positive coefficients, LANDSQLTY has the highest impact, followed by WATRAVAIL, ARESEXSYS, and WATRINSTN. The positive effects of WATRAVAIL, ARESEXSYS, LANDSQLTY, and WATRINSTN suggest the productivity-enhancing roles of irrigation water availability, agricultural research and extension system, land and soil quality, and effective water institutions.

Equation [21] represents the impact pathway in which the change in the levels of WATRPRODY is postulated to depend on four impact or impact transmission variables (CULTIAREA, CROPATERN, LANDPRODY, and LANDSQLTY) and three MPG-related institutional variables operating in agricultural and water sectors (AGINSUPLY, ARESEXSYS, and WATRINSTN). Since all these seven variables are endogenous or linkage variables, they are also instrumental in bringing the impact flows from the preceding equations in the system, i.e., [2], [7], [13], [14], [17], [18], and [20]. This means that these variables influence WATRPRODY not only directly through their effects within equation [21] but also indirectly via the effects as captured in other equations listed above. As to the estimated results, all variables, except ARESEXSYS, are statistically significant. Among the six significant variables, four (CROPATERN, LANDPRODY, LANDSQLTY, and WATRINSTN) and two (CULTIAREA and AGINSUPLY) have negative coefficients. In terms of the relative size of coefficients, LANDSQLTY dominates with the highest impact. While the positive effects of the four variables are understandable, the variables with negative effects need attention. The negative effect of CULTIAREA suggests that water productivity tend to be higher when water is used more intensively in a limited area instead of spreading its application over a larger area. On the other hand, the negative effect of AGINSUPLY indicates the agricultural input supply system is not that conducive for improving water productivity, especially when such input supply system implicitly promotes extensive rather than intensive production pattern.

Equation [22] represent yet another impact pathway capturing the productivity impacts. It shows how the levels of LABRPRODY depends on three impact variables (CULTIAREA, CROPATERN, and LANDPRODY) and one MPG-related institutional variable (AGINSUPLY). Since all of them are endogenous of linkage variables, the bring the impacts flows from other equations in the system such as: [7], [13], [17], and [20]. Such linkages obviously tend to affect the magnitude and direction of the impacts of these variables within the present equation. As per the results in Table 5, of the four variables, only two, i.e., LANDPRODY and AGINSUPLY, are statistically significant. Of these two, LANDPRODY has the expected positive sign with highest impacts, but AGINSUPLY has an unexpected negative sign. The positive coefficient of LANDPRODY clearly confirms the positive effects that land productivity has on labor productivity. On the other hand, the negative coefficient of AGINSUPLY can possibly suggest the unfavorable effects of inputs and technologies that tend to favor extensive and labor-intensive cultivation. While this point related to the negative effects of AGINSUPLY is consistent with the same made in the context of equation [21], more information is needed before making any definite conclusion in this regard.

The three previous equations (i.e., [20] to [22]) represent the impact pathways related respectively to the three productivity dimensions, but the next four equations (i.e., [23] to [26]) characterize the impact pathways associated respectively with the four production dimensions, i.e., FOODPRODN, INDCPRODN, FEEDSUPLY, and LIVSPRODN. Although all these four production dimensions are intricately linked in practical contexts, there is need to analytically separate them so as to highlight the differences in terms of their socio-economic significance, climatic exposure, and configuration of underlying factors. That is why food production system is distinguished from that related to the production of industrial and commercial crops (e.g., olive, sugar beets, cotton, argan, etc.). Despite the fact that feed and fodder come as by-products of both production systems noted above, feed production is treated separately not only to highlight the importance of mixed-farming and exclusive fodder-oriented production in the study basin but also to underline their critical role in supporting livestock production. Similarly, livestock production needs separate treatment partly because of its industrial scale operation at the regional level and partly because of its role as a climate adaptation strategy at the local and household levels. Despite its separate treatment within the pathway analysis, livestock production has significant implications not only for food supply via milk and meat but also for agricultural and industrial production via mixed-farming practice (especially in rainfed parts of the study basin), manure supply, and leather-related products. It is, therefore, important to keep these points in mind both in and beyond the context of analyzing the results of the four following equations, i.e., [23] to [26].

Equation [23] represent the impact pathway that captures the individual and interactive various variables on food production. Specifically, this equation shows how the levels of FOODPRODN is affected by the individual and interactive effects of seven variables, i.e., one hand and one TAO-related variable (CONFAMPPP), three impact variables (CULTIAREA, LANDPRODY, and WATRPRODY), and three MPG-related institutional variables (AFPRPOLCY, AGCRINSTN, and RSPROVIDR). Of the seven variables, except AFPRPOLCY, all are endogenous or linkage variables bringing the impact flows from other equations, i.e., [4], [9], [12], [17], [20], and [21]. In view of their linkages, these variables not only have direct effects on FOODPRODN but also transmit the indirect effects other variables as captured through the linkage equations. As can be seen from Table 5, of the seven variables, only four are statistically significant with the expected positive coefficients. These variables are: CULTIAREA, LANDPRODY, WATRPRODY, and RSPROVIDR. Their positive effects clearly suggest that food production is favorably influenced by expanding cultivated area, higher land and water productivity levels, and supportive network of rural service providers. Among the variables that are not significant, while APPRPOLCY has a positive effect, the other two variables, i.e., AGCRINSTN and CONFAMPPP, have negative effect, suggesting both credit and investment institutions and contract and corporate farming are not that oriented towards food production.

Equation [24] characterize the impact pathway that shows how the production variables INDCPRODN captures the individual and joint effects of a configuration of eight variables. They are the three impact variables (CULTIAREA, LANDPRODY, and WATRPRODY) and five MPG-related institutional variables (AMKTREGIM, ATRDREGIM, STAXPOLCY, CORPSECTR, and AVALCHAIN). Of these eight variables, except SYAXPOLCY, all are endogenous or linkage variables, which bring here the impact flows from other equations such as: [11], [16], [17], [20], [21], [28], and [29]. In view of their linkages, these variables, besides their direct effects on INDCPRODN, also bring to bear the indirect effects other variables as captured from the linkage equations. As per the results of Table 5, of the eight variables stipulated to affect INDCPRODN, only four variables, i.e., WATRPRODY, ATRDREGIM, AMKTREGIM, and CORPSECTR, are statistically significant. Of these four, the first two have positive coefficients whereas the last two have negative coefficients. In terms of the relative size of their impacts in absolute terms, AMKTREGIM with negative coefficient has the highest effect, followed closely by ATRDREGIM having the positive coefficient. The positive effects of WATRPRODY and ATRDREGIM actually imply that the levels of INDCPRODN depend more and more on high level of water use efficiency achieved mainly through dependable irrigation with advanced water and irrigation technologies and also export and niche markets. In contrast, the negative effects of AMKTREGIM and CORPSECTR suggest that domestic market regime and corporate sector involvement do not have any favorable effect on the levels of INDCPRODN.

Equation [25] represent the impact pathway that shows how the level of FEEDSUPLY is affected by the individual and joint effects of four impact variables (CULTIAREA, CROPATERN, FOODPRODN, and INDCPRODN) and one MPG-related institutional variables (CUSTINSTN). This pathway underlying equation [25] is important in view of its critical roles role in linking agricultural and livestock sectors. While the rationale for the inclusion of the four impact variables are clear in view of their implications for fodder and feed supply, the variable CUSTINSTN is included to capture the effects of local customary institutions in creating and maintaining community pastures and common grazing lands. In view of its structural and functional linkages, equation [25] also captures the impact flows from four other equations, i.e., [17], [19], [23], and [24]. Going by the results presented in Table 5, all the five variables have statistically significant effects, but vary in terms of the direction of their effects. While two variables (CROPATERN and INDCPRODN) have positive effects, the other three (CULTIAREA, FOODPRODN, and CUSTINSTN) have a negative effect. In terms of the magnitude of effects among the variables with positive coefficient, CROPATERN has the most dominant impact, followed somewhat distantly by INDCPRODN. Among the variables with negative coefficients, CULTIAREA has the largest impact, flowed closely by FOODPRODN. The positive effects suggest that diverse cropping system and industrial and commercial crop production favor feed and fodder supply. But changes in cultivated area and food production are not that conducive for feed and fodder supply. Notably, with the decline in and degradations of community pastures and common grazing lands, customary institutions seem to be loosing their effectiveness in this regard.

Equation [26] characterize the impact pathway that show how LIVSPRODN capture the individual and collective effects of a configuration of six variables, i.e., two impact variables (LIVSIZCOM and FEEDSUPLY) and four MPG-related institutional variables (AGCRINSTN, AMKTREGIM, ATRDREGIM, and CORPSECTR). As can be seen, like other equations, equation [26] asl have structural linkages with five other equations in the system, i.e., [11], [12], [25], [28], and [29]. Obviously, the impact flows from these equations tend to affect both the size, direction, and significance of the variables included in equation [26]. As per the results in Table 5, only four of the six variables are statistically significant. Unfortunately, FEEDSUPLY, despite its positive sign, remains insignificant. All the four significant variables, except AGCRINSTN, also have positive coefficients. In terms of the relative magnitude of the coefficients of the variables with positive effects, CORPSECTR has the largest impact, followed closely by LIVSIZCOM and AMKTREGIM. The variables with positive coefficients suggest that diverse livestock composition, favorable domestic market regime, and expanding corporate investment tend to promote livestock production in particular and livestock sector in general. But the negative coefficient associated with AGCRINSTN suggest the insufficient or ineffective role of agricultural credit institutions in supporting the livestock sector.

Equation [27] characterize the impact pathway associated with another key component of rural economy, i.e., agriculture-based rural non-farm sector, which plays a critical role in rural economic transformation as mediating and transitory mechanism between agricultural and industrial sectors within rural context. It shows how the emergence and performance of AGNFSECTR are affected by the separate and collective effects of a configuration of five variables, i.e., two production-related impact variables (FOODPRODN and INDCPRODN) and three MPG-related institutional variables (AGCRINSTN, AVALCHAIN, and CORPSECTR). In view of its structural functional linkages, equation [27] captures the impact flows of five other equations in the system, i.e., [11], [12], [16], [23], and [24]. Such impact flows obviously tend to affect both the size, direction, and significance of the variables included in equation [27]. As can be seen in Table 5, of the five variables in equation [27], only four are statistically significant. Among the four significant variables, INDCPRODN, AGCRINSTN, and AVALCHAIN have positive coefficients whereas CORPSECTR has a negative coefficient. In terms of the relative magnitude of the coefficients of the variables with positive effects, INDCPRODN has the largest impact, followed closely by AVALCHAIN and AGCRINSTN. The variables with positive effects suggest that the emergence and performance of rural non-farm enterprises are favorably influenced by industrial and commercial crops-oriented production system, facilitative credit and investment institutions, and conducive value chain networks. While this result is on expected line, the negative coefficient of CORPSECTR suggests the lack of any substantial involvement of corporate sector in rural non-farm activities, possibly due to them being informal in nature and less appealing for large scale corporate investment. Notably, in contrast to its negative role with regard to rural non-farm activities, CORPSECTR had a positive role in livestock production. Likewise, AGCRINSTN, which had a negative effect on livestock production, has a positive effect on rural non-farm enterprises.

Equations [28], [29], and [30] assume significance because they characterize the impact pathways associated respectively with three key dimensions of agricultural market, i.e., international trade regime (ATRDREGIM), domestic market regime (AMKTREGIM), and overall marker price levels for major agricultural products (AMKTPRICE). For instance, equation [28] specifically postulates how the nature and effectiveness of ATRDREGIM are affected by four variables, i.e., three production-related impact variables (FOODPRODN, LIVSPRODN, and INDCPRODN) and one MPG-related institutional variable (CORPSECTR). In view of its structural linkages, equation [28] captures the impact flows from equations [11], [23], [24], and [26]. Such multiple impact flows are likely to affect the relative size, direction, and significance of the included. As per the results in Table 5, among the four variables in equation [28], only three are statistically significant.[14] They are: FOODPRODN, INDCPRODN, and LIVSPRODN. Of the significant ones, the first two have positive coefficients while the last one has a negative coefficient. In terms of the relative magnitude of their coefficients, INDCPRODN has the largest impact, followed closely by FOODPRODN. The results suggest that agricultural trade regime is being positively influenced by both food and industrial and commercial-oriented production systems.[15] In view of the two-way relationships, the negative coefficient of LIVSPRODN suggest that a trade regime favoring meat import is likely to have an unfavorable impact of domestic livestock production. Looking from another angle, increasing domestic livestock production or achieving self-sufficiency in milk and meat consumption tend to dampen the import dimension of the agricultural trade regime.

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[14] Notably, CORPSECTR, though had a positive coefficient, remains statistically not significant, possibly due to insufficient involvement of corporate sector in agricultural trade.

[15] It is also equally reasonable to consider the positive effects can be a two-way process. That is, both food and industrial and commercial-oriented production systems are also being positively influenced by agricultural trade regime.

Equation [29] represents the impact pathway that stipulates how the nature and effectiveness of AMKTREGIM are affected by a configuration of five variables, i.e., three production-related impact variables (FOODPRODN, LIVSPRODN, and INDCPRODN) and two MPG-related institutional variables (AFPRPOLCY and ATRDREGIM). Since all of them, except AFPRPOLCY, are endogenous or linkage variables, equation [29] also captures the impact flows from equations [23], [24], [26], and [28]. As can be seen from the results presented in Table 5, only three of the five variables are statistically significant. They are: FOODPRODN, INDCPRODN, and LIVSPRODN. Of the significant ones, the first two have positive coefficients while the last one has a negative coefficient. It can be noted that the pattern and behavior of these variables remain the same in both equations: [28] and [29]. Obviously, all the observations made in the context of previous equations—including the one on the two-way flow of effects—apply equally here as well, with the only difference being the focus here is on the nature and performance of domestic market regime. This result also suggests that the configurations of significant variables affecting both trade and market regimes remain same. Despite their positive coefficient, both AFPRPOLCY AND ATRDREGIM remain statistically insignificant. This could possibly imply weak nature of agricultural and food price policies on the one hand and lack of integration between domestic and international spheres of agricultural marketing and trade.

Equation [30] captures yet another impact pathways that captures the interactions only within the MPG structure or among the MPG-related institutional variables. It shows how the level and effectiveness of AMKTPRICE are being affected by the individual and joint effects of a configuration of four MPG-related institutional variables (AFPRPOLCY, STAXPOLCY, AMKTREGIM, and ATRDREGIM). While the first two are exogenous variables, the last two are endogenous or linkage variable, bringing here the impact flows from the previous two equations, i.e., [28], and [29]. The 3-SLS estimate of this equation, as presented in Table 5, shows that all the four variables have statistically significant coefficients, though with different signs. While STAXPOLCY and AMKTREGIM have positive coefficients, AFPRPOLCY and ATRDREGIM have negative coefficient. In terms of the relative magnitude of the effect of variables with positive coefficients, AMKTREGIM has the highest impact, followed distantly by STAXPOLCY. On the negative side, ATRDREGIM has the largest impact, followed distantly by AFPRPOLCY. The variables with positive coefficients suggest that a robust domestic agricultural market regime coupled with effective subsidy and taxation policies tend to improve the level and effectiveness of the market prices of agricultural products. Interestingly, it seems that the combined effects of these two factors could even counter the negative effects emanating from the less integrated export trade regime and weak agricultural and food price policies.

Equation [31] represent another intermediate impact pathway wherein CULTICOST is postulated to capture the individual and interactive effects of three impact variables (CULTIAREA, CROPATERN, and AGINSUPLY) and two MPG-related institutional variables (STAXPOLCY and CREMINSUR). The rationale behind the inclusion of the three impact variables is, more or less, clear. The institutional variables are included as explanatory variables mainly to capture the impacts of subsidy and taxation policies and crop and employment insurance schemes on the level of cultivation costs from a generic perspective. As per the estimates of this equation in Table 5, all variables, except CREMINSUR, have statistically significant coefficients, but with different signs. Since the positive coefficient of CULTIAREA means the cultivations costs to increase with increasing in area cultivated, the implication is the absence of any significant area-based scale economy on the cost side. On the other hand, since the negative coefficient of CROPATERN suggests that diverse crop patterns tend to reduce average cultivation costs, there is considerable scope for crop composition-based scale economy on the same. But the positive coefficients associated with AGINSUPLY and STAXPOLCY look counter-intuitive as one would expect them to have inverse relations with cultivations costs. Such unexpected outcome cannot be avoided altogether, particularly when the agricultural input supply system and subsidy and taxation policies are weak and ineffective to counter factors that tend to distort real effects. To identify and understand these distorted factors, more information is needed on the entire impact chains operating around the impact and institutional variables suffering from such distorted impacts.

Equation [32] represents the impact pathway that shows how the level of CROPINCOM is affected by the individual and interactive effects of a configuration of seven variables. They include five physical and economic impact-related variables (CULTIAREA, CROPATERN, LANDPRODY, CULTICOST, and AMKTPRICE) and two MPG-related institutional variables (AVALCHAIN and CREMINSUR). Like most other equations in the system model, equation [32] also has structural linkages with six other equations, i.e., [16], [17], [19], [20], [29], and [31]. By capturing the impact flows from these equations, equation [32] captures both the direct effects of its independent variables as well as the indirect effects of other variables as captured by the set of independent from other equations.[16] Looking at the 3-SLS estimate of this equation presented in Table 5, it is clear only four of the seven variables in equation [32] are statistically significant with different and somewhat unexpected signs. For instance, as one would expect, the positive signs of AMKTPRICE and CREMINSUR suggest that agricultural market regime and crop and employment insurance policies have strong and favorable impacts on the income level from crop enterprises. However, the positive effect of CULTIAREA, though explicitly indicates a direct association between area cultivated and crop income level, implicitly means that crop income can increase essentially through area expansion rather than through productivity enhancement. This argument is supported indeed by the positive but insignificance coefficient of LANDPRODY. Similarly, the negative sign of CROPATERN suggests that crop diversity, though favors cost reduction, tend to reduce, at the same time, the level of farmers' income from crop cultivation.

The impact pathway represented by equation [33] shows how RURALWAGE captures the multifarious effects of five impact variables (LABRPRODY, FOODPRODN, INDCPRODN, LIVSPRODN, and AGNFSECTR) and one MPG-related institutional variable (AGWAGELAW). As can be seen, while the first four impact variables are related to productivity and production-related aspects, the last one is related to the performance of rural non-farm sector. Since all these five impact variables are endogenous or linkage variables, they also bring to here the impact flows from five preceding equations, i.e., [22], [23], [24], [26], and [27]. As can be seen from Table 5, of the five variables in equations [33], only three are statistically significant. Of these significant variables, LABRPRODY and AGNFSECTR have positive coefficients, but INDCPRODN has a negative coefficient. While the positive coefficient of LABRPRODY indicates the economic implications of higher labor productivity for rural wage level, the same for AGNFSECTR suggests the favorable effects of potential competition that rural non-farm enterprises create in rural labor market and its implications for rural wage level. The negative effects of INDCPRODN, on the other hand, can be explained in terms of labor-intensive practices involving cheaper labor in industrial and commercial crop production systems. Going by the relative size and direction of the impacts of these three variables, even though the negative effect is dominant, when one takes into account the combined impact, it is possible to see an overall net positive impact.

Equation [34] represents one of among the important impact pathways in terms of its extensive structural linkages with other equations in the system model. It captures of functional relationship

[16] It is possible to hypothesize that the relative nature and levels of the direct and indirect effects of these variables determine the size, direction, and statistical significance of their coefficients. For instance, if the direct effect of a given variable remains positive and exceeds its indirect but negative effect, then, the variable is likely to have a positive coefficient. Obviously, for a contrary situation, the reverse would be the case. However, if both the direct and indirect effects of a variable is insignificant or if either effect is too weak to be significant, then, the variable is likely to have an insignificant coefficient.

between RURALJOBS and a configuration of eight variables. These include two productivity-related impact variables (LANDPRODY and LABRPRODY), three production-related impact variables (FOODPRODN, INDCPRODN, and LIVSPRODN), two other impact variables (RURALWAGE and AGNFSECTR), and one MPG-related policy or institutional variable (CREMINSUR). All eight variables, except CREMINSUR, are endogenous and linkage variables in the sense that they are, in turn, affected by different configurations of other variables in the system. Equation [34], therefore, has structural linkages with equations: [20], [22], [23], [24], [26], [27], and [33]. As per the estimated results in Table 5, only five of the eight variables in equations [34] are statistically significant. Of these significant variables, RURALWAGE INDCPRODN, and CREMINSUR have positive coefficients. In terms of the relative size of impacts, INDCPRODN has the largest impact, followed by RURALWAGE and CREMINSUR. In contrast, LABRPRODY and AGNFSECTR, however, have negative coefficients. In terms of the relative size, LABRPRODY dominates over AGNFSECTR. It can be noted that INDCPRODN, which is shown to have an inverse relationship with rural wage level in equation [33], has a positive association with rural job level. This result read along with the negative coefficient of LABRPRODY implies that in the study basin, low levels of employment co-exist high wage and low productivity levels. The negative coefficient of AGNFSECTR suggests the expansion of rural non-farm enterprises can, at best, affect only the sectoral composition of rural jobs (i.e., by shifting labor force across sectors), but may not enhance the overall level of rural jobs. Taken together, the overall implication of these results is that labour force in the study basin remains, more or less, in a low-equilibrium state both in terms of productivity, wage rate, and employment. However, the bright side here is the positive role that crop and employment insurance policies play in promoting rural employment.

Our analysis has now reached the most important segment of the system model, wherein the focus is on five penultimate impact variables: FARMINCOM, LABRINCOM, FOODAVAIL, FOODPRICE, and WATRSECUR. As per our conceptualization of rural welfare at the household level, it is these five critical variables that actually represent the three key dimensions of rural welfare, i.e., income adequacy, food accessibility, and water as basic needs. These five variables are represented respectively by the five equations, i.e., [35], [36], [37], [38], and [39]. As can be seen in Figure 4, taken together, these five equations that capture and transmit the multifarious impact flows from all the intermediate pathways—as characterized by all the previous 34 equations—on the ultimate impact variable or policy goal, i.e., RURWELFAR. Understandably, equation [40], representing the ultimate impact variable RURWEFAR, is defined by all the five penultimate impact variables.

The pathway represented by Equation [35] captures the impact flows on FARMINCOM, which is one of the five penultimate impact variables. Since FARMINCOM relates to farmers' income at the household level, it includes income both from crop and livestock enterprises as well as from rural non-farm sector and government safetynet programs. As such, FARMINCOM is stipulated to depend on three sector-related impact variables (CROPINCOM, LIVSPRODN, and AGNFSECTR) and one policy-related institutional variable (SNETPOLCY). Through the three impact variables, equation [35] captures the impact flows both from the three equations: [26], [27], and [32] and also from those equations, which are, in turn, linked with these three equations themselves. As can be seen from Table 5, the 3-SLS estimate of equation [35] shows all the four variables have statistically significant coefficients and all of them, except AGNFSECTR, also have positive signs. As to the relative magnitude of impacts, CROPINCOM and LIVSPRODN have larger and, more or less, similar level of impact as compared to SNETPOLCY. In any event, the results clearly suggest that income from crop and livestock sources as well as the same from government safetynet policies have significant favorable impacts on farmers' income at household level. However, the negative coefficient associated with AGNFSECTR implies a tradeoff between non-farm income and overall household income, which means the income from non-farm participation is either relatively low or such income is realized only at the expense of the same from crop and livestock activities. It may also mean that those participating in non-farm activities do not have much income scope from crop and livestock activities. But clearer explanation in this respect requires more information.

Equation [36] represents the pathway that captures the impact flows on LABRINCOM, which is another penultimate impact variable. LABRINCOM is related to the household income of those who do not have land or crop enterprises. It covers income from wage employment, livestock and non-farm participation, and government programs such as employment insurance and safetynet programs. It is on this rationale that LABRINCOM is postulated to depend on two wage employment-related impact variables (RURALJOBS and RURALWAGE), two sector-related impact variables (LIVSPRODN and AGNFSECTR), and two MPG-related policy variables (CREMINSUR and SNETPOLCY). Of these six variables, only three are endogenous or linkage variables that brings the impact flows not only from three other equations: [26], [27], and [34] but also from those having linkages with these three equations themselves. As per the 3-SLS results in Table 5, only three variables have statistically significant coefficients with two of them having positive signs. Among the significant variables, RURALWAGE has a more dominant effect, though CREMINSUR also has substantial impact. This result clearly suggests that household income of farm workers depend more on wage level and government employment insurance than on the level of employment or income from livestock sector. As in equation [35], AGNFSECTR, again, has a negative coefficient. In this respect, the arguments and caveats made in the context of equation [35] can equally apply here as well.

The next two equations represent the impact pathways related to the food or consumption dimension of rural welfare. They deal respectively with the two sides of food accessibility, i.e., food availability and food price. While equation [37] captures the impact flows on the supply side of food accessibility, [38] captures the same on the demand side of food accessibility. Equation [37] shows how FOODAVAIL is affected by three sector-related impact variables (FOODPRODN, LIVSPRODN, and INDCPRODN) and two MPG-related institutional variables (AMKTREGIM and ATRDREGIM). While the sector-related variables capture production conditions affecting the supply levels of cereals, vegetables, meat, milk, sugar, etc., the institutional variables capture the market conditions affecting domestic markets and international trade. Since all the variables in equation [37] are endogenous or linkages variables, they bring the impact flows both from [23], [24], [26], [28], and [29] as well as those that are linked with these five equations themselves. As can be seen in Table 5, the 3-SLS estimate of this equation shows four of the five variables are statistically significant. Of them, while FOODPRODN and AMKTREGIM have positive coefficients, LIVSPRODN and ATRDREGIM have negative coefficients. The results clearly suggest that food availability depends more on the supply conditions related to food crops and market conditions related to price levels of food crops. In contrast, the supply conditions related to livestock production and market conditions affecting agricultural trade seem to have negative effects on food availability. From an overall perspective, as one goes by the relative magnitude and direction of all coefficients, positive effects are very dominant to more than counterbalance the negative effects.

As noted above, equation [38], capturing the impacts on food price levels, covers the demand side of food accessibility. It shows how the level of FOODPRICE affected by two food supply-related impact variables (FOODPRODN and FOODAVAIL) and two MPG-related institutional variables affecting market and price conditions (AMKTREGIM and AFPRPOLCY). Since three of the four variables in equation [38] are endogenous or linkages variables, they bring the impact flows both from equations [23], [29], and [37] as well as those linked with these equations within the system model. As per the 3-SLS estimate of this equation presented in Table 5, only three of the four variables are statistically significant with two of them (FOODPRODN and FOODAVAIL) having positive coefficients and the other (AMKTREGIM) showing coefficient. While the native effect of AMKTREGIME is on expected lines, the positive effects of both FOODPRODN and FOODAVAIL are unexpected and counterintuitive as one would reasonably expect them to have an inverse relationship. This is because higher food production and food availability tend to reduce food price levels. But, if one considers the reverse side of the two-way flow of impacts, the result can be consistent in the sense that higher food prices tend to enhance both food production and food availability. This is an important insight that underlines the two-way nature of impact flows with both forward and reverse feedback.

Equation [39], which represents the impact pathway affecting the extent and degree of water security, captures the role of water in the basic need dimension of rural welfare. It shows how the extent and degree of WATRSECUR is affected by the individual and interactive effects of five variables, i.e., two climate and water-related impact variables (CLCIMPACT and WATRSUPLY) and three MPG-related institutional variables (WATRINFRA, WATRINSTN, and CUSTINSTN). Since three of these five variables in equation [39] are endogenous or linkages variables, they bring the impact flows both from equations [2], [3], and [6] as well as those that are linked with these equations in the system. The 3-SLS estimate of this equation, as presented in Table 5, shows variables, except WATRINFRA, have statistically significant coefficients. Among these significant variables, WATRSUPLY and WATRINSTN have positive coefficients, but CLCIMPACT and CUSTINSTN have negative coefficients. As one would expect, the negative effects of CLCIMPACT confirm the inverse relationship that water security has with climate change. On the other hand, the positive effects of WATRSUPLY and WATRINSTN is consistent with the positive association that water security has with better water availability of household use and effective water institutions that assign top priority for fulfilling water demand for basic needs. The negative effect of CUSTINSTN suggests the declining significance of customary institutions in ensuring household level water security.

Turning now to equation [40], it is the final equation that ultimately captures the impact flows across all the pathways in the system. As noted already, it shows how the overall rural welfare is determined by five variables that capture the impacts on three key dimensions of rural welfare, i.e., income level, food consumption, and water as basic needs. In formal terms, equation [40] stipulates that the level and status of RURWELFAR is affected by the individual and joint effects of a configuration of five variables, i.e., two income-related impact variables (FARMINCOM and LABRINCOM), two food-related impact variables (FOODAVAIL and FOODPRICE), one impact variable capturing water as basic needs (WATRSECUR).[17] Through these five variables, equation [40] is obviously with all the five penultimate equations, i.e., [35], [36], [37], [38], and [39]. Through these five equations, equation [40] is also linked with all the equations in the system. By virtue of these linkages, therefore, equation [40] is the ultimate pathway that captures together the impact flows across all equations in the entire system. Such transmitted impact flows are likely to get reflected in size, direction, and significance of the coefficients of the five variables in equation [40]. The 3-SLS estimate of equation [40], as presented in Table 5, shows that all the five variables have statistically significant coefficients, that too, with signs that are on expected lines. While FARMINCOM, FOODAVAIL, and WATRSECUR have positive coefficients, LABRINCOM and FOODPRICE have negative effects. The results suggest rural welfare to have direct and favorable association with the level of farm income, food availability, and water security. In contrast, the same has an inverse or unfavorable relationship with the level of labor

[17] Notie the contextual character of equation [40]. That is, the configuration of variables will vary, depending on the occupational pattern of households. For those households relying only on wage labour, FARMINCOM will be absent. Similarly, for those farm households, which do not involve in wage employment, LABRINCOM will be absent. But for all other rural households, all five variables will apply. We can also note that in the case of those who involve neither in farming not wage labor, only the last three variables will apply.

income and food prices. Notably, the welfare implications of food prices are universal in the sense that they affect all households. But that of labour income also are specific only to non-farming households, which rely exclusively on wage and other non-farm sectors as income sources. It is these latter households that are particularly vulnerable from a welfare perspective.

9. Concluding Remarks with Policy Implications

Building on the earlier analytical and empirical works of Saleth, et al., (2007), Saleth and Dinar (2009), and Saleth, Dinar, and Frisbee (2011), this study has made an attempt to develop and empirically apply an innovative methodology. This methodology is rooted in an analytical framework that delineates various possible pathways through which the impacts of climate change are transmitted ultimately on rural welfare at the grassroots level. Since these impact pathways are being characterized by various configurations of climatic, economic, policy, technical, institutional, infrastructural, and welfare-related variables, they provide an excellent operational context not only for incorporating various elements of the MPG structure within a unified context but also for evaluating their roles in mediating and enhancing the climate resilience impacts of TAOs both across regional scales and sectoral contexts.

Notably, in contrast to prevalent approaches in current climate adaptation literature, the impact pathway-based analytical framework enables one to evaluate the welfare impacts of climate resilient coping and adaptation strategies in a more dynamic and interactive context. Clearly, the impact pathways, taken together, constitute the basic building blocks of the analytical framework underlying our evaluation methodology. By defining appropriate variables within relevant empirical context, these impact pathways can be formalized as an inter-related set of equations. Such an equation system can represent a mathematical analogue of the analytical framework, which is capable of being empirically estimated with appropriate data. For piloting the study and practical application and demonstration of its evaluation methodology, the Oum Er-Rbia Basin in Morocco is selected as an empirical context. The study basin and the sample country are selected in line with the main objectives of the study.

Morocco is a more appropriate for a case study of evaluating the welfare implications of climate resilient strategies on the following grounds, First, Morocco is highly susceptible to climatic risks as 93% of its area under arid and semi-arid conditions. Second, with a 20-percent reduction in rainfall and frequent droughts over the years, the precariously placed Moroccan agriculture faces severe welfare and food security implications. And, finally but more importantly, Morocco is also one among a few pioneering countries that have already implemented several TAOs under its three major programs, i.e., Green Morocco Plan (2010-20), National Irrigation Water Saving Program (since 2009-10), and Green Generation Plan (2020-30).

Similarly, within Morocco, the Oum Er-Rbia basin is selected as the study basin on the following reasoning. First, although it is only the third largest among the 12 river basins of Morocco, it is critical for total food and agricultural production in Morocco with a third each of total harvested area and irrigated area in the country and highest share in the production of all cereals, except wheat. And second, among all basins in Morocco, Oum Er-Rbia basin is extremely vulnerable to the impacts of climate change. Historical data suggest that the basin has experienced a 20% reduction in rainfall and a 40 to 49% decline in annual flow. All these factors tend to affect agricultural and food production with serious food and welfare implications both within and beyond the basins. Given the vast size of the study basin and the associated logistical problems, the Beni Mellal-Khenifra region, which accounts for the major share of agricultural areas within the basin, was selected as the study region. This region covers five provinces, i.e., Azilal, Beni Mellal, Fquih Ben Salah, Khenifra, and Khouribga.

While field visits were conducted in all five provinces, the sample selection and data collection covered all regional scales and sectoral context, going beyond the study region *per se*.

Once the empirical context is identified and it's the climatic, water, agricultural, and governance realities are reviewed, it is rather straightforward to develop the evaluation methodology. The evaluation methodology has three components: (a) analytical framework, (b) mathematical model, and (c) empirical approach. The basic building blocks of the analytical framework are impact pathways and their underlying chains of variables. As to the content of the analytical framework that is to be empirically applied in the context of the study region, besides the trigger element of climate change and the ultimate impact variable or policy goal of rural welfare, it covers three sectors, three sets each of TAOs and MPG structure elements, and several impact or impact transmission variables. The three sectors are: water, agriculture, water supply. However, other sectors such as livestock and rural non-farm enterprises are covered implicitly as part of the impact variables. The three TAOs are: (a) contract farming and public-private partnership in agriculture, (b) shift to tree and high-value crops, and (d) drip system conversion and irrigation modernization.

The MPG structure is represented by three groups, i.e., institutions (laws, policies, and organizations), infrastructures (water, agriculture, and environment), and players (the state, corporate sector, service providers, and civil society organizations) operating across regional scales and sectoral contexts. The three governance elements are, in turn, represented by a total of 20 institutional, infrastructural, and player-related variables. The impact or impact transmission variables that are mostly related to production, productivity, cost, and income-related aspects. These aspects are represented by 24 variables. Thus, taken together, the analytical framework captures the structural linkages and interactive effects of a total of 52 variables. It is the different configurations of these variables that characterize various possible pathways linking climate impact and social welfare.

The analytical framework and the mathematical model of CC-TAO-MPG-RW are closely linked. This is because by tracing all possible impact pathways and by defining each of the by using the 52 variables, the analytical framework can be translated into a mathematical model with a set of 40 sequentially and simultaneously inter-linked equations. These equations, which are defined by different configurations of variables, characterize, in fact, most of the important layers operating in the process of CC-TAO-MPG-RW interactions in the study basin. The analytical framework and its mathematical representation constitute only the two components of the evaluation methodology. The other, but more important, component relates to the empirical approach that is used to generate data needed for the numerical estimation of the mathematical model involving a system of sequentially and simultaneously linked equations.

The empirical approach involves major challenges as most of the 52 variables are inherently *ex-ante* nature. Observed data on them are either absent or irrelevant as such data remain static, outdated, and devoid of any expectational considerations. Absence of lack of observed data on most variables does not mean there is a complete absence of information because highly relevant information is constantly being processed, coded, and stored as perceptions in the minds of planners, experts, evaluators, and beneficiaries, and, even, informed common observers. The empirical approach underlying the evaluation methodology is, in fact, trying to elicit such valuable information from a suitable sample of stakeholders using a well-designed questionnaire. Notably, the use of perception-based data has a strong theoretical legitimacy and their reliance in empirical application and policy analysis also has a long tradition.

While the rationale and legitimacy of subjective and perception-based data is clear, it is important to recognize the way such information is elicited and recorded in the practical context of the study region. The questionnaire covers a total of 300 questions, involving nine identifier variables related to respondents' characteristics and 291 sub-variables to gather information on the 52 model variables from different angles and perspectives. While the identifier variables are recorded as real numbers, 291 sub-variables are recorded on a 0-10 scale, with zero denoting no effect and 10 denoting the highest possible impact. The questionnaire was administered to collect perception data from a purposive sample of 176 stakeholders spread both within and outside the study basin and having diverse background. Thus, the original dataset has a dimension of 176 by 300. However, since the 291 sub-variables are related to the different aspects of the 52 model variables, they were summarized using simple average. Thus, the final dataset, which was used for estimating the system model, has a dimension of 176 by 61.

With the finalization of the dataset, several diagnostic tests were performed on each of the individual equation of the structural model for evaluating their distributional and other econometric properties. After confirming the reasonable performance of individual equations, the system model with 40 inter-linked equations was estimated using a 3-SLS procedure by assuming four different functional forms (linear vs. logarithmic and constant vs. no constant). Of these alternative estimates, the one with a linear form and no constant term was selected based on criteria such as model fit, explanatory power, and estimation consistency. The results are interesting and highly significant. Going by very high R^2 and χ^2 values in the case of all model equations clearly suggest that the configurations of variables included in them are not only statistically significant but also explain almost all the variations in their respective dependent variables.

The equation-specific analysis of the 3-SLS results provides considerable insights on the relative size, direction and significance of different variables included in the model as well as the relative strength or weakness of inter-linkages among variables and impact flows across pathways. Looking from an overall perspective, of the 209 coefficients in the system model, 163 (78%) are statistically significant at 90% level or better. Only the remaining 46 (22%) are statistically insignificant. It is the information on the size, sign, and statistically significance of the coefficients in different equations that will be used to evaluate the relative role and significance of different policy, institutional, and impact variables that characterize different impact pathways. More importantly, both the overall as well as equation-specific 3-SLS results strongly attest not only to the robustness of individual equations representing different impact pathways but also to empirical validity of the system model that represents the analytical framework as such.

Before highlighting some of the important policy implications of the results from the system model, it is necessary to acknowledge some of the major limitations of the present attempt.

(1) The study evaluates only the grassroots level impacts of climate change essentially within the sectoral setting of agriculture, though other related sectors such as water, livestock, non-farm enterprises, and market and trade are also treated both implicitly and explicitly. Given such a focus, social welfare is defined only in the restricted sense of rural welfare.

(2) Obviously, the pathways between climate impact and rural welfare are many and varied. But the present study has considered only 40 of these pathways, which are the most important from economic and welfare policy perspectives.

(3) While the MPG structure covers myriad elements, are many vast, the present study has included only a select set within each of the three governance components, i.e., institutions, infrastructures, and players.

(4) The same is also the case with TAOs, as the candidate TAOs selected for evaluation are only a few among other possible ones.

(5) And, Finally, but more importantly, most of the variables defined to represent the sectors, TAOs, MPG elements, and impacts are in a composite or notional form. For instance, water institutions are taken as a single entity, though they have many distinct elements in reality (e.g., water rights, water law, water pricing, basin organization, etc.). Such conceptualization is inevitable given an ambitious analytical framework that tries to cover a total of 52 elements representing climate change, three sectors, three TAOs, 20 MPG-related elements, 22 impact variables, and rural welfare within a single framework.

Keeping the limitations of the present attempt as caveats and recognizing well the preliminary and tentative nature of the econometric results, let us list some of the important and policy-relevant implications of empirical results presented in this study. For a better understanding, the implications are listed by equations.

(1) Climate investments are positively influenced not only by climate change impact but also by government institutions—especially those operating in agricultural and environmental sectors—and donor agencies and international investors. Notably, government institutions play a more dominant role.

(2) Climate investments followed by customary institutions have a dominant effect on the overall performance of water institution. This fact, taken along with the negative effect of climate change, suggests that without substantial investment and significant improvement, existing water institutions in the study basin are under extreme stress due to the challenges of climate change.

(3) The performance of water infrastructure is favorably influenced by climate investment, followed by climate change and state subsidy and tax policies. Climate investment, again, has the highest positive impact as it has both direct effects and as well as capture and brings here the indirect effects of other variables. This suggests some synergy effects of impact flows across pathways. Notably, climate change, which had a negative effect on water institutions, now has a positive effect, suggesting the potential pressure that climate impacts tend to create for additional investment in or improved maintenance of water infrastructure.

(4) Regarding the growth and performance of rural service providers, corporate sector and climate investment play positive roles. But state taxation policies are immaterial whereas agricultural credit institutions have somewhat an unfavorable role. From a policy perspective, therefore, it is these two weak MPG elements that are to strengthen and reoriented for promoting the growth of rural service providers in the study basin.

(5) The extent of water availability for agriculture can be improved considerably by promoting the TAO involving crop pattern shifts, especially towards tree and other high-value crops and infrastructural development in the water sector, especially related to water storage and inter-basin water transfer. But water institutions, especially those related to inter-sectoral allocation, remain a significant constraint for enhancing water availability for agriculture. The insignificant and unexpected effects of the other TAO related to drip system conversion and irrigation modernization and the technical option of climatic information system suggest the need to investigate the missing or unfavorable conditions that limit expected impacts.

(6) Interestingly, water availability for household consumption is not negatively affected either by climate change impact or by enhanced water availability for agriculture. Though looks counter-intuitive, this result can be explained partly in terms of the relatively small share of

household water need and partly in terms of the long-standing policy norm for assigning top priority for basic water needs under water scarcity. Also, under favorable water scenarios, it is natural for water availability to increase for both sectors simultaneously. In any case, a closer investigation is needed to reach a firm conclusion in this respect.

(7) The adequacy and effectiveness of agricultural input supply system are positively influenced by three MPG elements, representing respectively agricultural research and extension system, agricultural credit and investment institutions, and rural service providers. The negative effect of the TAO involving contract farming and public-private partnership in agriculture suggests the fact that the TAO provides input and technical services, they are confined only to a limited areas or groups with participating farmers. Its sector-wide impact, therefore, cannot be expected to be positive.

(8) The main factors having a favorable effect on the overall performance of agricultural sector are a better availability of water, efficient climate information system, and the facilitative land tenure conditions. The positive effects of increasing allocation to household consumption on agricultural performance, though seems contrary to expectations, it can be a possible outcome of a more efficient water use in the face of water scarcity associated with an increasing water allocation to household use. In this respect, one also needs to the fact that against its negative direct effects, water supply for household consumption as a linkage variable also brings here the indirect but dominant positive effects of the variables representing both water availability for agriculture and water infrastructures from previous equations.

(9) The effectiveness and impacts of the TAO involving contract farming and public-private can be improved with a facilitative land tenure system, especially the policy changes allowing long-term land lease from government or rural communities, and better performing water institutions and credit and investment policies. This is an illustration of how the performance of TAOs is intricately linked with the existence and effectiveness of MPG-related institutional variables as well those related to impact and, even, other TAOs.

(10) Like the TAO noted above, the effectiveness and impacts of the TAO involving drip system conversion and irrigation modernization are positively linked with a better performing agricultural sector and water institutional arrangements as well as a facilitative land tenure system, especially the landholding pattern in large irrigation perimeters. But a lack of relevant service providers and the constraining nature of the prevailing water-related infrastructures, especially those related to water conveyance and delivery systems tend to reduce the expansion and effectiveness of the TAO related to drip system conversion and irrigation modernization.

(11) Although the corporate sector, as a player, is one among the key elements of the MPG structure, it is not independent because its extent and effectiveness of involvement in agricultural sector are affected by several other factors. In this respect, a favorable external trade regime, conducive subsidy and tax policies, and successful contract farming and public-private partnership policies are likely to encourage more extensive involvement of corporate sector. The result also implies that corporate farming is essentially oriented towards export and domestic niche markets of high-value crops.

(12) The impact and performance of agricultural credit and investment institutions are positively influenced by supportive agricultural and environmental institutions, favorable donor and international investments, and proactive corporate sector. Since all these four aspects represent different elements of the MPG structure, the positive relationship observed here

illustrates the strategic and beneficial effects of linkages within the MPG structure itself. Notably, the corporate sector, as a linkage variable, also brins here the positive impact flows captured from other pathways.

(13) The extent and effectiveness of yet another TAO involving crop shift towards tree and high-value crops are positively affected not only by the other two TAOs related respectively to contract farming and public-private partnership in agriculture and drip system conversion and irrigation modernization but also by domestic agricultural marketing regime and corporate sector. This result illustrates the linkages and synergies among the TAOs. However, unviable land tenure system coupled with the absence of local level rental or lease market for land, ineffective water institutions, export-oriented market regime, and absence of enough rural service providers remain as major constrains for making crop pattern shift as an ineffective option of transformative adaptation.

(14) The overall performance and impact of agricultural research and extension system are linked with the same of other three MPG elements. That is, a proactive corporate sector, efficient climate information system, and supportive agricultural and environmental institutions tend to improve the effectiveness and impact of agricultural research and extension system. In contrast, the TAO involving contract farming and public-private partnership in agriculture, though provide research extension services to participating farmers, do not contribute much to the overall impact and performance of the sectoral level agricultural research and extension system.

(15) The emergence and performance of the MPG-related institution of agricultural production and marketing cooperatives depend on effectiveness and support of other three MPG-related institutional elements, i.e., agricultural credit and investment institutions, relevant rural service providers, and customary institutions related to customs and traditions affecting management and cooperation. The result suggests that though customs and traditions remain as constraints, the performance of agricultural production and marketing cooperatives is influenced by the positive support from various kinds of rural service providers as well as agricultural credit and investment agencies.

(16) Agricultural value chain networks can be viewed both as institutions and as infrastructure. The effectiveness and performance of agricultural value chain networks are positively influenced by the role of agricultural credit and investment institutions, marketing cooperatives, export-oriented trade regime, and strong network of rural service providers. On the other hand, domestic-oriented production and corporate groups with their own and exclusive processing networks have unfavorable effects on the growth and performance of agricultural values chain networks.

(17) The extent of cultivated area in the study basin is likely to expand with an increasing trend in crop pattern shift towards tree and high-value crops and drip system conversion and irrigation modernization as well as by favorable changes in land tenure systems such as long-term land lease from state or remote tribal communities and expansion and performance of agricultural value chains. While the favorable effect the TAOs related to crop pattern shift on cultivated area is understandable, the unfavorable effect of TAO involving contract farming and public-private partnership is rather unexpected and requires further investigation on the factors leading to such counter-intuitive effect.

(18) As to the factors affecting land and soil quality, crop-livestock mixed farming and agricultural research and extension system contribute significantly towards improved land and soil quality. But cropping patterns with more intensive land use and cultivation is likely

to have a negative effect on land and soil quality. Contrary to expectation, the impact of climate change, which is supposed to be unfavorable for land and soil quality due to factors such as drought and wind erosion, has a positive effect. This may be due to possible scope for soil recuperation associated with long fallow following droughts.

(19) Crop pattern is an important impact variable that provides the context for evaluating the individual and interactive effects of all the three TAOs selected for evaluation in this study. The results support the fact that crop pattern in the sense of crop diversity is favorably influenced by increasing cultivated area, crop shifts towards tree and high-value crops, drip system conversion and irrigation modernization, and land and soil quality. But the production system based on larger farm sizes and oriented towards domestic and international markets tends to promote crop specialization. Crop specialization, though good for productivity, scale economy, and value chain development, tends to expose the production systems to climatic risks and uncertainties.

(20) Land productivity depends on the productivity-enhancing roles of irrigation water availability, agricultural research and extension system, land and soil quality, and effective water institutions. Notably, among these factors both water availability and soil quality have a more dominant effect. However, crop patterns in the sense of crop diversity obviously have an inverse relationship with land productivity. Notably, agricultural input supply system has a rather weak association with land productivity, suggesting the need to strengthen their productivity enhancing role.

(21) The major factors positively influencing the level of water productivity are land and soil quality, crop pattern, land productivity, and water institutions. As in the case of land productivity, land and soil quality also has the dominant impact on water productivity as well. Notably, land productivity, as linkage variable, also transmits the positive effects of factors that it has captured from other pathways. However, the negative effect of cultivated area means water productivity to be higher when water is used in a limited area rather than spreading its application over a larger area. Similarly, the agricultural input supply system, which implicitly promotes extensive rather than intensive production pattern, is not that conducive for improving water productivity.

(22) Understandably, the most dominant factor that favorably affects the level of labor productivity is land productivity. It clearly confirms the positive association with land and labor productivity levels. has on labor productivity. While crop pattern and cultivated area remain insignificant, agricultural input supply system has a negative effect on labor productivity, possibly reflecting the unfavorable effects of inputs and technologies that tend to favor extensive and labor-intensive cultivation.

(23) The level of food production is favorably influenced by expanding cultivated areas, higher land and water productivity levels, and supportive network of rural service providers. Since all factors are linkage variables, besides their direct effects, they also transmit the indirect effects to other factors as captured in other pathways or linkage equations. Notably, other factors such as agricultural food price policy, agricultural credit and investment institutions, and contract farming have either weak or unfavorable effects on food production. The reasons behind such a lackluster role of these factors require further and more focused investigation.

(24) The production levels of industrial and commercial crops are strongly influenced by the positive effects of export and niche markets and improved water productivity from efficient water use as achieved mainly through dependable irrigation and advanced water and

irrigation technologies. In contrast, domestic market regime and corporate sector involvement do not have any favorable effects on the production levels of industrial and commercial crops.

(25) As to the level of feed and fodder supply, a key factor for livestock production in the study basin, is positively affected by crop pattern with diverse cropping system, especially the mixed farming system, and higher levels of industrial and commercial crop production. In terms of the relative magnitude of effects, crop patterns have much stronger impact. However, the cultivated area and food production level are not that conducive for promoting feed and fodder supply. Notably, with the declining extent and degradation of community pastures and common grazing lands, customary institutions seem to be losing their effectiveness in this regard.

(26) The most dominant factors favorably affecting livestock production and livestock sector in general are a diverse livestock composition, favorable domestic market regime, and an expanding corporate investment. Notably, factors such as feed and fodder supply and international trade regime remain insignificant. But agricultural credit and investment institutions have an unfavorable impact on livestock production. This can possibly be due to the fact that with their predominant orientation towards crop sector, agricultural credit and investment institutions play rather an insufficient or ineffective role in supporting the livestock sector.

(27) The emergence and performance of rural non-farm sector, a key factor mediating rural economic transition, are favorably influenced by a production system oriented towards industrial and commercial crops, facilitative credit and investment institutions, and conducive and complementary value chain networks. But the corporate sector lacks any substantial involvement in rural non-farm activities, possibly due to them being informal in nature and less appealing for large scale corporate investment.

(28) The nature and effectiveness of agricultural trade regime are positively influenced by both food and industrial and commercial-oriented production systems. Viewed from a reverse perspective, it is also equally valid to argue that both the food and industrial and commercial-oriented production systems are also being positively influenced by agricultural trade regime. In terms of the same two-way relationship, the negative effect of livestock production on the trade regime can also be interpreted to mean that increasing domestic livestock production or achieving self-sufficiency in milk and meat production tend to dampen the import dimension of the agricultural trade regime.

(29) Interestingly, the configurations of variables having significant effects on the nature and effectiveness of agricultural market regimes are the same as those affecting the nature and effectiveness of agricultural trade regime. That is, while both food and industrial and commercial-oriented production systems have favorable effects, livestock production has a negative effect for similar reasons as noted above. However, here, there are two additional factors, i.e., agricultural and food price policies and the domestic market impact of agricultural trade regime. Despite having potentially positive effects, they both remain insignificant, clearly implying the ineffective nature of agricultural and food price policies on the one hand and lack of integration between domestic and international spheres of agricultural trade.

(30) Robust domestic agricultural market regime coupled with effective subsidy and taxation policies tend to improve the level and effectiveness of the overall market prices of agricultural products. In contrast, the other two factors, i.e., agricultural and food price

policies and agricultural trade regimes, have a rather dampening effect on the level and effectiveness of the overall market prices of agricultural products. Interestingly, however, it seems that the negative effects emanating from the less integrated export trade regime and weak agricultural and food price policies are more than counter-balanced by the combined positive effects of effective domestic agricultural market regime and favorable subsidy and taxation policies.

(31) As to the factors affecting overall cultivation in the study basin, crop pattern has a negative effect, but cultivated area, agricultural input supply system, and subsidy and tax policy all have positive effects. The results imply that while diverse crop patterns tend to reduce average cultivation costs through crop composition-based scale economies, cultivated area raises cultivations possibly due to the absence of any significant area-based scale economies on the cost side. Contrary to expectation, agricultural input supply system and subsidy and tax policies raise cultivations costs, possibly due to distortions caused by intervening factors. More information is needed to identify these factors causing such distortions.

(32) The income levels from crop enterprises depend on the strong favorable effects of area cultivated, agricultural market regime, and crop and employment insurance policies. The cultivated area, though has a positive effect on crop income, implicitly means crop income to increase essentially through area expansion rather than through productivity increase. This is actually reinforced by the positive but insignificant effect of land productivity. Besides it also explains as to why crop pattern has an unfavorable effect on crop income in terms of the inverse association between crop diversity and land productivity.

(33) The three main factors affecting rural wage levels are labour productivity, employment level in rural non-farm sector, and production systems oriented to industrial and commercial crops. The first factor has positive effects, the last one has a negative effect. The positive effect of labor productivity underlines the economic significance of productivity aspects, but that of rural non-farm sector implies the positive effects that the potential competition in rural labor markets have on wage levels. The negative effects of industrial and commercial crop production systems, on the other hand, are an outcome of its labor-intensive practices involving cheaper labor.

(34) The level of rural jobs is favorably affected by industrial and commercial crop production system, rural wage levels, and crop and employment insurance schemes. The positive effect of industrial and commercial crop production system om rural employment is consistent with its negative effect on rural wages. The positive effect of rural wages suggests employment level is directly related to wage level. The inverse relation between labour productivity and rural employment is not only consistent with the above results but also implies a low-level equilibrium, where low employment level co-exists with high wage and low productivity levels. The negative effect of rural non-farm employment suggests the expansion of rural non-farm sector to change only the sectoral composition (i.e., by shifting labor force across sectors) but not the overall level of rural employment.

(35) The level of household income of farmers is positively affected by the level of income derived from all three sources, i.e., crop and livestock enterprises as well as government safety net policies. But the same is negatively affected by income from rural non-farm participation, suggesting a tradeoff between non-farm income and overall household income. This can mean the income from non-farm participation is either relatively low or such income is realized only at the expense of the same from crop and livestock activities. It can also mean that those participating in non-farm activities do not have much income

scope from crop and livestock activities. However, a clear explanation in this respect requires further and closer investigation.

(36) The level of household income of laborers or rural workers having no land or participation in crop production, on the other hand, depend largely on wage levels and benefits from government employment insurance program. Neither the level of employment nor the income from livestock sector have any significant role in determining the household income of rural workers. In contrast, rural non-farm participation, again, has a negative effect as in the case of farm income, suggesting the relevance of the same arguments and caveats made earlier.

(37) The level of food availability, the key factor determining the supply side of food security, depends both on favorable supply side condition as determined by food production level as well as on favorable demand side condition as related to price levels in domestic agricultural markets. In contrast, the supply conditions related to livestock production and market conditions affecting agricultural trade seem to have negative effects on food availability. The bright side here is the fact that the positive effects are more than counter the negative effects.

(38) Regarding the level of food prices, the factor determining the demand side of food security, the two inter-related factors, i.e., food availability and food production, both have positive effect. This result seems to be counter intuitive as the food price levels are expected to decline with higher food production and food availability. But, if one considers the reverse side of the two-way flow of impacts, the result is consistent in the sense that higher food prices tend to enhance both food production and food availability. This is an important insight that underlines the need to consider the two-way nature of impact flows with both forward and reverse feedback in many contexts.

(39) Water security is as important as income and food security in view of the central role of water as a key component of the basic need dimension of rural welfare. The level of water security is positively influenced by better water supply for household consumption and more effective water institutions. Clearly, this is consistent with the favorable effects of both adequate allocation for meeting basic water needs as well as institutional norms that guarantee basic need-based water allocation. While the negative effects of climate change on water security is also consistent with expectation, the same related to customary institutions suggests the declining significance of customary institutions in ensuring household level water security.

(40) Finally, rural welfare at the household level, the ultimate policy goal that captures the impact flows across all pathways in the system, depends on the five penultimate factors, representing the roles of two income-related factors, two food consumption-related aspects, and water as basic needs. The results suggest rural welfare at the household level is directly and favorably affected by the farm income, food availability, and water security. But, as expected, the same has an inverse or unfavorable relationship with the level of labour income and food prices. Notably, the welfare implications of food prices are universal in the sense that they affect all households, the same associated with labour income also are specific only to non-farming households, which rely exclusively on wage income employment and income from other non-crop crop sectors such as livestock and rural non-farm activities. Obviously, it is these or similar households that are particularly vulnerable from the unfavorable welfare effects of climate change in the study region.

Despite the analytical limitations of the evaluation methodology and the tentative nature of the empirical results presents here, the study is still able to make significant contributions to both climate adaptation literature and policy. Using impact pathways as key building blocks of the evaluation methodology, the study has added dynamic aspects by bringing together all relevant elements, i.e., climate change, adaptation options, governance structure, impact transmission mechanism, and welfare, into a single analytical framework. The empirical approach has also opened up new avenues both in the way variables are to conceptualized and analytically approached and also in the way perception-based information can be used as a valid and legitimate source of information in many difficult and deficient contexts in climate-welfare interaction in particular and institutional and impact assessment in general. The empirical results presented in this study also clearly demonstrate not only the realistic nature of the evaluation methodology and empirical approach but also the practical and policy-relevant theoretical insights that one can gain on the process of CC-TAO-MPG-RR interactions in the study basin. In this respect, the following points can be highlighted:

(1) The MPG structure is conceptualized by distinguishing three sets of elements, i.e., institutions (laws, policies, and organizations), infrastructure, and key players in the state, private sector, and civil society spheres. Despite such an analytical decomposition, there are strong strategic and operational connections among these three components of governance elements both across regional scales and sectoral contexts. For instance, the players form part of the strategic and decision-making dimension of governance, whereas the institutions and infrastructures form part of the operational dimension of governance. In other words, the former represents the process perspective of governance, but the latter represents the structural perspective of governance.

(2) Rural welfare is conceptualized in terms of basic needs perspective by focusing on three key dimensions, i.e., income security, food security, and water security. While income security is represented by variables to distinguish the income levels of farmers from that of rural workers, food security is represented by two variables to capture both supply and demand aspects. Water security is represented by a variable capturing water availability for household consumption.

(3) Although the four key dimensions rural production system, i.e., food production, industrial and commercial crop production, are intricately linked, they are analytically separated essentially to highlight their differential socio-economic significance, climatic exposure, and configuration of underlying factors. Feed and fodder supply, though comes as by-products of food and commercial crops, is treated separately to highlight the role of mixed-farming and exclusive fodder-oriented production in the study basin. Similarly, livestock production is separated partly due to its industrial scale operation at regional scale partly due to its role as a climate adaptation strategy at household level.

(4) Likewise, based on similar reasoning, the productivity is also distinguished in terms of its three dimensions, i.e., land, land, water, and labour productivities. But such an analytical separation or distinction, as in the case of production, is also used not only to understand their distinct individual roles and impacts but also to evaluate their operational linkages and interactive impact.

(5) Since the evaluation framework is vase canvas covering 52 variables and their intricate interactions, it is but natural that by conceptualization, most of them are composite in nature and notional in character. As a result, the roles and effects cannot be uniform, but vary considerably by context. For instance, when considering aspects such as productivity, it has a negative effect due to the constraining role of holding size. But, in context of contract

farming and public-private partnership, it has a positive effect due to the facilitative effects of the introduction of the policy of promoting long-term land lease from government or rural communities.

(6) As to the legitimacy and acceptability of the estimated results, it is important to understand their true nature. Since the coefficients of all model variables are estimated using perception-based data, the relative size, direction, and significance of their impacts on one or more other variables are to be interpreted as an econometric representation of the prevailing consensus on the same among the sample stakeholders in the study basin. As long as the stakeholder sample is representative and the perceptional information is a faithful reflection of basin realities, the results can be considered as realistic and reliable. This fact provides legitimacy for the policy implications derived from the nature and behavior of variables in different equations.

(7) The impact-pathway-based analysis clearly demonstrates the mechanics and implications of the roles and impacts of the linkage variables (i.e., those appear as dependent variables in the system model). These variables capture and transmit the impacts across pathways in terms of both their direct and indirect effects, which are nothing by the effects other variables that are captured by a given linkage variable in other related equations. Notably, since the coefficients of these linkage variables capture and quantify the relative size, direction, and significance of these dual effects together, their behaviors vary across equations or impact pathways. For instance, if the direct effect of a given linkage variable remains positive and exceeds its indirect but negative effect, then, it is likely to have a positive coefficient and *vice versa*. But, if both or either of these effects remain too weak to be significant, then, the variable is likely to have an insignificant coefficient.

(8) With its results, the study also confirms the impact flows both within and across impact pathways are not unidirectional, but a two-way process. For instance, it is as reasonable to postulate that agricultural trade regime affecting domestic agricultural production—covering both food and industrial and commercial production—as the domestic production system affecting agricultural trade. Similar is also the case of the two-way relationship between land and water productivity levels. What is this means from a policy perspective is that for improving overall economic and welfare benefits in contexts involving two-way impact flows, policies can be implemented focusing on either or both sides, depending on investment availabilities and strategic considerations.

(9) Another strategically important key result of this study is that variables differ in terms of the extent of linkages with other variables and the relative size of the total impacts of variables is directly proportional to the extent of their linkages with other variables or the number of impact pathways where they appear. For instance, the number of links varies from one (livestock composition and wage and labor laws) to 10 (cultivated area and corporate sector). Among other variables, four MPG-related institutional elements (water institutions, agricultural credit and investment, and market and trade regimes) and two production-related elements (food and livestock production) have nine links each. On the other hand, another four variables (crop pattern, industrial and commercial crop production, land tenure, and rural service providers) have eight links each. Among the TAOs, while contract farming and public-private partnership has eight links, drip system conversion and irrigation modernization and crop shift to tree and high-value crops have five and four links respectively. It is obvious that it is these variables with extensive links and larger total impacts that are to be prioritized while framing adaptation policies to counter the negative economic and welfare effects of climate change.

Overall, the study has made important contributions with considerable implications for theory, methodology and policy within the realm of climate adaptation literature. But it is certainly not free of limitations and caveats. While this is understandable for a study on a pilot scale with severe time and resource limitations, there is considerable scope for improvement. More analysis of even the results obtained with current limitations is possible and such analysis can also provide still more interesting insights on impact synergies among factors operating within the intrinsic process of climate-adaptation-governance-welfare interactions. The current methodological framework is rather ambitious in terms of its coverage, but the advantages of scale also have their inevitable tradeoffs in terms of lack of specificity. It needs to be refined for a more focused and in-depth analysis and finer and disaggregated treatment of variables and impact layers. These and related factors provide directions for future research on this important frontier area of empirical analysis of climate-welfare interactions.

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Annex-A: Results of Order and Rank Tests

Eqn. No:	Dependent Variables	Parameters				Order Condition			Rank condition	Identification Status
		K	*M*	*G*	*K-M*	*G-1*	*(K-M)-(G-1)*	*K-M > G-1*	*Non-zero |Det|*	
1	CLIMINVST	52	4	40	48	39	9	Yes	Yes	Overidentified
2	WATRINSTN	52	5	40	47	39	8	Yes	Yes	Overidentified
3	WATRINFRA	52	5	40	47	39	8	Yes	Yes	Overidentified
4	RSPROVIDR	52	5	40	47	39	8	Yes	Yes	Overidentified
5	WATRAVAIL	52	7	40	45	39	6	Yes	Yes	Overidentified
6	WATRSUPLY	52	5	40	47	39	8	Yes	Yes	Overidentified
7	AGINSUPLY	52	5	40	47	39	8	Yes	Yes	Overidentified
8	AGPERFORM	52	7	40	45	39	6	Yes	Yes	Overidentified
9	CONFAMPPP	52	6	40	46	39	7	Yes	Yes	Overidentified
10	DCONVIMOD	52	6	40	46	39	7	Yes	Yes	Overidentified
11	CORPSECTR	52	6	40	46	39	7	Yes	Yes	Overidentified
12	AGCRINSTN	52	4	40	48	39	9	Yes	Yes	Overidentified
13	CROPSHIFT	52	9	40	43	39	4	Yes	Yes	Overidentified
14	ARESEXSYS	52	5	40	47	39	8	Yes	Yes	Overidentified
15	APMKTCOOP	52	4	40	48	39	9	Yes	Yes	Overidentified
16	AVALCHAIN	52	7	40	45	39	6	Yes	Yes	Overidentified
17	CULTIAREA	52	7	40	45	39	6	Yes	Yes	Overidentified
18	LANDSQLTY	52	6	40	46	39	7	Yes	Yes	Overidentified
19	CROPATERN	52	8	40	44	39	5	Yes	Yes	Overidentified
20	LANDPRODY	52	8	40	44	39	5	Yes	Yes	Overidentified
21	WATRPRODY	52	8	40	44	39	5	Yes	Yes	Overidentified
22	LABRPRODY	52	5	40	47	39	8	Yes	Yes	Overidentified
23	FOODPRODN	52	8	40	44	39	5	Yes	Yes	Overidentified
24	INDCPRODN	52	9	40	43	39	4	Yes	Yes	Overidentified
25	FEEDSUPLY	52	6	40	46	39	7	Yes	Yes	Overidentified

26	LIVSPRODN	52	7	40	45	39	6	Yes	Yes	Overidentified
27	AGNFSECTR	52	6	40	46	39	7	Yes	Yes	Overidentified
28	ATRDREGIM	52	5	40	47	39	8	Yes	Yes	Overidentified
29	AMKTREGIM	52	6	40	46	39	7	Yes	Yes	Overidentified
30	AMKTPRICE	52	5	40	47	39	8	Yes	Yes	Overidentified
31	CULTICOST	52	6	40	46	39	7	Yes	Yes	Overidentified
32	CROPINCOM	52	8	40	44	39	5	Yes	Yes	Overidentified
33	RURALWAGE	52	7	40	45	39	6	Yes	Yes	Overidentified
34	RURALJOBS	52	9	40	43	39	4	Yes	Yes	Overidentified
35	FARMINCOM	52	5	40	47	39	8	Yes	Yes	Overidentified
36	LABRINCOM	52	7	40	45	39	6	Yes	Yes	Overidentified
37	FOODAVAIL	52	6	40	46	39	7	Yes	Yes	Overidentified
38	FOODPRICE	52	5	40	47	39	8	Yes	Yes	Overidentified
39	WATRSECUR	52	6	40	46	39	7	Yes	Yes	Overidentified
40	RURWELFAR	52	6	40	46	39	7	Yes	Yes	Overidentified

Note: K = Total number of variables in the model, M = Number of variables in a particular equation, G = Total number of endogenous variables or equations in the model, and [Det] = Determinant.

Annex-B: Survey Instrument for Morocco Pilot Study

CLIMATE CHANGE, TRANSFORMATIVE ADAPTATION OPTIONS, MULTISCALE POLYCENTRIC GOVERNANCE, AND RURAL WELFARE: TOWARDS AN EMPIRICAL EVALUATION IN THE CONTEXT OF OUM ER-RBIA BASIN, MOROCCO

(Part of Research Preparation Activity under Work Package 4 of ClimBeR Project, IWMI, Colombo, Sri Lanka)

PART-I: INSTRTUCTIONS

(1) The **Conceptual and Analytical Framework** developed for empirical application attempts to capture the most relevant and pertinent aspects of climate change impacts and the actual and potential adaptation initiatives in the context of water, agriculture, and water supply sectors within the Study Basin (i.e., **Oum Er-Rbia (OER) Basin**) in particular and the Study Country (**Morocco**) in general; ***The Study Basin and the Conceptual Framework, and Empirical Model are presented in Part-II***;

(2) The **impact of climate change** is considered essentially in terms of two aspects:

(a) **temperature** *(directly affecting agriculture via evapotranspiration and water storage/supply loss via evaporation) and*

(b) **precipitation** *(directly affecting overall water availability, which covers both* ***blue water*** *from surface and sub-surface sources and* ***green water****, i.e., water directly used in rainfed agriculture and other natural ecosystems);*

(3) Regarding its main components, apart from the threat/trigger variable (i.e., climate change) and the ultimate development goal (i.e., rural welfare), the Analytical Framework covers **four inter-related components**:

- *(a) how climate change affects key* ***sectors****: water, agriculture, and water supply;*
- *(b) how* ***Transformative Adaptation Options*** (TAOs) *help in building the climate resilience of these sectors;*
- *(c) what roles national, regional, sectoral institutions—as elements of the* ***multi-scale poli-centric governance (MPG) structure****—play in enhancing the climate resilience roles of TAOs; and*
- *(d) how the interactive effects of these TAOs and MPG elements are transmitted through various* ***impact pathways*** *to get ultimately manifested in the overall development goal of rural welfare;*

(4) Among various respective possibilities, the **Analytical Framework directly covers** only:

- *(a)* ***three sectors****: water sector (in terms of overall water availability), agricultural sector (in terms of its output/income/livelihood performance), and water supply sector (in terms of water supply for people, animals, and industries);*
- *(b)* ***three TAOs****: (i) Contract Farming and Public-Private Partnership; (ii) Shift to Tree and High-value Crops; and (iii) Conversion to Drip Systems and Modernization of Irrigation;*
- *(c)* ***20 MPG elements*** *(representing various legal, policy organizational aspects), both at the national and regional levels as well as across sectors, including private groups and corporate sector; and*
- *(d)* ***24 impact variables****, which together characterize the impact pathways or routes through which various forms of the impacts of TAOs and MPG elements are transmitted and get ultimately reflected in the final development goal;*

(5) This **questionnaire is designed to elicit** the ***subjective, judgmental, and perceptional assessment*** of a sample set of stakeholders regarding the observed/expected/possible roles and impacts of one threat/trigger variable (climate change), three sectors, three TAOs, 20 MPG elements, 24 impact transmission variables, and one ultimate goal (rural welfare). Thus, the questionnaire will cover ***52 sets of questions***;

(6) The **sample of respondents or stakeholders has to represent** well different ***scales*** (*national, regional, and local*), ***sectors*** (*agriculture, water, environment, agro-industry, other non-farm enterprise, service, NGO, etc.*), ***profession*** (*government official, academic/expert, trade/business, technician, farming, etc.*), ***disciplines*** (a*gronomy, economics, engineering, hydrology, sociology, finance, management, law, etc.*), and, more importantly, ***genders*** (*at least, 10 to 15% females*);

(7) Before asking questions, the **first 20 to 30 minutes can be used to briefly explain** the ***Conceptual and Analytical Framework to give adequate context and background*** to the respondents or stakeholders. For this purpose, the Framework with six colored segments, representing different components of the Framework, can be used. The respective roles of the sectors, TAOs, MPG elements, and impact variables can be specifically explained in simple and intuitive terms;

(8) The respondents need also to be informed that the **answers to various questions** to be asked on different components of the Framework need *to* ***reflect the conditions prevalent in the OER basin*** in particular and ***Morocco*** in general. This means the sample of ***respondents or stakeholders are expected to be familiar with the study regions*** and its surroundings.

(9) The perception evaluation on each of the 52 variables are based on a number of questions asked from different directions and aspects. It is important for the Interviewer to read all questions to understand their collective logic;

(10) Most of the ***Concepts and Variables*** are explained in the context of each question as well as listed together in the table presented in ***Part-III***;

(11) More importantly, it is necessary to **convince them** that the evaluation is done both from an ***ex-post context*** (what was/is already observed) ***ex-ante context*** (what can be possible or expected). This will encourage them to be as free as possible to express what they observe, perceive, or believe about various relationships in the Analytical Framework; and

(12) Finally, all questions are formulated as requiring answers within the scale of 1-10, with ‘1’ being low or weak and ‘10’ being high or strong, depending on the context. In case a respondent is not able answer or not aware of the aspect being asked, the value of ‘0’ can be entered. Thus, the answer to all questions will be in the range of 0-10.

PART-II: KEY CONCEPTS AND DEFINITIONS

Sl. No:	Concepts	Definitions/Explanations/Coverage
1	Contract Farming and Public Private Partnership (PPP)	Aggregation and PPP Models; PPP Models include those based on leasing of both state lands by private investors as well as tribal and community lands by private investors or enterprising rural youth groups.
2	Shift to Tree and High-Value Crops	Shift to olives, oranges, and export-oriented tomato, fruits, vegetables, etc.
3	Industrial and Commercial Crops	Sugar beets, Cotton, citrus, and other export-oriented crops, high-end vegetables, argan, etc.
4	Drip System Conversion and Irrigation Modernization	Conversion of gravity and sprinkler-based irrigation systems to drip-based irrigation; Modernization of irrigation infrastructures and management system.
5	Agricultural Sector Performance	Performance is evaluated in terms of the output/income/livelihood outcomes of agriculture and allied sectors.
6	Water Institutions	Organizations involved in water development, allocation, and management (Ministry of Equipment and Water, River Basin Agencies, etc.); Water law and water policy systems, water rights/entitlements, water pricing and allocation, and groundwater regulation and management; and traditional (community-based) water management arrangements, especially in groundwater regions;
7	Water Infrastructures	Dams, storages, water transfer and distribution networks, groundwater wells/pump structures, water treatment and desalinization facilities, etc.
8	Land Tenure	Farm size distribution, land fragmentation from sub-divisions, leasing of state and community/tribal lands by private investors / youth entrepreneurs, etc.
9	Customary and Traditional Institutions	Local customs, conventions, traditions, and informal rules governing agricultural and livestock sectors, including common land ownership and community pastures, etc.
10	Agricultural Institutions	Organizations such as Ministry of Agriculture (MOA), Regional Agricultural Departments, ORMVA, etc. and legal and policy aspects related to Green Morocco Plan and Generation Green Plan.
11	Climate Information and Decision-Support System	Climate-related data gathering and management, building and applying climate prediction models across scales, etc.
12	International Donors and Investors	World Bank, African Development Bank, International Private Investors, etc.
13	Agricultural Credit and Investment Institutions	Government/public credit and Investment banks and Institutions, which provide credit and investment to agricultural sector.
14	Agricultural Research, Science & Technology, and Extension System	Agricultural universities, research institutions related to scientific, technological, and engineering aspects related to agriculture and water, publica and private agricultural extension system, etc.
15	Corporate Sector	Corporate agencies/players involved in the production and distribution of fertilizers/farm equipment/ technologies, agro-industries, trade and value chains, transport, storage, and processing, credit/investment/insurance activities, etc.
16	Rural Service Providers	Private groups involved in the provision/installation/maintenance of drip system, agricultural equipment, and other related farm input, credit, and investment services)

17	Subsidy and Tax Relief Policies	Subsidies on irrigation system modernization, farm inputs (fertilizer, credit, etc.), and livestock development and custom tax exemptions for the import of irrigation/farm technologies/equipment, etc.
18	Agricultural Wage Laws and Regulations	Legislations and other regulations on rural wage rates and working conditions.
19	Rural Social Safety net Policies	Rural Safety net Programs include (a) the Program of retirement benefits for farmers and monthly stipend for poor rural groups, etc. under Generation Green Plan (GGP) and (b) Social Agriculture Program under Green Morocco Plan (PMV) for supporting agriculture and livestock sectors in fragile and mountainous regions.
20	Crop and Employment Insurance Program	Crop and employment insurance planned/proposed under Green Generation Plan.
21	Agricultural Market Regime	Domestic market demand, supply, price regulations, storage and supply chains, etc.
22	Agricultural Trade Regime	International trade covering exports, imports, price levels, custom policies, trade agreements, quality standards, phyto-sanitary requirements, etc.
23	Climate Investments	Investments in macro/micro water infrastructures, water institutions, new organizational forms for farm production, water and farm technologies, market and value chain developments, subsidies on farm inputs and irrigation investments, social safety nets, etc.
24	Agricultural Service and Input Supply	Provision of seeds, credits, fertilizers, farm and water technologies, and irrigation, extension, and market and climate information services, renting of farm equipment, repair, and maintenance services, etc.
25	Land Productivity	Output per unit of land; As it differs by crops, it is evaluated from an aggregate or average perspective.
	Water Productivity	Output per unit of applied water; As it differs by crops, it is evaluated from an aggregate or average perspective
26	Labor Productivity	Output per unit of labor; As it differs by crops, it is evaluated from an aggregate or average perspective.
27	Fodder and Feed Supply	Includes industrially produced feed products, fodder/feed crop production, community pastures and grazing lands, and farm by-products such as wheat straw and husk, and biomass from sugar beet, olive trees, etc.
28	Livestock and Poultry Population Size and Composition	Population size means number of livestock/poultry units; Composition captures the relative share of animals reared for dairy and meat purposes; Covers both commercial and family level enterprises.
29	Livestock and Poultry Production	Covers livestock/poultry production from both commercial and family enterprises. Livestock production includes both dairy and meat outputs.
30	Agro-Industries and Rural Non-farm Sector	Includes sugar/olive oil mills, food/dairy/meat processing units, small enterprises, trade and handicraft activities, etc.
31	Rural Jobs or Employment	Covers employment opportunities from crop, livestock, and agro-industries and other rural non-farm activities.
32	Rural Wage Rates	As rural wage rates differ by sectors, activities, seasons, and gender, they need to be considered from an overall and average perspective.
33	Cultivation Costs in Crop Production	Cover all costs related to land preparation, irrigation, fertilizer, other inputs, operational/maintenance costs of farm equipment, crop insurance premium, etc.
34	Market Prices for Farm Products	As market prices differ by crops/farm products, price levels and trends are evaluated from an aggregate or average perspective.
35	Income from Crop Sector	Covers only Income from Crop Cultivation or Crop enterprises.

36	Farm Income	It is the household income of farmers. It covers the income of farmers from their crop, livestock, and other non-agricultural activities.
37	Labor Income	It is the household income of laborers. It covers the income of laborers from their farm employment crop, livestock, other non-agricultural activities.
38	Food Availability	Food availability is evaluated from an aggregate and overall perspective. It covers food available from both own and market sources. It covers all food items, including cereals, vegetables, fruits, meat/egg, milk and other dairy items
39	Food Prices	Food prices are also evaluated from an aggregate and overall perspective. It covers the prices of all items covered under food availability.
40	Water Security	It covers broadly the water needs of households, animals, and industries. Industrial needs are relevant in view of their being as a source of non-farm income and livelihoods as well as in supplying inputs to agriculture.
41	Rural Welfare	In evaluating Rural Welfare, the focus will be mainly on (a) two rural groups: farmers (crop, livestock, and mixed enterprises) and workers (farm and rural non-farm sectors) and (b) three key welfare dimensions: food, income, and water security.

PART-III: MODEL VARIABLE LIST AND DEFINITION

Sl. No	*Variable Categories*	*No*	*Names of Variables*	*Acronym*
1	Tigger/Threat Variable	1	Climate Change Impacts	CLCIMPACT
2	Development Goal	1	Rural Welfare	RURWELFAR
3	Sectors/Sub-Sectors	1	Agricultural Sector Performance (Output/Income/livelihood)	AGPERFORM
4		2	Water Sector (Water Availability)	WATRAVAIL
5		3	Water Supply (Water for People/Livestock/Industries)	WATRSUPLY
6	Transformative Adaptation Options *(TAOs)*	1	Contract Farming and Public-Private Partnership	CONFAMPPP
7		2	Drip Conversion and Irrigation Modernization	DCONVIMOD
8		3	Shift to Tree and High-Value Crops	CROPSHIFT
9	Institutional Variables *(Multiscale Polycentric Governance-MPG)*	1	Agricultural and Food Price Regulation Policies	AFPRPOLCY
10		2	Agricultural Credit and Investment Institutions	AGCRINSTN
11		3	Agricultural and Environmental Institutions	AGENINSTN
12		4	Agricultural Wage Laws and Regulations	AGWAGELAW
13		5	Agricultural Trade Regime	AMKTREGIM
14		6	Agricultural Production and Marketing Cooperatives	APMKTCOOP
15		7	Agl. Research/Science &Technology/Extension System	ARESEXSYS
16		8	Agricultural Market Regime	ATRDREGIM
17		9	Agricultural Value Chains	AVALCHAIN
18		10	Climate Information and Decision Support System	CLIMINSYS
19		11	Corporate Sector Agencies/Players	CORPSECTR

20		12	Crop and Employment Insurance	CREMINSUR
21		13	Customary and Traditional Institutions	CUSTINSTN
22		14	International Donors and Investors	DONINVSTR
23		15	Land Tenure (Farm Size, Land Leasing, etc.)	LANDTENUR
24		16	Rural Service Providers	RSPROVIDR
25		17	Rural Social Safetynet Policies	SNETPOLCY
26		18	Subsidy and Tax Relief Policies	STAXPOLCY
27		19	Water Infrastructures	WATRINFRA
28		20	Water Institutions	WATRINSTN
29	Impact Variables *(Impact transmission pathways/Channels)*	1	Agricultural Service & Input Supply	AGINSUPLY
30		2	Agro-industries and Non-farm Sector	AGNFSECTR
31		3	Market Prices of Farm Products (Crop & Livestock Sectors)	AMKTPRICE
32		4	Climate Investment Level	CLIMINVST
33		5	Cropping Pattern (Area Allocation Across Crops in a Year)	CROPATERN
34		6	Crop Sector Income	CROPINCOM
35		7	Cultivated or Cropped Area	CULTIAREA
36		8	Cultivation Costs	CULTICOST
37		9	Farm Income (from agriculture/livestock/other sources)	FARMINCOM
38		10	Fodder and Feed Supply	FEEDSUPLY
39		11	Food Availability	FOODAVAIL
40		12	Food Prices	FOODPRICE
41		13	Food Production	FOODPRODN
42		14	Industrial and Commercial Crop Production	INDCPRODN
43		15	Labour Income (from wage/non-farm/other sources)	LABRINCOM
44		16	Labor Productivity	LABRPRODY
45		17	Land Productivity	LANDPRODY
46		18	Land Quality and Soil Health	LANDSQLTY
47		19	Livestock and Poultry Population Size and Composition	LIVSIZCOM
48		20	Livestock and Poultry Production	LIVSPRODN
49		21	Rural Jobs	RURALJOBS
50		22	Rural Wage Rates	RURALWAGE
51		23	Water Productivity	WATRPRODY
52		24	Water Security for People, Animals, and Nature	WATRSECUR

PART-IV: BASIC DETAILS

(1) Respondent's Details:

(a) Name ……………………………………

(b) Age *(Years)* ……………………………………

(c) Gender *(Male or Female)* ……………………………………

(d) Education / Qualification ……………………………………

[No education = 1, Primary education = 2,

High-school education = 3, Graduate degree = 4,

Post-graduate degree = 5, Technical/special education = 6,

Others, if any (specify) = 7]

(e) Years of Experience *(in years)* ……………………………………

(f) Scale/Level ……………………………………

[International Level = 1, National level = 2,

Regional level = 3, Provincial level = 4, Local level = 5

Others, if any (specify) = 6]

(g) Sector ……………………………………

[Agriculture = 1, Water = 2, Environment = 3,

Agro-industries = 4, Dairy/meat/other non-farm enterprises = 5

Services = 6 , Academics/NGOs = 7, Others, if any (specify) = 8]

(h) Profession ……………………………………

[Government officials = 1, Researchers/experts = 2,

Political/community leaders = 3, Trade/business = 4

Credit/insurance/finance = 5, Farming/dairy/meat = 6,

technicians/service providers = 7, Others, if any (specify) = 8]

(i) Discipline ……………………………………

[Agronomy /soil science etc. = 1, Hydrology/water etc. = 2,

Engineering = 3, Economics = 4, Other social sciences = 5,

Finance/management = 6, Others, if any (specify) = 7]

(j) Contact Details **…………………………………….**

(At least, place and phone number and email

needed for Verification) **…………………………………….**

Phone …………………………….

Email……………………………

(2) Interview Details:

(a) Interviewer's Name **……………………………………**

(b) Place and Date **……………………………………**

(3) Verification Details:

(a) Verifier's Name **……………………………………**

(b) Place and Date **……………………………………**

PART–V: QUESTIONNAIRE

SECTION [I]: THREAT/TRIGGER VARIABLE (1)

[1] Climate Change Impact (CLCIMPACT) ***(On Sectors)***

(a) How strong is your belief that Climate Change Impacts are real?.. ☐

(b) In your view, how severe are the Climate Change Impacts on Water and Agriculture? .... ☐

SECTION [II]: SECTORAL IMPACTS VARIABLES (3)

[2] Overall Impact on Water Resources Availability (WATRAVAIL)

(a) To what extent do Climate Change Impacts negatively affect overall water resource availability? .... ☐

(b) How effective are Water Infrastructures in minimizing climate change impacts on water availability? ☐

(c) How effective are Water Institutions in minimizing climate change impacts on water availability?....... ☐

(d) How far can Drip System Conversion and Irrigation Modernization lead to water savings? .... ☐

(e) How far can Shift to Tree and High-value Crops lead to water savings? .... ☐

[3] Overall Impact on Agricultural Sector Performance (AGPERFORM)

(a) To what extent do Climate Change Impacts affect agriculture sector performance*?* .... ☐

(b) How far does a change in Water Resource Availability affect agricultural sector performance? .... ☐

(c) How far does a higher priority for water allocation to urban/rural Water Supply affect agricultural sector performance (*via reduced water resources for available for agricultural uses*)? .... ☐

[4] Overall Impact on Urban/Rural Water Supply (for Domestic Use) (WATRSUPLY)

(a) To what extent do Climate Change Impacts affect the levels of urban/rural water supply*?*.................... ☐

(b) How far do changes in Water Resources Availability affect the levels of urban/rural water supply*?* ..... ☐

(c) How effective are Water Infrastructures in securing the levels of urban/rural water supply? .... ☐

(d) How effective are Water Institutions in securing the levels of urban/rural water supply? .... ☐

SECTION [III]: TAO VARIABLES (3)

[5] Contract Farming and Public Private Partnership (CONFAMPPP)

(a) How far does Agricultural Sector Performance depend on the performance of Contract Farming/PPP? ☐

(b) How critical are the Land Tenure system for the performance of Contract Farming/PPP? .... ☐

(c) How critical are Water Infrastructures for the performance of Contract Farming/PPP? .... ☐

(d) How critical are Water Institutions for the performance of Contract Farming/PPP? .... ☐

(e) How critical are Credit and Investment Institutions for the performance of Contract Farming/PPP? ......

(f) How critical are Rural Service Providers for the performance of Contract Farming/PPP? ....

(g) How critical are Corporate Sector Agencies/Players for the performance of Contract Farming/PPP?......

[6] Shift to Tree and High-Value Crops (CROPSHIFT)

(a) How far does Agricultural Sector Performance depend on the extent of Crop Shifts? ....

(b) How far can Contract Farming/PPP promote Crop Shifts? ....

(c) How critical are the Water Infrastructures in promoting Crop Shifts? ....

(d) How critical are the Water Institutions in promoting Crop Shifts? ....

(e) How critical are the Credit and Investment Institutions in promoting Crop Shifts?................................

(f) How critical are the Rural Service Providers in promoting Crop Shifts? ....

(g) How critical are the Corporate Sector Agencies/Players in promoting Crop Shifts? ....

(h) How critical are the Drip Conversion/Irrigation Modernization in promoting Crop Shifts?....................

[7] Drip System Conversion and Irrigation Modernization (DCONVIMOD)

(a) How far does Agricultural Sector Performance depend on Drip Conversion/Irrigation Modernization? .

(b) How far do Contract Farming/PPP depend on Drip Conversion/Irrigation Modernization? ....

(c) How far do Water Infrastructures get improved by Drip Conversion/Irrigation Modernization? ....

(d) How far do Water Institutions get benefited from Drip Conversion/Irrigation Modernization? ....

(e) How far can Credit and Investment Institutions support Drip Conversion/Irrigation Modernization? .....

(f) How far can Rural Service Providers support Drip Conversion/Irrigation Modernization? ....

(g) How far can Corporate Sector Agencies/Players support Drip Conversion/Irrigation Modernization? ....

(h) How far do Crop Shifts get facilitated by Drip Conversion/Irrigation Modernization? ....

[IV] INSTITUTIONAL (MPG ELEMENT) VARIABLES (20)

[8] Land Tenure (LANDTENUR)

(a) How important is farm size for the decision to participation in Contract Farming? ....

(b) How important is farm size for adopting improved farm & water technologies and practices? ....

(c) How important is farm size for shifting to tree and high-value crops? ....

(d) How important is farm size in promoting efficient water allocation and management? ....

(e) How important is the long-term leasing of public lands for promoting PPP in agriculture?.....................

(f) How important is the long-term leasing of jointly-owned tribal lands for promoting PPP in agriculture?

[9] Customary and Traditional Institutions (CUSTINSTN)

(a) How strong is the influence of customs/traditions on farmers crop choice (especially, food/feed crops)f? ☐

(b) How important are the roles of customary/traditional institutions in livestock/pasture development? .☐

(c) How important are the roles of customary/traditional institutions in groundwater sharing/management? ☐

(d) How far do customary/traditional institutions facilitate PPP with long-term leasing of tribal lands?.......☐

(e) How far do customary/traditional institutions support government land/water management initiatives? ☐

(f) How far do customary/traditional institutions lead to farm divisions and land fragmentations?............ ☐

[10] Water Institutions (WATRINSTN)

(a) How adequate/ready are current Water Institutions to face the challenges of Climate Change? ....☐

(b) How strong are the linkages between Water Institutions and Ag. & Env Institutions?...........................☐

(c) How strong are the linkages between Water Institutions and Research/S&T/Extension System?..........☐

(d) How far does Land Tenure (farm size/sub-division) affect the effectiveness of Water Institutions? .....☐

(e) How far do Customary Institutions affect the effectiveness of Water Institutions? ....☐

(f) How far does Climate Information & Decision System improve the effectiveness of Water Institutions?☐

(g) How far do Climate Investments improve the effectiveness of Water Institutions?...............................☐

[11] Water Infrastructures (WATRINFRA)

(a) How adequate are Water Infrastructures to face the challenges of Climate Change? ....☐

(b) How urgent is the need for additional Water Infrastructures (e.g., North-South Water Transfer Project)? ☐

(c) How far can Climate Info & Decision Support System improve the performance of Water Infrastructures? ☐

(d) How far can Climate Investments enhance the extent and performance of Water Infrastructures? .....☐

(e) How far can Subsidy/Tax Relief Policy improve the extent and performance of Water Infrastructures?☐

[12] Agricultural and Environmental Institutions (AGENINSTN)

(a) How adequate/ready are Ag. & Env Institutions to face the challenges of Climate Change?.................☐

(b) How strongly do International Donor/Technical Agencies/Investors support Ag. & Env Institutions? ..☐

(c) How strong are the linkages between Ag. & Env Institutions and Water Institutions?...........................☐

(d) How strong are the linkages between Ag. & Env Institutions and Ag. Research/S&T/Extension System?☐

(e) How adequate is the Climate Information/Decision Support System with the Ag. & Env Institutions? ..☐

[13] International Donors, Development Agencies, and Investors (DONINVSTR)

(a) How strong is the response of Donors/Development Agencies/Investors to climate change impacts? ...

(b) How strong is the support of Donors/Development Agencies for water/agriculture/climate investment?

(c) How strong is the support of Private International Investors for water/agriculture/climate investment?

[14] Climate Information and Decision-Support System (CLIMINSYS)

(a) How adequate is Climate Info/Decision Support System to face the challenges of Climate Change?.....

(b) How far can Ag. & Env Institutions help to build/strengthen Climate Info/Decision Support System? ..

(c) How far can Climate Investments help to build/strengthen Climate Info/Decision Support System? ....

(d) How far can universities/international bodies support Climate Info/Decision Support System? ....

[15] Agricultural Credit and Investment Institutions (AGCRINSTN)

(a) How critical are Ag. & Env Institutions for the performance of Ag. Credit/Investment Institutions? ......

(b) How far do international donors/development bodies contribute to Ag. Credit/Investment Institutions?

(c) How far do private international investors contribute support Ag. Credit/Investment Institutions? .....

(d) In terms of overall performance, how adequate and efficient are the Ag Credit/Investment Institutions?

(e) In terms of accessibility, how adequate and efficient are the Ag. Credit/Investment Institutions? ....

[16] Agricultural Research, Science & Technology, and Extension System (ARESEXSYS)

(a) How strong is Ag. Research/S&T/Extension System to face the challenges of Climate Change? ....

(b) How far the Ag. Research/S&T/Extension System is accessible and affordable? ....

(c) How far can Ag. & Env Institutions contribute to Ag. Research/S&T/Extension System? ....

(d) How far can Climate Investments strengthen the Ag. Research/S&T/Extension System? ....

(e) How far can Climate Info/Decision Support System help the Ag. Research/S&T/Extension System? ....

(f) How far can Contract Farming/PPP contribute to Ag. Research/S&T/Extension System?........................

[17] Corporate Sector Agencies/Players in Agriculture and Rural Sectors (CORPSECTR)

(a) How strong are the Impacts of Climate Change on Corporate Sector performance?..............................

(b) How strong is the involvement of Corporate Sector in national Climate Adaptation Initiatives? ....

(c) How extensive does the Corporate Sector involve in Water/Agricultural Sectors? ....

(d) How far can Climate Investments promote Corporate Sector role in Water/Agricultural Sectors? ....

(e) How far can Subsidy & Tax Relief Policy promote Corporate Sector role in Water/Agricultural Sectors?

(f) How far can Ag. Credit & Investment Institutions promote Corporate Sector role in Water/Agriculture?

[18] Rural Service Providers (RSPROVIDR)

(a) How critical are the Rural Service Providers for the <u>Performance of Agricultural/Water/Rural Sectors</u>? ☐

(b) How <u>strong and accessible are the Rural Service Providers</u> in the Agricultural/Water/Rural Sectors?..... ☐

(c) How far do <u>Climate Investments</u> promote the development of Rural Service Providers? .... ☐

(d) How far does <u>Subsidy & Tax Relief Policy</u> promote the development of Rural Service Providers? .... ☐

(e) How far do <u>Ag. Credit & Investment Institutions</u> promote the development of Rural Service Providers? ☐

(f) How far does <u>Corporate Sector</u> promote the development of Rural Service Providers? .... ☐

[19] Agricultural Production and/or Marketing Cooperatives (APMKTCOOP)

(a) How critical are the Ag. Prod/Mktg Coops for the <u>Performance of Agricultural/Livestock Sectors</u>? .... ☐

(b) How <u>strong and accessible are the Ag. Prod/Mktg Coops</u> in the Agricultural/Livestock Sectors?............ ☐

(c) How far do <u>Rural Service Providers</u> contribute to the development of Ag. Prod/Mktg Coops? .... ☐

(d) How far do <u>Ag. Credit & Investment Institutions</u> support the development of Ag. Prod/Mktg Coops?.... ☐

(e) How far does <u>Corporate Sector</u> support the development of Ag. Prod/Mktg Coops?.............................. ☐

[20] Agricultural Value Chain Networks (AVALCHAIN)

(a) How critical are the Ag. Value Chains for the <u>Performance of Agricultural/Livestock Sectors</u>? .... ☐

(b) How <u>strong and accessible are the Ag. Value Chains</u> in the Agricultural/Livestock Sectors? .... ☐

(c) How far do <u>Ag. Prod/Mktg Coops</u> contribute to the growth/performance of Ag. Value Chains? .... ☐

(d) How far do <u>Rural Service Providers</u> contribute to the growth/performance of Ag. Value Chains? .... ☐

(e) How far do <u>Ag. Credit & Investment Institutions</u> support the growth/performance of Ag. Value Chains? ☐

(f) How far does <u>Corporate Sector</u> contribute to the growth/performance of Ag. Value Chains?................. ☐

[21] Subsidy and Tax Relief Policies (STAXPOLCY)

(a) How far can Subsidy/Tax Relief Policies <u>reduce cultivation/production costs</u>? .... ☐

(b) How far can Subsidy/Tax Relief Policies promote the <u>use of irrigation/farm technologies/equipment</u>?.. ☐

(c) How easy for farmers and other players to access the Subsidy/Tax Relief benefits? .... ☐

(d) How far can <u>Ag. & Env Institutions</u> enhance the effectiveness of Subsidy/Tax Relief Policies? .... ☐

(e) How far can <u>Climate Investments</u> contribute to the effectiveness of Subsidy/Tax Relief Policies?.......... ☐

[22] Agricultural Wage Laws and Regulations (AGWAGELAW)

(a) How strong are <u>local customs and social pressures</u> in influencing rural wage rates? .... ☐

(b) How effective are the <u>minimum wage legislations</u> in guiding rural wage rates? .... ☐

(c) How effective are the <u>special legal provisions</u> (e.g., female workers, child labor; working hour) in terms of their effect on rural labor supply and employment? ....

[23] Rural Social Safetynet Policies (SNETPOLCY)

(a) How important are the proposed retirement benefits for farmers under Generation Green Plan? ....

(b) How important are the proposed stipend for poor rural groups under Generation Green Plan?............

(c) How effective is the Social Agriculture Program in improving safetynet roles agriculture and livestock sectors in poor, fragile, and mountainous regions?...

[24] Crop and Employment Insurance Program (CREMINSUR)

(a) How important is crop insurance for protecting farmers from production uncertainties? ....

(b) How far is crop insurance accessible and affordable to average farmers? ....

(c) How important is employment insurance for protecting rural workers from employment uncertainties?

(d) How effective are government support and regulations in ensuring employment insurance?................

(e) How effective are crop & employment insurance as coping mechanisms for climate risks in agriculture?

[25] Agricultural Market Regime (AMKTREGIM)

(a) To what extent does Agricultural Imports/Exports affect Agricultural Market Regime? ....

(b) How effective are the agricultural markets in providing the Right Prices for farmers? ....

(c) How important are the Roles of Traders and Middlemen in the marketing of farm outputs? ....

(d) How effective are Government Policies in Regulating Agricultural and Food Prices? ....

(e) How serious can the Impacts of Droughts/Disasters be on Agricultural Trade Regime? ....

[26] Agricultural Trade Regime (ATRDREGIM)

(a) To what extent do the levels of domestic production affect Agricultural Trade Regime? ....

(b) To what extent do domestic market regulations affect Agricultural Trade Regime? ....

(c) How important are the impacts of international trade agreements on Agricultural Trade Regime? ....

(d) How important are the roles of corporate sector (as importers/exporters) Agricultural Trade Regime?

(e) How serious can the impacts of droughts/disasters be on Agricultural Trade Regime? ....

[27] Agricultural and Food Price Regulation Policy (AFPRPOLCY)

(a) How effective are price regulations in controlling the food prices for consumers? ....

(b) Do price regulations distort agricultural markets and producers' prices? If so, how serious is this effect?

<u>*SECTION [V]: IMPACT TRANSMISSION VARIABLES (24)*</u>

[28] Cultivated or Cropped Area (CULTIAREA)

(a) How far can <u>Crop Pattern changes</u> increase cultivated area *(via water savings and expanded irrigation)*? ☐

(b) How far can <u>leasing of state & common tribal lands under PPP</u> increase the area under cultivation? .... ☐

(c) How far can <u>Drip System & Irrigation Modernization</u> increase area under cultivation *(via water savings)*? ☐

(d) How far can <u>Ag. Value Chains</u> encourage more cultivated area *(via better price and marketing options)*? ☐

(e) How far can <u>Farm Technologies</u> *(e.g., **<u>zero tillage</u>**, farm mechanization, etc.)* increase cultivated area?. ☐

[29] Crop Pattern (CROPATERN)

(a) How strong are the roles of farm size and land fragmentation in crop choice?...................................... ☐

(b) How far can <u>Contract Farming & PPP</u> alter crop pattern <u>towards industrial and commercial crops</u>? .... ☐

(c) How far can <u>Shift to Tree & High-value Crops</u> affect the <u>area under food and fodder crops</u>?................. ☐

(d) How far can <u>Drip System & Irrigation Modernization</u> <u>increase area under cultivation</u> (*via water savings)*? ☐

(e) How far can changes in <u>Crop Pattern</u> improve <u>land productivity and farm income</u>? .... ☐

(f) How far can changes in <u>Crop Pattern</u> improve <u>land and soil health</u> *(via crop rotation)*? .... ☐

(g) How far can <u>Crop Pattern change</u> help <u>Agro-industries/Rural Non-farm Sector</u> *(via raw materials supply)* ? ☐

(h) How far can <u>these Crop Pattern changes</u> affect <u>Livestock Sector</u> *(via fodder/feed supply)*? .... ☐

[30] Climate Investments (CLIMINVST)

(a) How strong is the <u>commitment of the government</u> for making/promoting Climate Investments?.......... ☐

(b) How adequate are the <u>contributions of Ag. & Env Institutions</u> to Climate Investments? .... ☐

(c) To what extent do <u>International Donors/Devt. Agencies/Investors</u> contribute to Climate Investments? ☐

(d) How <u>adequate and effective</u> are Climate Investments in meeting the challenges of Climate Change? ... ☐

(e) How effectively are Climate Investments used to build ? .... ☐

[31] Agricultural Service and Input Supply (AGINSUPLY)

(a) How well does the <u>Research/S&T/Extension System</u> deliver these Agricultural Services and Inputs? ... ☐

(b) How well do the <u>Ag. Credit & Investment Institutions</u> deliver these Agricultural Services and Inputs?.. ☐

(c) How well do the <u>Rural Service Providers</u> deliver these Agricultural Services and Inputs?...................... ☐

(d) To what extent does <u>Corporate Sector</u> contribute to Agricultural Services and Inputs? .... ☐

(e) How adequate and effective is the supply of Agricultural Services and Inputs? ....

(f) How accessible and affordable are Agricultural Services and Inputs to farmers? ....

[32] Land Quality and Soil Health (LANDSQLTY)

(a) To what extent do Small and Fragmented Farms reduce land and soil quality *(via intense land use)*?.....

(b) To what extent does Crop Pattern (e.g., repeatedly cultivating same crop) reduce land and soil quality?

(c) To what extent do Soil Erosion and Soil Salinity reduce land and soil quality *(via intense land use)*?.......

(d) How effective is the Zero-tillage Technology in improving the productivity of poor lands in rainfed zones?

(e) How important are livestock manures and farm bio-wastes in improving soil fertility and land quality?

[33] Land Productivity (LANPDRODY)

(a) To what extent does Farm Size affect Land Productivity *(via scale economies & land use intensity)*? ....

(b) To what extent does Crop Pattern affect Land Productivity *(e.g., high-value crops vs. food crops)*? ......

(c) To what extent do Ag. Services & Inputs contribute to Land Productivity (*via input complementarities)*?

(d) To what extent does Irrigation Availability contribute to Land Productivity?...

(e) How far do Water Institutions contribute to Land Productivity *(via water use efficiency/water productivity)*?

(f) How effective is the Zero-tillage Technology in improving Land Productivity in rainfed zones? ....

(g) How important are livestock manures and farm bio-wastes in improving soil fertility and land quality?

[34] Water Productivity (WATRPRODY)

(a) To what extent does Farm Size affect Water Productivity *(via scale economies & land use intensity)*?..

(b) To what extent does Crop Pattern affect Water Productivity *(e.g., high-value crops vs. food crops)*?....

(c) To what extent do Ag. Services & Inputs affect Water Productivity *(via input complementarities)*? ......

(d) How far do Water Institutions contribute to Water Productivity *(via water use efficiency)*? ....

(e) How far can Drip System & Irrigation Modernization enhance Water Productivity *(via water use efficiency)*?

(f) How far does Land Productivity contribute to Water Productivity *(via soil fertility and land quality)*?...

[35] Labor Productivity (LABRPRODY)

(a) To what extent does Farm Size affect Labour Productivity *(via scale economies & labour use intensity)*?

(b) To what extent does Crop Pattern affect Labour Productivity *(e.g., high-value crops vs. food crops)*? ....

(c) How far does Farm technologies contribute to Labour Productivity (*via input complementarities)*? ....

(d) How far does Irrigation Availability contribute to Labour Productivity *(via land productivity and labour use)*?

(e) How far does Land Productivity contribute to Labour Productivity *(via soil fertility and land quality)*? ... ☐

(f) How strong (or weak) is the association between Labor Productivity and Rural Wage Rates? .... ☐

[36] Food Production (FOODPRODN)

(a) How sensitive are the levels of Food Production to Climate Change *(e.g., droughts & rainfall deficits)*? . ☐

(b) How far do Contract Farming/PPP/Shift to tree & HV Crops affect Food Production?............................. ☐

(c) How far does a change in Area under Food Crops affect Food Production Levels? .... ☐

(d) How far can improved Land/Water Productivities compensate for change in Area under Food Crops? .. ☐

(e) How far do the Agricultural Value Chains support/contribute to Food Production? .... ☐

(f) How far do the Ag. Production & Marketing Coops support/contribute to Food Production? .... ☐

(g) How far do the Rural Service Providers support/contribute to Food Production? .... ☐

(h) How far do the Ag. Credit & Investment Institutions support/contribute to Food Production? .... ☐

(i) How far do the Trade and Domestic Market and Conditions affect Food Production? .... ☐

[37] Industrial and Commercial Crop Production (INDCPRODN)

(a) How sensitive is Ind & Commercial Crop Production to Climate Change *(e.g., droughts & rainfall deficits)*? ☐

(b) How far do Contract Farming/PPP/Shift to tree & HV Crops promote Ind & Com Crop Production? ..... ☐

(c) How strong are the Productivity & Income effects of Ind & Com Crop Production? .... ☐

(d) How important are the Trade and Domestic Market contributions of Ind & Com Crop Production? ..... ☐

(e) How strong are the links between Ind & Com Crop Production and Agro-Inds & Rural Non-farm Sector? ☐

(f) How far do the Agricultural Value Chains support/contribute to Ind & Com Crop Production? .... ☐

(g) How far do the Rural Service Providers support/contribute to Ind & Com Crop Production? .... ☐

(h) How far do the Ag. Credit & Investment Institutions support/contribute to Ind & Com Crop Production? ☐

(i) How far does the Corporate Sector support/contribute to Ind & Com Crop Production?....................... ☐

[38] Fodder and Feed Supply (FEEDSUPLY)

(a) How important are the Rainfed Areas for Fodder/Feed Production? .... ☐

(b) How sensitive is Fodder/Feed Supply to Climate Change *(e.g., droughts & rainfall deficits)*? .... ☐

(c) How strong are the links between Food Crop Production and Fodder/Feed Production?........................ ☐

(d) How far do Crop Pattern Changes (to Industrial & Commercial Crops) affect fodder/feed supply? .... ☐

(e) How important are the roles of Common Pastures & Grazing Lands as fodder/feed supply sources? ..... ☐

(f) To what extent can Zero-tillage Technology can enhance the production of Fodder/Feed Crops? .... ☐

(g) How extensive is the use of <u>Commercially Produced Fodder/Feed Productions</u>? ☐

[39] Livestock and Poultry Population Size and Composition (LIVSIZCOM)

(a) How strong are the linkages between <u>Farm Size</u> and Livestock Population? ☐

(b) How strong are the linkages between <u>Fodder/Feed Supply</u> and Livestock Population? ☐

(c) How dominant is the <u>Share of Commercial Enterprises (dairy + meat)</u> in total Livestock Population? ☐

(d) How dominant is the <u>Share of Dairy Animals</u> (relative to Meat Animals) in Total Livestock Population? ☐

[40] Livestock and Poultry Production (LIVSPRODN)

(a) How important are the <u>Rainfed Areas</u> for Livestock Production? ☐

(b) How sensitive is Livestock Production to <u>Climate Change</u> *(e.g., droughts & rainfall deficits)*? ☐

(c) How strong are the <u>links between Food Crop Production and Livestock Production</u>? ☐

(d) How far do <u>Crop Pattern Changes</u> (to Industrial & Commercial Crops) affect Livestock Production? ☐

(e) How sensitive are Livestock Production to changes in <u>Trade and Market Conditions</u>? ☐

(f) How far do the <u>Agricultural Value Chains</u> support/contribute to Livestock Production? ☐

(g) How far do the <u>Production & Marketing Cooperatives</u> support Livestock Production? ☐

(h) How far do the <u>Rural Service Providers</u> support/contribute to Livestock Production? ☐

(i) How far do the <u>Ag. Credit & Investment Institutions</u> support/contribute to Livestock Production? ☐

(j) How far does the <u>Corporate Sector</u> support/contribute to Livestock Production? ☐

[41] Agro-Industries and Rural Non-farm Sector (AGNFSECTR)

(a) How strongly are the <u>Agro-Inds/Rural Non-Farm Sector linked with Food Crop Production</u>? ☐

(b) How strongly are the <u>Agro-Inds/Rural Non-Farm Sector linked with Ind & Com Crop Production</u>? ☐

(c) How strongly are the <u>Agro-Inds/Rural Non-Farm Sector linked with Livestock Production</u>? ☐

(d) How far do the <u>Agricultural Value Chains</u> support Agro-Inds/Rural Non-Farm Sector? ☐

(e) How far do the <u>Rural Service Providers</u> support Agro-Inds/Rural Non-Farm Sector? ☐

(f) How far do the <u>Ag. Credit & Investment Institutions</u> support Agro-Inds/Rural Non-Farm Sector? ☐

(g) How far does the <u>Corporate Sector</u> support Agro-Inds/Rural Non-Farm Sector? ☐

[42] Rural Jobs or Employment (RURALJOBS)

(a) How far does <u>Labor Productivity</u> contribute to the level of Rural Employment? ☐

(b) How far does <u>Land Productivity</u> contribute to the level of Rural Employment? ☐

(c) How far does <u>Livestock & Poultry Sector</u> contribute to the level of Rural Employment? ☐

(d) How far do <u>Agro-Inds & Rural Non-Farm Sector</u> contribute to the level of Rural Employment? ☐

(e) How far do <u>Rural Wage Rates</u> determine the level of Rural Employment? .... ☐

(f) How far do <u>Wage Laws and Regulations</u> affect determine the level of Rural Employment? .... ☐

(g) How far can the requirement of <u>Employment Insurance</u> affect the level of Rural Employment? .... ☐

(h) How dominant is the Share of Women in total Rural Employment? .... ☐

[43] Rural Wage Rates (RURALWAGE)

(a) How strong is the <u>association between Labour Productivity and Rural Wage Rates</u>? .... ☐

(b) How strong is the <u>association between Labour Demand *(from all rural sectors)* and Rural Wage Rates</u>? ☐

(c) How strong are the <u>effects of Minimum Wage Regulations</u> on Rural Wage Rates? .... ☐

(d) How serious is the <u>Gender-based Discrimination</u> in Rural Wage Rates? .... ☐

[44] Cultivation Costs in Crop Production (CULTICOST)

(Covers costs of land preparation, irrigation, fertilizer, other inputs, operational/maintenance costs of farm equipment, crop insurance premium, etc.)

(a) How far does the <u>Scale of Operation (Farm Size)</u> reduce Cultivation Costs? .... ☐

(b) How far do <u>Crop Pattern Shifts</u> (to tree/Hight-value crops) increase Cultivation Costs?.......................... ☐

(c) How far the do <u>Labor Costs (Wage Rates)</u> contribute to Cultivation Costs? .... ☐

(d) How costly are <u>Ag. Services & Inputs</u> and how far such costly services/inputs raise Cultivation Costs? .. ☐

(e) How far do the <u>Subsidy & Tax Relief Policies</u> reduce Cultivations Costs? .... ☐

(f) How far can <u>Crop Insurance increase</u> Cultivations Costs? .... ☐

[45] Market Prices for Farm Products (AMKTPRICE)

(a) How effective and efficient are Market Prices in <u>Conveying Real Incentive</u> to farmers?........................ ☐

(b) How far do the Market Prices remain <u>Stable</u> (i.e., free of manipulations & seasonal/regional variations)? ☐

(c) How far do the Market Prices get affected by <u>Changes in Production Conditions</u>?................................ ☐

(d) How far the do Market Prices get influenced by <u>Trade Policy Changes</u> (i.e., imports and exports)?....... ☐

[46] Income from Crop Sector (CROPINCOM)

(a) How far do Crop Shifts to Industrial/Tree/Commercial Crops raise the level of Crop Sector Income? ..... ☐

(b) How critical are Crop Productivity levels for determining the level of Crop Sector Income? .... ☐

(c) How critical are Predictable Market Prices for determining the level of Crop Sector Income? .... ☐

(d) How far does rising Cultivation Costs affect the level of Crop Sector Income? .... ☐

(e) How important are the Contributions of Ag. Value Chains to level of Crop Sector Income?.................... ☐

(f) How far does the effectiveness of Crop Insurance contribute to the stability of Crop Sector Income?.... ☐

[47] Labor Income (LABRINCOM)

(a) How dominant is the role of the Wage Income in the total income of laborers? .... ☐

(b) How critical are Livestock and Rural Non-Farm Sectors as additional income sources for farmers? .... ☐

(c) How far do Social Safetynets (e.g., retirement, stipend, etc.) contribute to laborers' income?............... ☐

(d) How adequate is the Income of Laborers to meet their Household Food, Income, and Water Security? ☐

(e) How serious are the effects of Climate Change on the level and fluctuations of laborers' Income? .... ☐

[48] Farm Income (FARMINCOM)

(a) How dominant is the role of the Income from Crop Sector in the total income of farmers? .... ☐

(b) How critical are Livestock and Rural Non-Farm Sectors as additional income sources for farmers?....... ☐

(c) How far do Social Safetynets (e.g., retirement benefits, stipends, etc.) contribute to farmers' Income? ☐

(d) How adequate is the Income of Farmers to meet their Household Food, Income, and Water Security? ☐

(e) How serious are the effects of Climate Change on the level and fluctuations of Farmers' Income?....... ☐

[49] Food Availability (FOODAVAIL)

(a) How far does Food Availability depend on domestic Food Production? .... ☐

(b) To what extent does Food Availability depend on the production performance of Rainfed Regions?.... ☐

(c) How effective are the roles of domestic Market Regime in ensuring adequate Food Availability?......... ☐

(d) How critical are the roles of Food Imports in ensuring adequate Food Availability?.............................. ☐

(e) How important are the roles of price and supply regulations in ensuring adequate Food Availability? . ☐

(f) How serious are the effects of Climate Change on the level of Food Availability? .... ☐

[50] Food Prices (FOODPRICE)

(a) How far do Food Prices depend on domestic Food Production? .... ☐

(b) How strong are the roles of domestic Market Regime in ensuring stable Food Prices? .... ☐

(c) How critical are the roles of Food Imports in stabilizing Food Prices? .... ☐

(d) How important are the roles of price and supply regulations in ensuring stable Food Prices? .... ☐

(e) How serious are the effects of Climate Change on the level and variations of Food Prices?.................. ☐

[51] Water Security (WATRSECUR)

(a) How adequate/efficient are Water Infrastructures (e.g., dams/storage) in ensuring Water Security?... ☐

(b) How adequate/efficient are Water Institutions (e.g., basin agencies) in ensuring Water Security? .... ☐

(c) As per the Water Law provision, two-year worth of water is reserved in dams for meeting domestic and industrial needs. How strictly is this provision followed? .... ☐

(d) How strong are the roles of Customary/Traditional Institutions in Water Security at local levels?......... ☐

(e) How sensitive is Water Security to the vagaries of Climate Change?.. ☐

[VI] DEVELOPMENT GOAL VARIABLE (1)

[52] Rural Welfare (RURWELFAR)

(a) How strong is the Food and Income Security status of rural groups in rainfed regions?.......................... ☐

(b) How strong is the Food and Income Security status of rural groups in irrigated regions? .... ☐

(c) How strong is the Food and Income Security status of rural groups in commercial/HV agriculture? ...... ☐

(d) How strong is the Food and Income Security status of rural groups in food crop-based agriculture? ..... ☐

(e) How strong is the Water Security status of rural groups in rainfed regions? .... ☐

(f) How strong is the Water Security status of rural groups in irrigated regions? .... ☐

(g) How strong are the contributions of Social and Safetynet Programs to Rural Welfare? .... ☐

(h) How serious are the effects of Climate Change on the overall Welfare Status of all rural groups? .... ☐

Annex-C: CC-TAO-MPG-RW Model: Diagnostic Test Results

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
[1]	F (3,173)	724.52	0.000	0.926	0.925	+
	D-W’s d-Statistic	1.57				+
	B-G’s LM Test - χ2(1)	8.08	0.005			—
	Mean-VIF	10.98				—
	White’s Test - χ2(9)	5.76	0.764			+
	SK Test - Adj.χ2(2)	4.39	0.111			+
[2]	F (4,172)	609.34	0.000	0.934	0.933	+
	D-W’s d-Statistic	1.78				+
	B-G’s LM Test - χ2(1)	2.27	0.132			+
	Mean-VIF	12.52				—
	White’s Test - χ2(14)	63.69	0.000			—
	SK Test - Adj.χ2(2)	4.76	0.093			—
[3]	F (4,172)	1056.83	0.000	0.961	0.960	+
	D-W’s d-Statistic-	1.91				+
	B-G’s LM Test - χ2(1)	0.32	0.574			+
	Mean-VIF	14.67				—
	White’s Test - χ2(14)	49.40	0.000			—
	SK Test - Adj.χ2(2	31.00	0.000			—
[4]	F (4,172)	1390.75	0.000	0.970	0.969	+
	D-W’s d-statistic	1.65				+
	B-G’s LM Test - χ2(1)	5.42	0.020			—
	Mean-VIF	15.14				—
	White’s Test - χ2(14)	58.64	0.000			—
	SK Test - Adj.χ2(2)	11.04	0.004			—
[5]	F (6,170)	947.30	0.000	0.971	0.970	+
	D-W’s d-statistic	1.45				—
	B-G’s LM Test - χ2(1)	13.00	0.000			—
	Mean-VIF	23.33				—
	White’s Test - χ2(27)	57.66	0.001			—
	SK Test - Adj.χ2(2)	6.93	0.031			—
[6]	F (4,172)	1530.03	0.000	0.973	0.972	+
	D-W’s d-statistic	1.38				—
	B-G’s LM Test - χ2(1)	16.05	0.000			—
	Mean-VIF	26.93				—
	White’s Test - χ2(14)	35.27	0.001			—
	SK Test - Adj.χ2(2)	9.06	0.011			—
[7]	F (4,172)	547.52	0.000	0.927	0.926	+
	D-W’s d-statistic	1.78				+
	B-G’s LM Test - χ2(1)	1.57	0.211			+
	Mean-VIF	17.04				—
	White’s Test - χ2(14)	41.80	0.000			—
	SK Test - Adj.χ2(2)	5.55	0.062			—
[8]	F (6,170)	1654.31	0.000	0.983	0.983	+

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
	D-W's d-statistic	1.74				+
	B-G's LM Test - $\chi2(1)$	2.79	0.095			—
	Mean-VIF	26.65				—
	White's Test - $\chi2(27)$	48.22	0.007			—
	SK Test - Adj.$\chi2(2)$	8.82	0.012			—
[9]	F (5,171)	839.69	0.000	0.961	0.960	+
	D-W's d-statistic	1.82				+
	B-G's LM Test - $\chi2(1)$	1.47	0.226			+
	Mean-VIF	14.52				—
	White's Test - $\chi2(20)$	25.50	0.183			+
	SK Test - Adj.$\chi2(2)$	8.67	0.013			—
[10]	F (5,171)	333.09	0.000	0.907	0.904	+
	D-W's d-statistic	1.12				—
	B-G's LM Test - $\chi2(1)$	38.84	0.000			—
	Mean-VIF	20.47				—
	White's Test - $\chi2(20)$	44.66	0.001			—
	SK Test - Adj.$\chi2(2)$	12.16	0.002			—
[11]	F (5,171)	731.28	0.000	0.955	0.954	+
	D-W's d-statistic	2.03				+
	B-G's LM Test - $\chi2(1)$	0.05	0.825			+
	Mean-VIF	20.14				—
	White's Test - $\chi2(20)$	24.88	0.206			+
	SK Test - Adj.$\chi2(2)$	45.26	0.000			—
[12]	F (3,173)	640.75	0.000	0.917	0.916	+
	D-W's d-statistic	1.61				+
	B-G LM Test	7.44	0.006			—
	Mean-VIF	11.02				—
	White's Test - $\chi2(9)$	61.24	0.000			—
	SK Test - Adj.$\chi2(2)$	27.83	0.000			—
[13]	F (8,168)	1108.06	0.000	0.981	0.981	+
	D-W's d-statistic	1.94				+
	B-G's LM Test - $\chi2(1)$	0.17	0.677			+
	Mean-VIF	29.25				—
	White's Test - $\chi2(44)$	132.36	0.000			—
	SK Test - Adj.$\chi2(2)$	8.66	0.013			—
[14]	F (4,172)	1157.14	0.000	0.964	0.963	+
	D-W's d-statistic	1.47				—
	B-G's LM Test - $\chi2(1)$	12.71	0.000			—
	Mean-VIF	14.37				—
	White's Test - $\chi2(14)$	38.70	0.000			—
	SK Test - Adj.$\chi2(2)$	11.44	0.003			—
[15]	F (3,173)	978.40	0.000	0.944	0.943	+
	D-W's d-statistic	1.56				+
	B-G's LM Test - $\chi2(1)$	8.33	0.004			—
	Mean-VIF	7.22				+

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
	White's Test - χ2(9)	54.55	0.000			—
	SK Test - Adj.χ2(2)	2.98	0.226			+
[16]	F (6,170)	1102.70	0.000	0.975	0.974	+
	D-W's d-statistic	1.85				+
	B-G's LM Test - χ2(1)	0.74	0.390			+
	Mean-VIF	30.02				—
	White's Test - χ2(27)	66.97	0.000			—
	SK Test - Adj.χ2(2)	20.42	0.000			—
[17]	F (6,170)	942.68	0.000	0.971	0.970	+
	D-W's d-statistic	2.02				+
	B-G's LM Test - χ2(1)	0.02	0.889			+
	Mean-VIF	25.87				—
	White's Test - χ2(27)	73.77	0.000			—
	SK Test - Adj.χ2(2)	7.53	0.023			—
[18]	F (5,171)	1046.70	0.000	0.968	0.967	+
	D-W's d-statistic	1.73				+
	B-G's LM Test - χ2(1)	2.96	0.086			—
	Mean-VIF	27.03				—
	White's Test - χ2(20)	84.91	0.000			—
	SK Test - Adj.χ2(2)	12.87	0.002			—
[19]	F (7,169)	1827.85	0.000	0.987	0.986	+
	D-W's d-statistic	1.69				+
	B-G's LM Test - χ2(1)	3.75	0.053			—
	Mean-VIF	29.89				—
	White's Test - χ2(35)	77.92	0.000			—
	SK Test - Adj.χ2(2)	10.95	0.004			—
[20]	F (7,169)	1599.12	0.000	0.985	0.985	+
	D-W's d-statistic	1.86				+
	B-G's LM Test - χ2(1)	0.86	0.353			+
	Mean-VIF	33.77				—
	White's Test - χ2(35)	75.91	0.000			—
	SK Test - Adj.χ2(2)	15.45	0.000			—
[21]	F (7,169)	1584.75	0.000	0.985	0.984	+
	D-W's d-statistic	2.20				+
	B-G's LM Test - χ2(1)	1.90	0.168			+
	Mean-VIF	40.52				—
	White's Test - χ2(35)	63.34	0.002			—
	SK Test - Adj.χ2(2)	3.67	0.159			+
[22]	F (4,172)	1158.46	0.000	0.964	0.963	+
	D-W's d-statistic	2.08				+
	B-G's LM Test - χ2(1)	0.37	0.543			+
	Mean-VIF	40.62				—
	White's Test - χ2(14)	23.34	0.055			—

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
	SK Test - Adj.χ2(2)	66.81	0.000			—
[23]	F (7,169)	1382.36	0.000	0.983	0.982	+
	D-W's d-statistic	1.65				+
	B-G's LM Test - χ2(1)	5.54	0.019			—
	Mean-VIF	30.24				—
	White's Test - χ2(35)	80.41	0.000			—
	SK Test - Adj.χ2(2)	9.56	0.008			—
[24]	F (8,168)	603.77	0.000	0.966	0.965	+
	D-W's d-statistic	1.82				+
	B-G's LM Test - χ2(1)	1.40	0.290			+
	Mean-VIF	41.00				—
	White's Test - χ2(44)	75.73	0.002			—
	SK Test - Adj.χ2(2)	44.08	0.000			—
[25]	F (5,171)	1001.57	0.000	0.967	0.966	+
	D-W's d-statistic	1.67				+
	B-G's LM Test - χ2(1)	5.09	0.024			—
	Mean-VIF	39.72				—
	White's Test - χ2(20)	107.62	0.000			—
	SK Test - Adj.χ2(2)	35.35	0.000			—
[26]	F (6,170)	1937.94	0.000	0.986	0.985	+
	D-W's d-statistic	1.75				+
	B-G's LM Test - χ2(1)	3.14	0.076			—
	Mean-VIF	27.45				—
	White's Test - χ2(27)	112.47	0.000			—
	SK Test - Adj.χ2(2)	15.87	0.000			—
[27]	F (5,171)	518.83	0.000	0.938	0.936	+
	D-W's d-statistic	1.86				+
	B-G's LM Test - χ2(1)	0.78	0.378			+
	Mean-VIF	24.59				—
	White's Test - χ2(20)	103.66	0.000			—
	SK Test - Adj.χ2(2)	12.19	0.002			—
[28]	F (4,172)	1269.75	0.000	0.967	0.967	+
	D-W's d-statistic	1.66				+
	B-G's LM Test - χ2(1)	5.15	0.023			—
	Mean-VIF	37.33				—
	White's Test - χ2(14)	77.74	0.000			—
	SK Test - Adj.χ2(2)	73.47	0.000			—
[29]	F (5,171)	1387.74	0.000	0.976	0.975	+
	D-W's d-statistic	2.19				+
	B-G's LM Test - χ2(1)	1.74	0.187			+
	Mean-VIF	36.79				—
	White's Test - χ2(20)	52.18	0.000			—
	SK Test - Adj.χ2(2)	15.87	0.000			—

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
[30]	F (4,172)	1353.35	0.000	0.969	0.969	+
	D-W's d-statistic	2.07				+
	B-G's LM Test - χ2(1)	0.23	0.632			+
	Mean-VIF	27.75				—
	White's Test - χ2(14)	18.99	0.165			+
	SK Test - Adj.χ2(2)	59.95	0.000			—
[31]	F (5,171)	880.15	0.000	0.963	0.962	+
	D-W's d-statistic	1.90				+
	B-G's LM Test - χ2(1)	0.40	0.529			+
	Mean-VIF	34.72				—
	White's Test - χ2(20)	21.48	0.369			+
	SK Test - Adj.χ2(2)	-	0.000			—
[32]	F (7,169)	941.40	0.000	0.975	0.974	+
	D-W's d-statistic	1.47				-
	B-G's LM Test - χ2(1)	12.16	0.001			—
	Mean-VIF	40.73				—
	White's Test - χ2(35)	90.27	0.000			—
	SK Test - Adj.χ2(2)	29.00	0.000			—
[33]	F (6,170)	583.90	0.000	0.954	0.952	+
	D-W's d-statistic	2.04				+
	B-G's LM Test - χ2(1)	0.09	0.770			+
	Mean-VIF	34.63				—
	White's Test - χ2(27)	103.47	0.000			—
	SK Test - Adj.χ2(2)	12.38	0.002			—
[34]	F (8,168)	929.55	0.000	0.978	0.977	+
	D-W's d-statistic	1.83				+
	B-G's LM Test - χ2(1)	1.12	0.290			+
	Mean-VIF	40.45				—
	White's Test - χ2(44)	130.48	0.000			—
	SK Test - Adj.χ2(2)	11.19	0.004			—
[35]	F (4,172)	1284.97	0.000	0.968	0.967	+
	D-W's d-statistic	1.45				—
	B-G's LM Test - χ2(1)	13.45	0.000			—
	Mean-VIF	18.81				—
	White's Test - χ2(14)	36.00	0.001			—
	SK Test - Adj.χ2(2)	5.07	0.079			—
[36]	F (6,170)	1160.10	0.000	0.976	0.975	+
	D-W's d-statistic	1.63				+
	B-G's LM Test - χ2(1)	5.92	0.015			—
	Mean-VIF	23.69				—
	White's Test - χ2(27)	54.91	0.001			—
	SK Test - Adj.χ2(2)	4.29	0.117			+
[37]	F (5,171)	1094.45	0.000	0.970	0.969	+

Table C1. Equation-Specific Diagnostic Test Results.

qn. No	Test/Statistic	Values of Statistic	Prob > Critical Value	R^2	Adj- R^2	Test Results
	D-W's d-statistic	1.71				+
	B-G's LM Test - χ2(1)	3.66	0.056			—
	Mean-VIF	45.36				—
	White's Test - χ2(20)	95.96	0.000			—
	SK Test - Adj.χ2(2)	14.70	0.001			—
[38]	F (4,172)	2208.24	0.000	0.981	0.981	+
	D-W's d-statistic	1.90				+
	B-G's LM Test - χ2(1)	0.28	0.594			+
	Mean-VIF	25.49				—
	White's Test - χ2(14)	64.01	0.000			—
	SK Test - Adj.χ2(2)	14.43	0.001			—
[39]	F (5,171)	775.54	0.000	0.958	0.957	+
	D-W's d-statistic	1.88				+
	B-G's LM Test - χ2(1)	0.70	0.403			+
	Mean-VIF	24.52				—
	White's Test - χ2(20)	25.74	0.175			+
	SK Test - Adj.χ2(2)	23.46	0.000			—
[40]	F (5,171)	1416.23	0.000	0.976	0.976	+
	D-W's d-statistic	1.75				+
	B-G's LM Test - χ2(1)	2.04	0.153			+
	Mean-VIF	47.91				—
	White's Test - χ2(20)	16.82	0.665			+
	SK Test - Adj.χ2(2)	34.97	0.000			—

Notes:

(a) The F statistic tests for how well the model fits the data. Under F Test, H0 (Model without independent variables fits the data better) against H1 (i.e., Model with independent variables fits the data better). H0 is accepted when Prob > 0.100 and conversely, H1 is accepted when Prob ≤ 0.100 (equivalent to 10% Level of Significance). .

(b) R2 and Adj-R2 (adjusted for degrees of freedom) indicated the extent the independent variables explain variations in dependent variables in the model.

(c) B-G LM = Breusch-Godfrey Lagrange Multiplier Statistic tests for higher-order serial correlation. Under this test, H0 (i.e., No-serial autocorrelation) is rejected, if Prob ≤ 0.100 (equivalent to 10% Level of Significance). Unlike D-W Test, which is focused on first-order autoregression, the B-G Test can detect higher order autocorrelation up to any predesignated order. It also supports a broader class of regressors, involving lagged or cross-sectional dependence.

(d) VIF = Variance Inflation Factor. VIF Test indicates the existence of multicollinearity (i.e., correlation among independent variables) in a model, but it is not a measure of multicollinearity. Under VIF Test, H0 (No multicollinearity) is accepted if the value of VIF ≤ 10 or tolerance (1/VIF) ≥ 0.10. Else, H1 (Existence of serious multicollinearity) is accepted.

(e) White's Test is a test for Heteroskedasticity, i.e., unequal variance (or disproportionate change in standard error) over a range of observed values. Under this test, H0 (i.e., Homoskedasticity) is rejected and H1 (Heteroskedasticity) is accepted if Prob ≤ 0.100 and vice versa.

(f) SK = Skewness-Kurtosis. SK Test checks for the normality of distribution. Under this test, H0 (i.e., Normal distribution) is rejected and H1 (Non-normal distribution) is accepted if Prob ≤ 0.100 and vice versa.